

Chapter 10

Vegetable Equipment and Irrigation Essentials

Ben Beale

The variety of new and innovative equipment offers today's farmers many choices. Equipment provides the mechanism to accomplish much of the work carried out on a farm. The correct selection and application of equipment can improve farm efficiency, remove drudgery and reduce labor expenses. However, to ensure healthy profit margins it is important for small farmers to understand their economy of scale and the potential return per dollar for each piece of equipment purchased. The cost of equipment can quickly absorb profit margins. Consider if the piece of equipment is an essential component of the operation before purchases are made.

Conduct Research to Ensure Prudent Purchases

Equipment decisions begin with understanding the needs of your particular operation. Due to the wide selection of equipment—including various brands and implement types and condition, it is critical to conduct thorough product research. Research can be performed by visiting different farming operations, farm shows, or equipment dealers to determine which equipment best meets the needs of the grower. The Internet can be utilized to examine equipment options and uses, as well as regional availability and prices. It is prudent to complete product testing prior to making a purchase—equipment can be rented or borrowed. Such actions will help ensure that the equipment is well suited for the grower's operation.

Essential Equipment

The below discussion summarizes essential equipment for a small commercial vegetable farm using intensive production techniques. However, the equipment listed and discussed is not prescriptive. Each grower should review the needs of their operation to determine the ideal mix of equipment. What may be essential on one operation may be useless or obsolete on another.

The following guidelines are helpful when deciding the best mix of equipment for a farm operation. First, select equipment based upon your production system and needs. Often, the production system is suited to the equipment because the equipment is already available or a great "deal" is found for a piece that doesn't fit the operation's needs. In the long-term, this practice leads to inefficiencies and lower profitability. If the capability of one piece of equipment is altered, evaluate the affect of that capability on the entire operation. For example, will the adoption of plasticulture increase field output, resulting in a strain on the washing and packing facilities or will the change to a smaller

cultivating tractor increase the need for hand weeding, thus reducing labor available for harvest?

Secondly, consider the ability and comfort level of the grower in operating and maintaining equipment. Organic farming can be profitable at many scales, and the grower's personal goals and interests can reflect their equipment strategies. Consider your farm mission and make sure it is reflected in your operational plan.

Thirdly, do not rely on equipment to compensate for poor management or bad growing practices. For example, a grower may excessively till using a disc or rototiller which results in poor soil structure. To fix this "problem" another piece of equipment, such as a manure spreader, is need to add more organic matter. A general principle for organic systems is the equipment should work in conjunction with natural systems to enhance the overall benefit to the grower.



Figure 1. Ag Progress Days

Finally, equipment purchases should not be made at the last minute. Rather it is prudent to monitor equipment availability and prices over time. Prices are generally less in the off season. End-of-year sales and tax considerations also help determine when equipment should be purchased.

Primary Tractor

The tractor is the center of most farm operations; it pulls various implements and also serves as a power unit for stationary operations. Successful vegetable operations require tractors that are efficient and reliable. Growers cannot afford to suspend harvest and planting activities while waiting for a part to be shipped, a hydraulic hose to be repaired, a battery to charge overnight, or another equipment failure. Therefore, when purchasing used equipment it is imperative to carefully assess the tractor's condition and if necessary, consult a trusted associate for a second opinion. A few purchasing tips:

- Diesel tractors are preferable to gas tractors due to their fuel efficiency and durability.
- Properly size the tractor. A 40-60 horsepower (hp) unit has adequate power capacity for most operations, including the power-guzzling tillage operations for a small vegetable farm.
- If the scale of the operation does not warrant a large tractor, consider the use of a "walking tractor" which can provide much of the traction needed for tillage, cultivating and even bed-laying operations.

