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Equipment and Tools for Small-Scale Intensive Crop Production

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This publication focuses on equipment and tools for intensive crop production on a small-scale commercial farm. It details equipment and hand tools for soil preparation, planting, and weed management. The use of appropriate equipment and tools, both in terms of size and practicality, can increase production efficiency and profits while minimizing the disturbance to soil and to plant health. A list of further resources and tool and equipment suppliers is included.

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Introduction/Overview

The use of appropriate agricultural equipment and tools for small-scale intensive crop production contributes to the viability of the farm by enhancing production efficiency. Equipment and tools are necessary for plant propagation, soil preparation, planting, pest and weed control, irrigation, harvesting, postharvest handling, storage, and distribution. Sustainable agriculture can be a labor-intensive business and by selecting the appropriate tool for the task at hand, farmers can increase profits by increasing crop yields, improving crop quality, and reducing expenses. Factors to consider when choosing appropriate agricultural equipment and tools include the location and growing conditions of the farm, the type of crops being grown, the production practices being used, and how the crops will be marketed.

In the past, the volume of business—or size of the farm—was the most important factor in yielding a profit (Kains, 1973). Many small-scale farmers today are generating high profits from land bases that are five acres or less. Practical farmers at this scale are able to sustainably manage their production and their farm finances, which are the result of reasonable capital costs and low annual operating expenses. Farms intensively producing on five acres or less rely on the versatility of their manual labor but also may utilize mechanized equipment to maximize production efficiency.

Tools and equipment should relate to the scale of production, and compromises are necessary as farming systems transition from a hand-labor scale to a tractor scale. Limiting the number of different row spacings, limiting the number of different bed widths, and designing beds that consider slope, soil erosion, and tractor-wheel widths are important considerations when scaling up production to include a tractor and implements. It is also important to consider how best to match the right equipment to the cropping system, including such factors such as how the soil and plants are managed and how the use of cover crops and crop rotations is incorporated. Diversified cropping systems can complicate matters because various crops require different row spacing, which means the implements may need to be adjusted for each crop.

The author's Farmall 140 with belly-mounted implements. Photo: Andy Pressman, NCAT

Equipment for small-scale intensive crop production tends to be simple and less specialized than equipment for larger-scale production. As a result, the equipment is often affordable and requires less capital. The economics of owning and maintaining farm machinery may appear

to be complicated and even overwhelming. Renting or borrowing equipment may be an option for some farmers; however, investing in appropriate and practical equipment that matches the whole-farm cropping system can result in a minimal increase in cost per hour. The investment pays off in hand-labor savings, even after costs such as labor for the driver, fuel, maintenance, and equipment depreciation are factored in. A 2005 study published by the Center for Integrated Agriculture found market vegetable farms using sustainable farming practices invest between $2,011 and $26,784 per acre in equipment (Hendrickson, 2005).

Hand tools for small-scale intensive crop production. Photo: Andy Pressman, NCAT

Small-scale farms tend to invest in used equipment primarily due to the high cost of new equipment and the fact that new equipment available in the U.S. is generally no longer designed for small-scale production. Many small-scale farmers are finding new equipment to meet their scale of production from manufacturers located overseas and are working with local distributers, investing in the costs of having it imported, or having it fabricated locally. Many of the tools mentioned in this publication are of European origin. No matter where it is manufactured, generating a profit after the initial investment of purchasing the equipment also depends on the associated costs of maintaining, storing, and repairing it (Grubinger, 1999).

Although draft-animal power does find a place on many sustainable small farms, this publication does not include a discussion on equipment for draft power. However, many of the implements described in this publication were originally designed for the horse and can be used with both draft and tractor power. Refer to ATTRA's *Draft Animal Power for Farming* for information on the use of draft animals.

Related ATTRA Publications
www.attra.ncat.org

Draft Animal Power for Farming

Conserving Fuel on the Farm

Market Gardening: A Start-Up Guide

Flame Weeding for Vegetable Crops

Pursuing Conservation Tillage Systems for Organic Crop Production

There are a number of characteristics that determine appropriate agricultural tools (Village Earth, 2011):

- They should allow for efficient and speedy work with a minimum of fatigue.
- They should be safe.
- They should have a simple design that allows them to be made locally.
- They should be light for easy transportation.
- They should be ready for immediate use without preparatory adjustments that cost time.
- They should be made of readily available materials.

Hand Tools

There are two key components to consider when selecting a hand tool for commercial crop production: ergonomics and durability. Ergonomics refers to how a tool is best designed for comfort, efficiency, safety, and productivity. The more ergonomically designed a tool is, the easier it will be on the human body. The length of a handle, the type of handle grip, the weight of the tool, and the angle of the tool head to the handle affect the ergonomics of a tool.

The more durable a tool is, the longer it will last without sustaining significant damage or wear. Durability can be measured in the strength of the handle and tool head. The harder the steel used for the tool head, the better it will hold an edge—which in turn improves efficiency and reduces wear. How the tool head and handle are joined together also affects the durability of the tool and determines whether parts can be replaced.

Tractors, PTOs, and Toolbars

One horsepower is equal to the force required to raise 33,000 pounds one foot in one minute.

Tractors provide the power to push and pull farm machinery and are designed with one thing in mind: utility. The best type of tractor to use should be determined by the farm's acreage, physical layout, and soils, as well as the tasks the tractor is needed for and the implements that will be mounted to it. Small-scale farms do not need large quantities of horsepower for mechanical tillage or weed cultivation. For intensive crop production, farmers generally can achieve

their goals with tractors in the 5- to 30-horsepower range, but may need up to 30 additional horsepower for deep tillage.

In 1939, Ford Motor Company came out with the 3-point hitch on its Model N tractors. Prior to this time, the brand of most implements had to match the brand of the tractor because each manufacturer had its own way of hitching its implements to its own tractors. The 3-point hitch allows for implements to be easily attached to a tractor so that the tractor carries the weight of the implement. Although single and double hitches served in a similar capacity, the 3-point hitch allowed for the implement to be lifted by the tractor's hydraulic system. As a result, the depth of the implement could be controlled; therefore, the load on the tractor also was controlled. The 3-point hitch became standardized in the 1960s, making different manufacturers' tractors and implements compatible.

A toolbar also can be used to attach implements to a tractor and can be set up with multiple implements that can work in conjunction with one another. A shank is used to attach the tool, such as a sweep or shovel, to the toolbar. Depending on how much action, or mobility, is needed by the tool, different types of shanks can be used. For example, C-shanks vibrate slightly, S-shanks vibrate aggressively, and straight shanks are firm.

Starting in 1947, manufacturers began adding a built-in transmission device known as a power take-off (PTO) to tractors. The PTO allows the tractor to power an implement while the tractor is being driven. PTOs are a main feature on tractors today, including walk-behind tractors.

Many of the tractors from this era are preferred by small-scale farmers who practice intensive crop production. A well-cared-for older tractor can run for years and is much more affordable than a new tractor for small-scale production. Not only was the horsepower designed for this scale of farming, the mechanical systems are not as complicated as they are on newer tractors, and parts are relatively easy to come by and install.

A three-point hitch. Photo: Andy Pressman, NCAT

Walk-Behind Tractors

A walk-behind tractor, or walking tractor, can be an effective, even essential, tool for small-scale farming. At five to 14 horsepower, these two-wheeled power sources can provide a farm that is two acres or less with its necessary tillage and cultivation needs. Their versatility also allows them to be used in combination with a 4-wheeled tractor to manage a few acres of production. Walk-behind tractors are affordable, appropriately scaled, and easy to operate and maintain. They can be equipped with a wide range of implements, including a PTO-driven rear-tine rotary tiller. Other implements that can be pulled or powered by a walk-behind tractor include mowers, hillers, rotary plows, seeders, and harvesters.

Tanya Srolovitz of Bloomfield Farm in Charlotte, Vermont, using a walk-behind tractor with a rototiller attachment. Photo: Andy Pressman, NCAT

Soil Preparation

Preparing the soil for seeding and planting crops is a multistep process. Depending on the soil condition and the kinds of crops to be planted, famers can decide which tool or piece of equipment to use, the depth to which the soil needs to be prepared, and when the soil should be worked. Soil preparation disrupts soil structure and soil life. Maintaining and enhancing the life of the soil is the farmer's responsibility, and it depends on the farmer's ability to select and use the right tools and practices to prepare the soil for crop production. In some instances, farmers can get exceptional crop quality and yields with minimal soil disturbance through such practices as no-till farming or preparing raised garden beds through the technique of double-digging, in which the soil is loosened to a depth of 24 inches.

Breaking the soil for commercial crop production usually requires the art of plowing or tilling the soil. The goal of soil preparation is to minimize soil damage while creating a smooth, deeply loosened seed bed with as little residue and as few weed seeds as possible in the top three to six inches. The tools loosen and aerate the soil, break up residues and weeds, and incorporate organic matter and soil amendments. A well-prepared bed will be easy to seed or transplant into, have good water drainage, and be easy to cultivate. Soil amendments and organic matter can be incorporated into the soil as it is being prepared for seeding or planting.

Hand Tools for Soil Preparation

Hand tools can thoroughly prepare a small amount of land for planting. Spades and digging forks are designed to thrust vertically into the soil rather than at an angle. They are preferable to a shovel because the blade of a shovel is often shorter than the blade of a spade; in addition, the curve of a shovel blade makes it difficult to deeply penetrate the soil. Short-handled spades and forks with a D- or T-shaped handle allow for more efficient use of energy when digging deeply and when moving soil.

A digging fork (left) with a T-handle and a spade with a D-handle. Photo: Andy Pressman, NCAT

After the soil has been forked or spaded, a garden rake can be used to break up larger clods and remove residues and stones that, left alone, could interfere with planting, cultivation, and overall plant health. Rakes can also be used to level a bed and open furrows for seeding. They can be used with the head facing either up or down and by using a push-pull motion. The handle of a rake can also be held parallel to the body so that the head can be used to lightly tamp down the soil after seeding. The seedbed rake is designed with longer tines that can be covered with tubing to mark out specific rows for planting.

The broadfork, or U-bar, is a 2-foot-wide spading fork used for deep tillage. It consists of two handles, one on each side of the fork, and teeth that are spaced about four inches apart. The teeth are designed and spaced so that as the handles of the broadfork are pulled down, the tines break the soil and lift it without the broadfork itself being lifted. Once the soil is loosened, the broadfork is moved back about six inches, and the procedure is repeated down the bed. Many farmers find the broadfork useful for harvesting crops such as scallions and potatoes as well.