- Bed-forming tasks, such as a 4-foot production bed, may require 60-70 hp 2-WD for single-pass operation. Smaller tractors may need a few passes for that particular task.
- 4wd/MAWD Tractors are useful for a variety of work. These tractors are better suited to front-end loaders and offer greater traction for field work. As a note of caution, do not rely on 4wd/MAWD tractors to conduct field work when field conditions are not suitable. Much damage can be done working wet soils with 4wd/MAWD tractors.
- A primary tractor must have a slow first gear, sometimes referred to as a creeper gear, for transplanting and harvesting tasks.
- Infinite speed options or hydrostatic drives are beneficial, but not essential.
- A reliable hydraulic system is important for both auxiliary hydraulic lines and a 3-point hitch system.
- The 3-point hitch system should be at least a Category II to accommodate most implements.
- Adequate ground clearance is important for cultivation and harvesting. Although hybrid utility/farm tractors recently have increased in popularity for landscape and homeowners, they often lack adequate ground clearance for vegetable farm use.



Figure 2. Medium Size Tractor

Tillage

Tillage is divided into primary and secondary passes. Vegetable producers use tillage to create clean, firm seed beds; develop raised beds; prepare for plastic mulch; and incorporate old crop residue and manure. However, tillage also destroys organic matter—the primary source used to build soil tilth and structure. It is important to achieve an effective balance for an operation; till only when needed, explore no-till options, and if possible avoid tilling wet soils. In organic systems, tillage is also an important component of the soil fertility regimen. The ability to incorporate green manure cover crops, organic matter and manure is an important consideration. For more discussion regarding soil health, see Chapter 4 Soil Health.

Primary tillage includes the first tillage pass to undisturbed land, usually by means of a plow. Equipment options include the most commonly used moldboard plow or the chisel plow. A two- or three-bottom moldboard plow can till a small vegetable farm in 1-2 days. Moldboard plows are easily repaired and can be purchased used. A chisel plow uses several shanks that penetrate the ground 6-12 inches and fracture the topsoil. Chisel plows are popular because they (1) disturb less soil, (2) do not leave compaction layers as easily as the moldboard, and (3) leave more residue (organic matter) on the soil surface. If compaction is a problem, then it may be necessary to complete sub-soiling

prior to conducting primary tillage passes. Subsoilers are tillage implements with long, heavy shanks that break up compaction layers deep into the soil. Subsoilers are relatively expensive and require 50-60 hp per shank to operate; therefore, they are not recommended for vegetable operations with less than 3-5 acres. Smaller farm operations should consider hiring a custom operator with specialized equipment for subsoiling.

Secondary tillage is used to finish the land in preparation for transplanting, direct seeding, or forming beds. There is a multitude of equipment options and configurations for completing the secondary tillage task. The traditional approach includes 2-3 secondary passes with a disc harrow; followed by a pass with a finishing harrow. A final pass with a cultipacker may be needed to remove clods and firm the seed-bed. This approach is still being utilized on many of today's farms. The disadvantages of solely relying on a disc harrow include the formation of horizontal compaction zones in the soil at the lower disc depth, inability to control the amount of residue left on the surface, and the need to make several passes resulting in compaction and reduced soil tilth.



Figure 3. Harrow Disc

During the past 20 years, finishing implements (i.e. field cultivators), have been used in conjunction with the disc harrow to complete the task of field finishing. Field cultivators combine various tillage units in sequence on a tool bar or frame to help prepare a fine seed-bed and accomplish several tillage tasks at once. Field cultivators also can be used for very shallow tillage prior to planting in order to kill emerging weeds. Typically, field cultivators include a group of sweeps or shovels on spring-loaded S-tines or C-tines,

followed by a leveling bar, and finally, a rolling basket or cultipacker. The majority of finishing implements are most effective on fields with very little residue; however, there are models specifically made for reduced-till fields. These units incorporate amendments while leaving a percentage of residues on the soil surface.

Some growers use rotovators or rototillers that quickly prepare a final seedbed. These machines are usually very heavy and attach to the tractor via a 3-point hitch; they range in size from three to eight feet. The 5-foot models are sufficient for most small farms and require a 40-50 hp tractor to pull. These units can be set to work aggressively, break up clods quickly, and may eliminate the need for several pieces of equipment. In some instances, rototillers can destroy soil structure — especially if the soil is too wet or too dry; therefore, this equipment must be used with caution. Growers are advised to use rotovators and rototillers as a part of the overall tillage system, rather than the sole source of tillage.