Equipment for Soil Preparation

Selecting the right piece of equipment for tillage depends on the type of soil that is desired. Tillage can be broken down into two kinds: primary and secondary. Primary tillage aggressively loosens the soil and breaks up residues at a depth of as much as two feet. Secondary tillage pulverizes and smooths the top several inches of soil. Equipment should be selected based on the type of tillage desired and how the equipment works given the specific characteristics of the soil. The tools' ability to perform correctly also depends on the horsepower of the tractor. Soils that are heavy, compacted, or have significant amounts of residues, for example, may require greater horsepower.

Primary Tillage Equipment

Primary tilling is performed by different types of plows, discs, rototillers, and spading machines. The moldboard plow is one of the oldest implements used for soil preparation; it consists of one or more curved pieces of metal, called bottoms, attached to a frame. The bottoms are pulled through the soil to cut and then invert, either partially or wholly, the soil. One- to 4-bottom plows are common for small-scale production, and each bottom requires approximately 10 to 15 horsepower from the tractor. Plows come in various shapes and sizes, which determine the depth of the plow and how it moves the soil. Disc coulters can be added to the front of the plow to cut the soil so that the bottom penetrates the soil more effectively.

Chisel plows, or field cultivators, have curved shanks (also known as chisels) with sweeps or other tips attached to them. They are used for loosening the soil without inverting it, thus leaving residues on the soil surface. They are often used to break up hardpans and heavy soils and can be run across a bed before planting root crops. Root penetration can also be improved with a subsoiler. Subsoilers have straighter and longer shanks than chisel plows, usually about

18 inches; each shank needs about 25 horsepower to penetrate 18 inches or so. Subsoilers are also used to break up compacted soils and improve drainage and aeration by penetrating deeper than a chisel plow into the soil.

Discs can be used for both primary and secondary tillage. Discs are ground-driven implements that cut and mix the soil. They come in several different shapes and sizes and can be arranged in different rows and at different angles. Discs perform best on soils that don't have a lot of residue and on soils that are not so wet that they will clog or so dry that they don't cut. Heavy discs can be used for primary tillage, and adding additional weight to the disc can help it cut farther and incorporate better. Lighter discs can be used for secondary tillage after the soil has been plowed.

Rotary tillers also can be used for primary and secondary tillage up to eight inches deep. Rotary tillers are instrumental in small-scale vegetable production because they have the ability to produce fine seedbeds at varying widths. They are suitable to use with walk-behind tractors that have as little as 5 horsepower and ridden tractors of up to 100 horsepower. Rotary tillers have a rotating shaft with several attached tines that mix the soil at various depths. While most tillers on the market use a forward rotation to mix the soil, newer reverse-tine tillers use reverse action to pull the tiller into the ground by burying larger soil clods underneath smaller clods, often leaving a finer seedbed with less compaction.

Rototilling is an effective way to prepare a seedbed; however, there are serious drawbacks when the tool is overused. Continuous rototilling can create a hard layer of soil, or plow pan, underneath the tilled soil and increase organic matter decomposition. It can also create soils that quickly erode. Reducing the rototiller's revolutions per minute or increasing the tractor's ground speed can be less harmful to the soil than normal rototilling (Wiswall, 2009).

Spading machines are an alternative to using a rotary tiller. Common in Europe, spading machines loosen the soil and incorporate residues without turning the soil. Spaders are either rotary or reciprocating, and the spades on both types move more slowly than a rotary tiller through the soil. This action works the soil more effectively without causing compaction. Depending on the condition of the soil, a fine seedbed can be accomplished in a single pass without secondary tillage.

A Celli spading machine at Pennypack Farm and Education Center in Horsham, Pennsylvania. Photo: Andy Pressman, NCAT

Secondary Tillage Equipment

Depending on how rough or crusted the soil is and how much plant residue remains, using secondary tillage equipment can further refine and level the soil before seeding or planting. Harrowing is used for shallow tillage and is most commonly practiced after plowing. Harrows can be used to break down the furrow slices caused by the plow, reduce clods, smooth out the soil surface, and kill young weeds. The types of harrows include light disc harrows, chain-link harrows, spring-tooth harrows, and spike-tooth harrows. If sod has been plowed under, the disc harrow will not bring lumps of sod up to the soil surface—unlike the spring-tooth or spike-tooth harrow. Although spike-tooth harrows do not pulverize the soil as well as other types of harrows, they can sometimes be used to cover broadcast seed.

Field cultivators consist of a toolbar with different implements mounted on it. They are heavier than harrows and are used when the soil is too rough, is too compacted, or has too much residue for a harrow. The toolbar usually has C-shanks or S-shanks with sweeps, tines, chains, or rollers attached to the bottom.

Bed Shaping

There are several advantages to forming raised beds, including warmer soils and better drainage. In addition, raised beds make it easier to steer a tractor and implement for planting and cultivating. Bed shaping is usually done by

Continuous rototilling can create a hard layer of soil, or plow pan, underneath the tilled soil and increase organic matter decomposition. It can also create soils that quickly erode.

pushing loose soil into ridges with a hilling disc or other implement and then forming and pressing the soil into a bed. There are many different styles of bed shapers. Some can lay drip tape and plastic mulch and apply fertilizers; many designs are made right on the farm.

Seeding and Planting

Farmers must take several factors into consideration when choosing how best to establish a crop for production. Local soil and growing conditions, market considerations, and production resources affect whether a crop should be direct seeded or transplanted. How a crop is planted will affect its performance in establishment, earliness, quality, and yield.

Equipment for Direct Seeding

Direct seeding requires contact between the seed and the soil so that the crop can establish itself once it germinates. Spin seeders are used for broadcasting cover-crop seeds at a set desired rate. They can be handheld or tractor mounted. Light harrowing, raking, irrigating, or adequate rainfall will help ensure good seed-to-soil contact.

Other types of seeders should be used for crops that need to be planted in the soil at a uniform spacing and depth. These include precision seeders, pinpoint seeders, stick- or jab-type seeders, and drills. Precision seeders can be manually pushed or tractor mounted and dispense individual seeds in a furrow. Seeds can be singulated through several different mechanisms, including cups, belts, vacuums, plates, and rollers. For small-scale farms, Glaser, Earthway, and Jang are brand names of precision push seeders that use plates or rollers. The Stanhay uses belts, and the Nibex uses cups—both are available as walk-behind push seeders or toolbar-mounted seeders (Volk, 2009). Many of these single-row seeders offer attachments that can connect seeders together for seeding multiple rows, attach seeders to a wheel hoe, or mount seeders with a fertilizer attachment.

Pinpoint seeders are designed to be manually pulled and perform well for greenhouse planting. Medium- to large-sized seeds can be hand planted through a stick- or jab-type seeder that can also plant through plastic mulch. Seed drills also are available for manual or tractor-mounted seeding. Discs can be set for the size of the seed, but thinning may be necessary to achieve proper spacing between plants. Planet Jr. is a classic name associated with vegetable drills. Drills can also be used for planting grains and cover crops.

Desirable Features of a Hand-Pushed Precision Seeder

In his book *The New Organic Grower,* Eliot Coleman suggests a number of characteristics to look for in a hand-pushed precision seeder:

- It is easy to push in a straight line
- It gives precise seed placement
- It allows accurate depth adjustments
- It is easy to fill and empty
- It is flexible and adaptable
- It has a visible seed level and seed drop
- It includes a dependable row marker

SPIN farmer Wally Satzewich of Wally's Urban Market Garden in Saskatoon, Saskatchewan, using an Earthway seeder. Photo: Courtesy of SPIN-Farming

Equipment for Transplanting

Setting out transplants helps to extend the growing season and harvest. Many farmers transplant crops by hand using a trowel, a dibbler, or a jab-style planter, but mechanical transplanters can speed up the planting process with more accuracy and less labor. Mechanical transplanters require one person to drive the tractor while a crew of one or more people drops transplants into the soil. Many farmers have designed simple sled-type transplanters that allow the crew to sit or lie down while they transplant by hand. Commercial transplanters have a shoe, coulter, or some other device to open the planting furrow. They also have a closing wheel that packs

the seedlings, which are held on trays, in place once they are planted. Water-wheel transplanters inject water into the hole after the plant is set. Other types of transplanters include the gripper type, the carousel, the spade type, and the no-till transplanter.

A Rainflo water-wheel transplanter at Pennypack Farm and Education Center in Horsham, Pennsylvania. Photo: Andy Pressman, NCAT

Weed Control

Weeds compete with crops for light, water, and nutrients, and they can affect a farm's economic bottom line. Weeds can reduce crop yields through competition with cash crops, promote pests and disease, and even be problematic in the harvesting process. As a result, there is a large cost associated with controlling weeds. Minimizing weed growth both in the short term and the long term should be considered when designing a cropping system. Careful planning to limit weeds' competition with cash crops and to reduce the amount of time, fuel, and other resources spent on controlling weeds can be vital to a farm's economic viability.

There are several techniques for effectively controlling weeds, including chemical and cultural approaches, as well as the use of cultivation tools. Many of the control techniques can be integrated together to be more effective. All of the techniques are focused on either preventing weed seeds from germinating (pre-emergence) or suppressing established weeds (post-emergence).

A weed-management strategy includes a number of factors:

- Timing weed control-operations
- Selecting the most appropriate tools for cultivating
- Forming planting beds and crop-row spacing to match the cultivation tool and its configuration
- Incorporating other cropping practices such as cover crops, crop rotation, irrigation, fertilization, and pest management

Cultural Practices

Cultural practices utilizing equipment include cover cropping, the use of stale seedbeds, mulching with both organic and inorganic materials, and mowing. The practice of using a stale seedbed targets weed seeds within the top one to two inches of soil and is usually performed mid to late season. This technique allows for the weed seeds to germinate, but the young weeds are then killed through such practices as flaming or scraping just below the soil surface. This prevents new seeds from coming up to the surface. Mowing weeds can stress the weed plants so that they are unable to flower and set viable seed. Mowing around crops also can limit weeds' ability to compete.

Mulching can create a physical barrier to limit weed growth. Organic mulches such as straw can also reduce the soil temperature, which may slow down the growth of weeds. Plastic mulches are used with heat-loving plants and promote an earlier harvest by raising the soil temperature. Plastic mulches come in a variety of colors that affect the soil temperature differently. Although black plastic mulch doesn't provide much heat to the soil, it effectively suppresses weeds. A plastic-mulch layer is an implement that can quickly lay plastic in a straight, flat, and tight manner over a bed. Depending on the unit, plastic-mulch layers can level the soil surface, shape beds, lay plastic over hoops or raised beds, and even lay drip tape under the mulch, all in one pass. Plastic-mulch lifters can be used to assist in pulling up the plastic mulch at the end of each season.