A soil spader is similar in nature to a rototiller, but it turns with slower rotations per minute (rpm) and is generally better at retaining soil structure while incorporating crop residue. A soil spader may be used as a primary tillage implement as well.

Weed Control Equipment

A continuous challenge for organic growers is the control of unwanted vegetation and weeds in crop fields. Several strategies for controlling weeds include the use of cover crops or smother crops, fabric cloth or plastic mulch, organic mulch, weed flamers or torches, organic herbicides, mechanical cultivation, and reduction in seed bank. Successful growers employ several of these strategies simultaneously. These strategies are discussed in detail in Chapter 8 Weed Management.

Numerous weed control techniques and innovations are available; this can be overwhelming for some growers. An excellent resource for the new grower is the Sustainable Agriculture Research and Education (SARE)-sponsored video entitled Vegetable Farmers and their Weed-Control Machines, produced by University of Vermont and University of Massachusetts. Weed control equipment is situation- and operation-specific, often requiring mechanical expertise to adapt equipment.

Mechanical cultivation is essential for growing row crops without using beds or mulches. Beds or plastic mulch may require cultivation on the plastic edges or in the row middles. A cultivating unit typically consists of a power unit, such as a tractor, and the cultivating attachment. The cultivating tractor can be the same as the primary farm tractor that's used for tillage and other farm tasks. However, a second tractor dedicated to cultivating is highly recommended for operations with more than two or three acres. Cultivating equipment should be used before weeds grow larger than 1-2 inches. If rain or other events delay cultivation, it may be necessary to use more aggressive back-up options and techniques. Uniform row widths that match the cultivator spacing make the most effective use of cultivation equipment; however, some hand-hoeing may be required.

Cultivating Tractors

Cultivating tractors should have enough clearance to pass over the crops under cultivation. A slow gear is needed for cultivating smaller plants and good visibility of the cultivating row is helpful. Many cultivating models have off-set seats that allow the operator to look directly down at the plant row. Many farmers rely on older tractor models produced in the 1940's, 1950's and 1960's for cultivating. The John Deere models M, H, B, 50, or 520; Farmall models A, C, H, 120, 130, or 140; the Allis Chalmers models B, C, Ca, or G Potato Bug; the Ford 8N or 9N (just to name a select few -- no endorsement intended) are widely available and often will have cultivator attachments with them. The Allis Chalmers G model is especially coveted for cultivating small plants, because the engine is mounted in the rear, which allows the operator to carefully watch the plant row as the cultivator sweeps pass by.



Figure 4. Rear Mounted Cultivator

Many modern tractor models are designed specifically for cultivating. Major manufacturers, such as Ford, Kubota, Massey Ferguson, Case-International, and John Deere, mostly produce smaller cultivating-type tractors. Tuff-Built produces a rear-mounted model similar in design to the Allis Chalmers G. Newer tractor models are available with either diesel or gasoline engines. These models operate much more efficiently, whereas, older gasoline models have poor fuel efficiency. Newer models also have more advanced hydraulic and electric systems, as well as more safety features such as roll-over protection. Late models are

considerably more expensive than older models. Whether it is more prudent to rely upon an older model or purchase a newer model should be based upon the grower's intended purpose, the amount of use, acreage requirements, as well as the grower's mechanical abilities.

Cultivating attachment arrangements depend on the desired use, plant size, and application; hundreds of variations exist. Cultivator attachments can either be mounted under the belly of the tractor on applicable tractor models, or may be mounted in the rear of the tractor on a tool bar hooked to the 3-point hitch or other hydraulic arm system. Rear-mounted systems are popular because they can be hitched to any tractor with a 3-point hitch and appropriate wheel spacing. A major disadvantage of this system is the limited number of shanks that can be mounted on one toolbar, another disadvantage is that the operator cannot watch or control a rear mounted unit as well.