Cover crops can be planted to suppress weeds. Cover crops such as rye, oats, buckwheat, and sorghum-Sudan grass can be planted during certain times of the year in order to smother out weeds through competition or by creating a mulch layer. Some crops, such as rye, contain alleleopathic chemicals that prevent weed seeds from germinating. The roller-crimper is a cutting-edge implement that is being used in no-till planting. It consists of a metal drum with protruding blunt metal blades arranged in a pattern

designed to roll over a cover crop and crimp the plants so that they die, creating a mulch layer. Crops can then be planted or transplanted directly through the mulch.

Hand Tool Cultivation

The primary tool used in hand cultivation is the hoe. For many farmers, hoeing may seem like back-breaking and labor-intensive work. This may well be the case, especially when using the standard hoe with a 90-degree angled blade and a 54- to 57- inch handle for weeding. These hoes are designed for such tasks as digging, chopping, and hilling soil, and they are inadequate for cultivating smaller weeds that have germinated in intensively planted beds. Understanding when to hoe and how to use different hoes will allow for easy cultivation of weeds.

The eye-hoe, or chopping hoe, is one of the oldest and most traditional tools in the world. The eye-hoe is designed with a heavy head for chopping larger weeds and roots and for moving soil. They are swung similarly to an axe, with the weight of the head doing the work.

Upright hoes allow for smaller weeds to be sliced just below the soil surface. Their blades can fit in narrow spaces and are relatively lightweight. The handles tend to be longer, between 66 and 74 inches, which allows for a farther reach and for hand positioning that allows the user's back to stay straight. Examples of upright hoes are the narrow collinear hoe, the swan-neck or half-moon hoe, the push hoe, the diamond hoe, and the stirrup hoe, which is also known as the oscillating or hula-hoe.

The author, standing straight and holding the handle with thumbs pointing up, is demonstrating the correct position for using a long-neck hoe. Photo: Andy Pressman, NCAT

The narrow collinear hoe has a thin metal blade, usually 3¾-inches or 7-inches long, placed at a 70-degree angle to the handle. The blade runs parallel to the soil surface and is used in a pulling motion with the user standing sideways. The swan-neck hoe also is used in a pulling or sweeping motion, and the blade is a bit heavier and wider than the blade of the collinear hoe. The push hoe is designed with the front of the blade sharpened and lies flat on the ground so that it can "scuffle" across the soil surface in a pushing motion. The diamond hoe is sharpened on both the front and back of the blade, allowing it to cut in both a pushing and a pulling motion. The blade of a stirrup hoe is not fixed like the diamond hoe's, which allows it to dig deeper into the soil as it cuts in both directions. In addition, the stirrups, or sides of the blade, make it possible for users to see how close they are cutting to the cash crop.

From left to right, a collinear hoe, a swan-neck hoe, a stirrup hoe, a "regular" hoe, and an eye-hoe. Photo: Andy Pressman, NCAT

Wheel hoes are one of the most efficient tools for weed cultivation on small land bases. The ability to attach different cultivation implements, such as stirrup hoes, chisels, and sweeps, onto a wheeled frame allows the user to stay upright while pushing and pulling the tool at a decent speed. Wheel hoes have either one or two wheels. Although the double-wheeled version is less common, it allows for cultivation on both sides of a crop row at the same time. Wheels come in different diameters, usually from nine to 24 inches, with the smaller-wheeled models being easier to direct and less tiring and cumbersome to use (Coleman, 1995).

The author using a single-wheel hoe with a stirrup attachment. Photo: Andy Pressman, NCAT

Huguenot Street Farm in New Paltz, New York, received funding from the USDA-SARE program to develop detailed instructions on converting an Allis Chalmers Model G into an electric vehicle. The instructions are available online at: www.flyingbeet.com.

An Allis Chalmers G converted to electric at Fair Share Farm, Kearney, Missouri. Photo: Rex Dufour, NCAT

Mechanical Cultivation

For many farms, an increase in production efficiency begins with a cultivating tractor. Farmall, Allis Chalmers, Ford, Case, Oliver, Kubota, and John Deere are some common brand names of cultivating tractors, and many models are designed for accuracy by allowing the driver to steer closer to the crops while cultivating. Guidance accuracy was incorporated into the design of many models through the use of belly-mounted toolbars and by offsetting the motor to give the driver a clear line of sight. Having the toolbar belly mounted also compensates for the lateral direction of the toolbar while steering. In other words, the toolbar moves slightly in the same direction the tractor is being steered. With rear-mounted implements, on the other hand, the toolbar moves slightly in the opposite direction of the tractor as it turns.

Many cultivating tractors were manufactured during the late 1940s and early 1950s and are still common on small-scale vegetable farms. The Allis Chalmers Model G, for example, was built between 1948 and 1955, and, unlike other cultivating tractors, its motor was placed behind the driver to provide even further guidance when cultivating. While some cultivating tractors were designed to be low to the ground for precision cultivation between young or low-growing crops, other tractors, such as the Landini, were built with a high clearance to cultivate between larger crops throughout the growing season.

There is a broad range of tractor-drawn and PTO-driven implements for weed cultivation. In addition to reducing weed populations and the use of herbicides, many of the implements function to loosen, aerate, and till the soil, as well as incorporate fertilizers into it. Implements for cultivation are designed for both post- and pre-emerging weeds and include sweeps, discs, torsion hoes, brush hoes, spider wheels, finger weeders, S-tines, basket weeders, rolling cultivators, and other specialized cultivating devices. Some of the more common implements are described below. For a detailed explanation of weed-management tools, see "Steel in the Field" in the Further Resources section.

Cultivation Equipment for Pre-Emergence Weed Control

Controlling weeds before they germinate involves cultivating just below the soil surface. Pre-emergence cultivation can be done prior to or in between plantings or shortly after a crop has been planted. "Clean fallow" is a term used to describe the repeated cultivation before or in between plantings and is used to kill annual weeds, reduce weed-seed banks in the soil, and remove perennial weed growth (Grubinger, 1999). Once a crop has been planted, and even germinated, a technique known as blind cultivation is used in and between rows. Blind cultivation targets small weeds that have been up for a week or less and does not prevent large-seeded crops that have been sown deeply from germinating.

Disc harrows are one of the most versatile cultivation tools for clean fallowing. The blades of the disc loosen and mix the soil through a lifting action, which then leaves the soil level. Tandem disc blades are usually 16 to 18 inches in diameter and are set about seven inches apart, while offset disc harrows have discs 20 to 24 inches in diameter and are set nine inches apart (Schwenke, 1991). Offset disc harrows are often used in orchards because they can be set up to stir the soil close to trees. Some perennial weeds, particularly those that spread through rhizomes, are better dealt with by equipment that can dig the rhizomes up to the soil surface, where they can dry out and die. Spring–tooth harrows or field cultivators equipped with sweeps or shovels work well for uprooting perennial weeds.

Tine weeders and rotary hoes are two implements commonly used for blind cultivation. Tine weeders, also known as flex-tine weeders, consist of many small metal tines that are pulled through the soil at a fast speed, causing the tines to vibrate and remove the weeds from the soil. Timing is key because the tines scratch the cash crop as well as the weeds growing in between the rows. The depth of the tines can be controlled by gauge wheels or by using a 3-point hitch. Rotary hoes often are used for blind cultivation in corn and beans and for breaking up the surface of crusted soils (Grubinger, 1999). Rotary hoes are ground driven and consist of several spider wheels with "spoons" or tips that rotate and remove weeds.

Cultivation Equipment for Post-Emergence Weed Control

Tools for post-emergent weed cultivation are designed to be used for specific crop stages. As a crop grows and gains strength, more aggressive tools that throw soil can be used, such as sweeps, basket weeders, Spyders™, hilling discs, finger weeders, row-crop cultivators, and rolling cultivators. Implements such as wiggle hoes and brush weeders are designed for cultivating smaller crops between rows.

The sweep is one of the most basic tools used for cultivation. Sweeps are V-shaped blades that attach to a shank that is attached to a toolbar. Depending on the style of sweep, the blade faces forward and slices, drags, or buries the weeds while throwing soil into the rows. The toolbar can be rear mounted, front mounted, or belly mounted to the tractor. Sweeps are usually set to a depth of one inch below the soil surface, and the depth of the sweeps can be adjusted to accommodate for differences in elevation within a bed. Running a sweep too deeply can disturb plant roots and throw more soil. However, sweeps set at a deeper depth can also be used for hilling-up such crops as Irish potatoes, sweet corn, and broccoli (Schonbeck, 2010). Shovels are narrower than sweeps and throw less soil.

A basket weeder belly mounted to an Allis Chalmers G at Pennypack Farm and Education Center in Horsham, Pennsylvania. Photo: Andy Pressman, NCAT

Basket weeders consist of two rows of metal baskets that roll across the soil surface at different speeds. The first row is ground driven, which also drives a chain to power the rotation of the second row. This increases the rotation speed of the baskets in the second row so that they cultivate weeds that survive the cultivation of the first-row baskets. The baskets scuff the soil surface without moving the soil. Basket weeders are belly mounted, can be driven at moderate speeds, and are ideal for cultivating various greens such as lettuce. Buddingh basket weeders are designed for cultivating two- to eight-row beds.

The Spyder™ is a ground-driven wheel with offset teeth angled to either throw soil toward or away from the row. Torsion weeders and spring-hoes can be mounted to the Spyder™ to take care of weeds missed by the teeth of the Spyder™.

Hilling discs are used to pull soil away from small crops or to hill (throw soil toward) larger crops, such as potatoes and sweet corn.

Finger weeders are metal cone-shaped wheels mounted to the belly of a tractor. Protruding from the wheels are rubber-coated metal fingers that cultivate around the stems of plants. The wheels are ground driven and cultivate closely in rows.

Rolling cultivators contain gangs of wheels with tines angled to either throw or hill soil into the rows. The gangs swivel as they slice through the soil digging up weeds. A fertilizer attachment can be used at the same time as a rolling cultivator for side-dressing crops (Grubinger, 1999).

A row-crop cultivator is a metal frame with several attached shanks and cultivators. The shanks can be set for specific crop rows and throw the soil as the frame is pulled by a tractor. Shields can be mounted to protect the more delicate plants.

Wiggle hoes are steered from the back of the implement as it is pulled by a tractor. They consist of half sweeps that face either to the left or the right and are attached to a shank. Wiggle hoes can be steered by the driver close to the crops but require wide crop spacing.