Figure 5. Weed Attachment

Attachment types include cultivating hoes, sweeps, rolling baskets, spider wheels, disc wheels, weed brushes, flame or heat weeders, knives, rolling cultivators, and torsion weeders. Attachments are designed for different stages of crop and weed growth, and for cultivating the area between rows, directly beside the plant row, the area in the plant row, or overtop of the plant row. Several resources describe the different attachment options, costs and uses. Vern Grubinger, the Vegetable and Berry Specialist at the University of Vermont, authored an excellent resource Cultivation Equipment for Weed Control: Pros, Cons and Sources. Another outstanding publication is available through the extension website --An Organic Weed Control Toolbox by Mark Schonbeck, Virginia Association for Biological Farming. This site also contains video clips of different attachments working in the field.

Hand Weed Control Tools

Tractor-mounted cultivators and weed control units greatly assist with weed control, but no single strategy is perfect. There will always be the need for hand work. A selection of weed hoes is essential. Find one that fits your hands well and is ergonomically designed. A wheel hoe can be used to navigate the areas between rows. Smaller operations without tractor-mounted cultivators can use smaller rototillers to remove or mowers to manage small weeds. Cover crops inter-sown in beds or pathways can also reduce cultivation passes.



Figure 6. Peppers Raised on Bed System

Plasticulture Equipment and Supplies

Plasticulture is the use of plastic mulch, raised beds, and drip irrigation -- either in combination or separately. Plasticulture gained popularity in the 1980's and has become a standard for many vegetable crops in the United States. Plasticulture generates increased yields with better quality, and results in an earlier harvest, especially with muskmelon, tomato, green pepper, cucumber, squash, eggplant, watermelon, and okra. Equipment options required for each plasticulture component are noted below.

Plastic mulch and raised beds work together to provide an ideal environment for vegetable growth. The plastic warms the soil, prevents weed growth, and controls moisture, while the raised bed provides a deeper soil profile and better drainage around the root system. Creating a raised bed on a small farm can be accomplished using several methods. The first and easiest method is to use a raised bed mulch layer—an “all-in-one” machine that creates the bed, lays the plastic, and lays the drip line in one pass. These machines require 60-70 hp to operate adequately. The other option is to



Figure 7. Stake and String Tomatoes



Figure 8. Laying Plastic

use a bed forming machine in the first pass followed by the plastic and drip tape layer in the second pass, which requires less horsepower but more time and machinery expense. Tight and tall as possible; a six to eight inch bed is recommended for most crops. The last option is to eliminate the raised bed and use a flat plastic layer. The flat plastic mulch layer does not form a bed; however, this design is simpler and requires only 30-35 hp to install.

Many crops require additional supplies to keep the fruit off the ground and facilitate the harvest. Tomato, eggplant, and pepper are often staked and strung using a string and weave system. Other trellis crops use longer stakes and netting to support growth. Stakes for the string and weave system can be constructed from wood or fiberglass. The trellis string is packaged in a box that attaches to the grower's belt for ease of use.

Mulch Grades

Vegetable growers may use either embossed plastic or smooth plastic film. Embossed plastic stretches over raised beds tightly; it resists tearing and wind damage, and is a superior grade to slick or smooth grade plastic mulch. Typically, raised beds are covered with embossed plastic. Smooth plastic is less expensive and works well for flat beds. However, when used on a raised bed system, it has the tendency to expand in the summer heat and tends to tear easily. The thickness of mulch varies according to the brand and manufacturer; the standard is 1-1.25 mil plastic for one-season durability.

Mulch Color

Black plastic is the most common, and most effective for preventing weed growth. Black quickly warms the soil in the spring; however, this may present a problem for heat-sensitive crops during the summer months. Black plastic should be used for muskmelon, tomato, green pepper, cucumber, squash, eggplant, watermelon, and okra.