The European brush weeder sweeps weeds out of the soil. The brushes fit between narrow rows of crops, which are protected by a shield. As with the wiggle hoe, a brush weeder is steered from the back of the implement by a driver.

Flame weeders use propane burners that create a flame of intense heat to control small weeds. Flame weeding is often used to kill weeds in the stale-seedbed technique, particularly for intensive plantings of greens and herbs, because it does not disrupt or throw the soil. There are different scales of flame weeders, from handheld or backpack flamers to tractor-mounted implements. The ATTRA publication *Flame Weeding for Vegetable Crops* has additional information on the use of flame weeders.

Foggy Meadow Farm – Benson, Vermont

Paul Horton and Sally Beckwith of Foggy Meadow Farm produce naturally grown vegetables and herbs on 4½ acres in Benson, Vermont. Foggy Meadow is a year-round operation that direct markets its crops through farmers markets and restaurants. From its start in 2004, Foggy Meadow has invested in small-scale equipment and tools, which has resulted in the farm being able to continue producing at this scale and remain economically viable.

Horton and Beckwith believe every farm should develop a reputation for growing certain crops; Foggy Meadow is known for its high-quality greens and carrots. Although most crops on the farm are transplanted, the farmers at Foggy Meadow direct seed 1,000 row feet of salad mix and 10,000 row feet of carrots each week from March through September to ensure a continuous supply. Greens are grown in two 15-foot by 96-foot high tunnels during the spring and winter months, and tomatoes take root in them during the summer. The high tunnels are moved once or twice a year to new soil to help protect plants from soil salinity issues, pests, and disease.

Field crops are grown in ¾-acre sections. This amounts to having six to seven sections, which allows Horton and Beckwith to plan for extensive crop rotations. As spring crops come out of the ground, some land becomes a stale seedbed while other parcels are cover cropped or sheet mulched for use the following spring.

The farm uses a 70-horsepower John Deere tractor for field tillage and bed preparation. Beds are prepared for planting with a combination of a 5-shank chisel plow and a 70-inch rototiller. This creates beds for up to three crop rows, which are marked out in the bed by using pins on a basket weeder. The Buddingh basket weeder is attached to a Farmall Cub—one of four tractors used for cultivation. There are two Farmall Super Cs, one with sweeps and hilling discs and the other with shovels that are matched with the rows in each bed. In addition, a Farmall A tractor is set up with a 6-foot disc and harrow for planting cover crops. Having tractors set up with only one implement reduces the time and stress involved with switching implements on a single tractor. As Foggy Meadow Farm looks to produce more crops for winter markets, Horton is interested in purchasing another cultivating tractor with a toolbar set up for single-row crops.

Foggy Meadow Farm, Benson, Vermont. Photo: Courtesy of Sally Beckwith

Summary

Choosing the right tool or piece of equipment can be a challenge, but it can greatly affect production efficiency and the economic bottom line for the small-scale farmer. Investing in well-designed hand tools of good quality enhances the farmer's ability to maximize production on an intensive scale. Using tractors and implements designed for small-scale intensive crop production can increase crop quality and yields while reducing labor inputs. Such factors as soil type and crop selection play an important role in the utilization of farm equipment.

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Further Resources

Books

Steel in the Field – A Farmer's Guide to Weed Management Tools. 1997. Edited by Greg Bowman. A publication of the Sustainable Agriculture Network (SAN), Beltsville, MD.

Organizations

The Core Historical Literature of Agriculture (CHLA)
http://chla.library.cornell.edu

Cornell University's electronic collection of more than 1,800 agricultural texts published between the early 19th century and the middle to late 20th century. CHLA contains numerous titles on farm equipment, many of which provide illustrations and descriptive uses of tillage, cultivation, and soil-preparation equipment.

eXtension
www.extension.org

Extensive information from land-grant universities on agriculture, including articles and videos on organic soil and weed management.

Growing for Market
P.O. Box 3474
Lawrence, KS 66046
800-307-8949
www.growingformarket.com

Subscription journal with news, advice, and resources for market farmers. Articles are written by market farmers and regularly include information on equipment and tools for market farms.

The Healthy Farmers, Healthy Profits Project
http://bse.wisc.edu/hfhp/index4.htm

Tip sheets on small farm tools and equipment from a team of researchers and outreach specialists that finds and shares work-efficiency methods to improve health, safety, and profits for nursery growers, berry and fresh-market vegetable farmers, and dairy producers.

NCAT Small-Scale Intensive Farm Training (SIFT) Program
http://sift.ncat.org

This new program is providing in-depth, hands-on training to local food producers who will learn how to commercially produce a large amount of high-value, nutrient-rich food on small parcels of land in a sustainable and environmentally responsible manner.

Rodale Institute
611 Siegfriedale Road
Kutztown, PA 19530
610-683-1400
www.rodaleinstitute.org

Organization dedicated to researching and promoting organic farming practices. It produces extensive information on organic crop production, including no-till farming and the use of the roller-crimper.

Village Earth

P.O. Box 797
Fort Collins, CO 80522
970-237-3002
info@villageearth.org
http://villageearth.org

Extensive information on appropriate technologies from a network of organizations and people who work to support marginalized communities around the world.

Yesterday's Tractor Company
www.ytmag.com

Website with active forums, photos, and extensive information about pre-1985 farm equipment.

Videos

Vegetable Farmers and Their Sustainable Tillage Practices. Created by Vern Grubinger of University of Vermont Extension.
Center for Sustainable Agriculture
University of Vermont
106 High Point Center, Suite 300
Colchester, VT 05446-8800
802-656-5459
sustainable.agriculture@uvm.edu
www.uvm.edu/sustainableagriculture

Vegetable Farmers and Their Weed Control Machines. Created by Vern Grubinger of University of Vermont Extension and Mary Jane Else of University of Massachusetts Extension.
Center for Sustainable Agriculture
University of Vermont
106 High Point Center, Suite 300
Colchester, VT 05446-8800
802-656-5459
sustainable.agriculture@uvm.edu
www.uvm.edu/sustainableagriculture

Suppliers

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www.amleo.com

Offers quality horticulture tools and equipment for nursery, landscape, and agriculture customers.

Bountiful Gardens
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bountiful@sonic.net
www.bountifulgardens.org

Supplier of durable hand tools from England.

Earth Tools
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Owenton, KY 40359
502-484-3988
www.earthtoolsbcs.com

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Tornio, Finland
+358 16-472 000
Petri.leinonen@elomestari.fi
www.elomestari.fi/english/english.htm

Finnish company specializing in products for small-scale sustainable farming. The company is the maker of the Weed Master (a manual carrier for seeding, planting, flaming, spraying, and hoeing) and the Crawler (a motorized lay-down working cart for all horticultural work).

Ferrari Tractor C.I.E.
P.O. Box 1045
Gridley, CA 95948
530-846-6401
sales@ferrari-tractors.com
www.ferrari-tractors.com

Dealer of new and used equipment for the small farm, with expertise in carrying European-made 2- and 4-wheel compact tractors and implements.

Green Heron Tools
P.O. Box 71
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610-844-5232
info@greenherontools.com
www.greenherontools.com

Maker of high-quality hand tools and equipment specifically designed for women farmers.

Gulland Forge Broadfork
502-682-8529
gullandbroadfork@me.com
http://gullandforge.com
Online business offering a high-quality forged broadfork.

Harmony Farm Supply and Nursery
P.O. Box 460
Graton, CA 95444
707-823-9125
info@harmonyfarm.com
www.harmonyfarm.com

Offers a full range of tools and supplies for the small-scale farm.

Hida Tool & Hardware Company, Inc.
1333 San Pablo Avenue
Berkeley, CA 94702
800-443-5512
hidatool@hidatool.com
http://hidatool.com

Specializes in Japanese handcrafted weeders, hoes, sickles, and cutting implements.

Johnny's Selected Seeds
955 Benton Avenue
Winslow, ME 04901
877-564-6697
communications@johnnyseeds.com
www.johnnyseeds.com

Offers a complete line of tools for the gardener or commercial grower, including flame weeders, wheel hoes, seeders, and hand tools.

Lee Valley Tools
P.O. Box 1780
Ogdensburg, NY 13669
800-267-8735
customerservice@leevalley.com
www.leevalley.com

Offers an extensive inventory of gardening tools and implements.

Market Farm Implement
257 Fawn Hollow Road
Friedens, PA 15541
814-443-1931
www.marketfarm.com

Specializes in vegetable-crop machinery from tillage to harvest.

Mechanical Transplanter Company
1150 Central Avenue
Holland, MI 49423
800-757-5268
mtc@mechanicaltransplanter.com
www.mechanicaltransplanter.com

Offers a full range of manual and tractor-mounted equipment for tillage, planting, and cultivation.

Organic Growers Supply (FEDCO)
P.O. Box 520
Waterville, ME 04903
207-873-7333
www.fedcoseeds.com

Cooperative supplier of hand tools, orchard supplies, irrigation, and seed-starting supplies for the organic grower.

Peaceful Valley Farm and Garden Supply
125 Clydesdale Court
Grass Valley, CA
888-784-1722
helpdesk@groworganic.com
www.groworganic.com

Offers a full line of hand tools; growing supplies; irrigation and season-extension supplies; organic soil amendments; seed; and pest and weed controls.

Purple Mountain Organics
7120 Carroll Avenue
Tacoma Park, MD 20912
877-538-9901
http://purplemountainorganics.com

Offers a full line of high-quality tools and equipment for the small farm, including hand tools, walking tractors, compact tractors, and implements.

Red Pig Tools
12040 SE Revenue Road
Boring, OR 97009
503-663-9404
redpigtools@frontier.com
www.redpigtools.com

Maker of forged-steel hand tools, including left-handed tools.

Rogue Hoe
4360 Bado Road
Cabool, MO 65689
417-962-5091
sales@roguehoe.com
www.roguehoe.com

Maker of hand-crafted hoes made from recycled agricultural disc blades that are sharpened on three sides.

Seeds of Change
P.O. Box 4908
Rancho Dominguez, CA 90220
888-762-7333
www.seedsofchange.com

Offers seeds, digging and cultivating tools, hand tools, rakes and hoes, and seed-saving supplies.

Small Farm Innovations
3701 State Highway 36, South
Caldwell, TX 77836
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smallfarminnovations@hughes.net
www.smallfarminnovations.com

Supplier of compact tractors and farm implements for small acreages, including compact hay equipment.

Valley Oak Tool Company
P.O. Box 301
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david@valleyoaktool.com
www.valleyoaktools.com

Specializes in high-quality wheel hoes and broadforks.

Notes

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