White on Black plastic uses a reflective white layer on top of a standard black layer. The advantage of this design is reduced heat on sensitive crops, such as many cut flowers. The black under-layer serves to restrict weed growth more effectively than white alone.



Figure 9. Fabric Cloth and Plastic Mulch for Weed Control

Clear plastic warms the soil faster than other colored mulch; it's most commonly used for sweet corn to promote quick germination and spring growth. After the corn emerges,

holes must be punched and later split to prevent the temperature from injuring plants. The plastic can be purchased pre-cut. It should be noted that clear plastic does not impede weed growth.

Green plastic is a compromise between black and clear. Green plastic provides better weed control than clear and also warms faster than black plastic. However, caution is required when using this method for crops other than sweet corn as weed control is not satisfactory for season-long use.

Red plastic shows slight yield increases for tomato crops; this is due to the reflection of the light spectrum that is the most favorable for growth. The light spectrum then reflects onto the foliage canopy. Growers should experiment with red plastic on a small scale to determine whether it is suitable for their particular operation. Red plastic is more expensive than black; therefore, the added cost must be considered. For more information regarding mulch color and affect on plant growth see the Penn State Center for Plasticulture website at <http://plasticulture.psu.edu/>.

Drip Irrigation

If using plastic mulch, you will also need to use drip irrigation under the mulch to provide water. Drip irrigation may be used on crops grown without mulch as well. The key advantage of drip irrigation is the ability to apply water and nutrients in a controlled manner directly to the plant root zone. Drip irrigation may reduce water use by up to 50%, as well as reduce foliage disease. Also, it can provide tailored nutrient application, reduce labor needs, and requires smaller water sources under lower pressures than many other forms of irrigation. Drip line is installed with the plastic layer or can be pulled by hand on crops without mulch.

Although drip irrigation systems have many components, they are relatively easy to set up for small operations. Components include the water source, pump, filtering systems, fertilizer injector, distribution lines (header lines), fittings and couplings, and drip tubing or tape.

A clean water source is required for drip irrigation. Organic matter and particulates can clog filters and drip line emitters. Water sources may include surface water from a pond or stream, ground water well, or artesian well. Whatever the water source, it is important to calculate the quantity of water available and recharge rate. A typical system on 5-foot row centers, with 1-line per row, at 10 PSI, and will use 30-40 gallons per minute per acre. If using a well, determine the available water discharge capacity. Though expensive, city water may be used. Be sure to use a back flow check valve to ensure water does not flow back into and contaminate the original source.

Pumps are used by most small farms to irrigate 2-3 acres at one time. Pumps should be chosen to fit acreage and water specifications. It is advisable to select a pump that is an established brand, and also is efficient, dependable, and has a fuel tank capacity for long run times (2-3 hours). Most small farms use gas pumps; however, electric pumps

also work if power is available. Electric pumps are generally convenient to power on and off.

Filters are necessary for pond or surface water; water must be filtered prior to drip tape use. The most common system is the sand filter; a large tank filled with filter grade sand. As the water passes through the sand particles, large particulates are removed from the water and trapped within the sand. These particulates are then washed out of the system through backwashing. Sand filters allow high flow rates of water and removal of large amounts of particulate matter. As the filters become clogged, the water pressure declines and backwashing is required. After sand filtration, a secondary filter screen or disc filter is used to remove fine particles.

Fertilizer injectors add nutrient solutions to the irrigation system. Injectors may use a simple venturi-type system to pull the nutrient solution into the irrigation stream. Also, a more accurate water-powered injector can be used to pump the nutrient solution into the system at preset ratios. Nutrient sources must be water soluble and thoroughly dissolved to avoid clogging the small emitter holes in the drip tape. The Dosatron and Chemilizer injectors are the most commonly used brands. Organic amendments, such as seaweed, fish emulsion and biological additives should be considered before deciding on the irrigation system to use. These organic compounds can clog small emitters and often will not work well in injectors. Choose an injector/irrigation system that can accommodate these products if you plan to apply them via the irrigation system.

A distribution system carries filter and fertilized water to the individual rows through a distribution line. Generally, two types of material are used for tube lines—vinyl lay-flat line or poly flat. These lines are easily maneuvered and are designed for low- to mid-pressures. Vinyl lay flat can withstand higher pressures than poly flat and is easy to roll. The distribution lines are punched with a small insert tool and small diameter spaghetti tubing inserted into the line for distribution directly to the drip line.

Fittings and couplings are inexpensive and necessary for connecting the various parts of the irrigation system. In the distribution system, the spaghetti tube is inserted into the lay-flat line with a specialized coupling and to the drip line with another coupling. Extra fittings and many extra drip tape couplings should be kept on-hand to patch holes in the field.

The drip line or tape contains emitters spaced at intervals from 4 - 24 inches. Most vegetable crops require the 8 or 12 inch spacing. Very sandy ground or crops requiring high water use may require a tape with shorter emitter spacing. Drip line or tape is available with different water flow rates, measured in gallons per minute per 100 feet of tape (GPM/100ft). Standard flow rates are range from 0.40 - 0.50 GPM/100ft. A general rule of thumb for the mid-Atlantic region during summer when vegetables are maturing is 0.50 GPM/100ft drip line must run for 2-3 hours to supply adequate water.

Removing plastic mulch at the end of the season is one of the most significant challenges for plasticulture systems. A mulch lifter may be used to lift the plastic from the bed; however, the removal of the mulch and drip-line are laborious tasks when done by hand. This process can be time-consuming and also may require a fee for disposal. Some states offer recycling services for spent plastic mulch, drip line and plant pots. The availability of these services is not common. In order to recycle the plastic, it must first be compressed and molded into fuel blocks. These fuel blocks can then be burned under high heat and pressure. If using plastic mulch, disposal will be an additional cost to the farm.



Figure 10. Vegetable Transplanter

Planters and Transplanters

Usually, small vegetable farms have a minimum of two planters; one for direct seeding and the other for planting transplants.

Direct-Seeded Row Crops

Direct-seed crops, such as sweet corn, beans, pumpkin, gourds, sunflower, etc., require a direct-seeding planter capable of planting in rows with various spacing. A 2-row model is sufficient for a small vegetable operation and a 1-row model usually suffices for two acres or less. Many types of planters are available. Single-row push seeders, such as the Earthway, work well on $\frac{1}{2}$ acre or less for large-seeded crops. For larger areas, pull-type planting units, such as the JD Planter Junior, dispense seed into the soil from a hopper through a seed tube. Planters for small-seeded crops, such as the brassicas, are more specialized and often use seed plates, seed belts, and vacuum or air pressure to disperse seed more accurately. Older John Deere planting units, such as the JD Flex Seeder, are effective for small-these crops. Larger growing operations may require a modern air or vacuum seeder, such as the Monosem, MaterMac, or Stan-hay brands. A converted 2-row corn planter is often used on small farms for the large-seeded crops. Consider these tips before purchasing a planter.

Depth Control.

The planting unit should provide a uniform planting depth. Seed planted too deep may never emerge; seed planted too shallow will have poor seed-to-soil contact and may dry out in the summer heat. Seeding depth is especially critical for small-seeded crops planted over ground that is not perfectly flat and uniform. The most accurate way to achieve good depth control is to use depth wheels which ride directly beside each individual planting unit and precisely control the depth of the seed. Some units may have depth wheels mounted behind the unit, which does not compensate for depth

differences between the planting unit and depth wheel. Other units have depth wheels mounted on the planting frame or tool bar, which does not compensate for individual depth differences among planting units. Depth control devices should be matched with the planting conditions. Uniform land requires much less attention to depth variation, whereas, no-till or higher residue fields require greater attention.

Seeding Furrow

Planters either use a set of disc openers set at slight angle to each other to slice through the soil to create a small opening for the seed, or a stationary shoe that slices through the soil. The stationary shoe opener works well for prepared land with little residue, but the disc openers are essential if residue is present. Disc openers perform more effectively on wetter ground and do not clog as easily as stationary shoes.

Coulter Attachments

Planters often have several types of coulter attachments that help prepare the area directly ahead of the seeding unit. Coulter attachments are used when heavy residue is present; this can occur from a cover crop in either no-till or reduced-till sites. Coulters are heavy-duty discs that slice and cut away residue ahead of the planting unit. Coulters can be straight, rippled, bubbled, or wavy. More aggressive waves or ripples cause greater disturbance and manipulation of the soil area. Coulters may be mounted directly to the seeding unit or to the planting frame itself. In addition to the coulters, row cleaner attachments can be added, including rolling baskets or finger discs, to clear the area ahead of the planting unit.

Direct Seeding -- Drill or Broadcast

Most cover crops and some field crops must be sown over the entire field instead of in rows. A seeding drill with 7-inch spacing can be used. The drill uses individual seed openers (either discs or shoes) to drop seed from a hopper through a tube and into the furrow. The seed placement is not as accurate as the row crop planting unit, but many solid-stand crops don't require such accuracy. Many cover crops, such as cereal rye or oats, may be broadcast using a simple spin spreader. Seeding rates should be increased for broadcast seeding method. After applying the seed, a pass with a cultipacker or very light tillage will increase seed to soil contact and result in better germination rates.



Figure 11. Drill (Rear View)

Transplanters

Transplanting in smaller areas can be accomplished by hand. Transplant setting in bare ground over larger areas is conducted using a transplanter (e.g. tobacco transplanter or vegetable transplanter). This unit uses a shoe to open a furrow, and then a set of rotating arms grasps a transplant from the worker who's riding the planter, and the transplant is finally dropped into a furrow. Large



Figure 12. Bare Ground Vegetable Transplanter

metal wheels close the furrow around the plant and drive the rotating arms; these units also have water attachments. Generally, a 1-row model is sufficient for small farms. Tobacco or vegetable transplanters are widely available as new or used, and are often found on tobacco farms. A 1-row model requires a tractor operator and two operators riding on the planter to drop plants. Vegetable transplanters also are available for no-till operations; they use a set of coulters and

row cleaners ahead of a disc opener to slice through residue and prepare the planting row area.

A water wheel transplanter is most frequently used for plastic mulch applications. It places a hole in the plastic and leaves an indentation in the soil. The transplant is manually set in the hole by a person(s) riding on the machine. Plant spacing can be changed by changing the water wheel. Automated transplanters punch holes through the plastic and mechanically drop and set plants. This equipment is costly; which usually precludes its use on small farms. For hand-planting through plastic, it is necessary to use a small propane torch to burn a small hole in the plastic, this will facilitate planting.

Farm Maintenance

A mower is needed to maintain field edges, mow old crop residue, and for overall maintenance of the farm. A rotary mower, such as a bushhog, works well for the majority of these activities. Rotary finish mowers can be used to maintain lawns and turf; however, they are not effective when used for taller grass or residue. Heavy-duty rotary mowers often have stump jumper shields and swing away blades to mow areas that are particularly rough. A flail mower uses a rotating drum with a chain and small blade attached that's designed to chop and mow crop residue. Flail and rotary mowers can be used for similar terrain and crop tasks. However, flail choppers are preferred for chopping cover crops residues due to the fact that they uniformly cut and fracture the residue without leaving swaths. Flail mowers also can handle taller material, and therefore, are preferred for chopping cover crops used for bio-remediation such as rape or sorghum-sudan grass.



Figure 13. Water Wheel Transplanter

Harvesting Equipment

Most vegetable crops are harvested manually; this creates significant labor expenses. Harvesting tools that make the harvesting process more efficient are generally excellent

investments. A 5-acre farm should have a minimum of 100 buckets or lugs, two wagons or carts or a single flat-bed truck to transport the harvest to the packing shed. Crops, such as watermelon, pumpkin, and cantaloupe are usually harvested in cardboard bins that rest on pallets. Some growers use conveyors 20-25 feet in length to harvest cucurbit crops. The conveyer spans across the wagon into the field and pickers place the melons on the conveyer, which carries the produce to the wagon for packing. Sweet corn may be harvested in bins, boxes, or burlap sacks. To prevent bruising, soft-bodied produce, such as tomato and squash should be harvested in smaller containers.

Sorting and grading is most efficient when conducted in the field during the picking process. Crops that do not require cleaning, such as sweet corn, pumpkin, watermelon, and gourds can be field-packed. Harvesting lanes in the field on which wagons and harvesting equipment can travel will help reduce field compaction, shorten the distance from the full harvest lugs to the wagon, and provide access to the crop in wet conditions.



Figure 14. Lugs and Buckets of Produce

Post-Harvest Equipment: Clean, Grade, Sort, Cool and Pack

Post-harvest activities vary by farm, and are largely dependent upon how the final product is sold, the grading and packaging required, as well as other requirements. A designated area for post-harvest should be large enough to accommodate the packing line, packaging material (often stored overhead), sorting and grading activities, and have easy access to the fields. A packing barn or shed

should have a concrete floor, running water, electric or other power source, and a small office.

It is not necessary for the area to be elaborate; however, it should be practical. If the produce will be loaded onto trucks, then it may be helpful to have a loading dock. A walk-in cooler is recommended if the produce will be held for any length of time or wholesaled.

After produce is harvested and delivered to the packing house, it is graded and cleaned. Grading is manually executed by pouring the product onto a table, sorting and grading it, and finally packaging the product. Packing lines that carry the produce through a set of processes, starting with cleaning and ending with the grading line are readily available. Packing lines can be simple or complex, depending upon the operation's needs. Even small three to five acre operations can greatly benefit from simple packing line designs; including:

- a conveyor table where produce is emptied from harvest lugs and carried to a set of soft bristle brushes combined with water to clean produce,
- a set of roller sponges to dry produce,

- and finally, a round grading table that turns slowly so product can be sorted and packed.

This design is available for approximately \$2,800-\$3,000. To help clean produce and prevent microbial contamination, many growers add disinfectant to the water.

Delivery Equipment

A reliable transport truck or van is needed if the producer offers delivery of product to a wholesale market, Community Supported Agriculture (CSA) deliveries, or directly to restaurants or stores. The same principles and guidelines for car buying can be applied to the process of purchasing a delivery truck. Some tips to consider include:

- Size the truck accordingly. Produce contains a lot of water, therefore, it is heavy. A common mistake is to purchase a truck that is not large enough to accommodate the weight of the produce. A sound brake system is equally important as having enough power. It is advisable for growers to research the transportation regulations in their respective states as there are certain exemptions with regard to commercial licensing requirements. Typically, these requirements are contingent upon size and braking limitations (usually fewer than



Figure 15. Vegetable Line Packing Table



Figure 16. Vegetable Packing Line.

26,000 GVW). Many states still require commercial DOT registration.

- Neighborhood or city deliveries may require a truck with a tight turning radius, such as cab-over models.
- A box truck protects produce from weather elements. Other advantages of box trucks include the provision of additional storage space and the ability to lock a truck to prevent theft. Box trucks also may be refrigerated if needed, though this is not usually a requirement for short deliveries.
- Consider fuel efficiency and reliability. Diesel models generally have better fuel efficiency. As with other equipment, when using a delivery truck on a regular basis it must be reliable.

Other Infrastructure

This chapter does not go into great detail regarding buildings or other related infrastructure that is necessary for farming; however it is important to consider the cost and availability of these items. The majority of farms will require a farm shop, where equipment can be repaired, modified, and maintained. The farm shop should be dry and have a hard floor; also it should be outfitted with a welder, cutting torches, various wrenches, hammers and hand tools, air compressor as well as a working fire extinguisher. An efficient shop is especially important when purchasing used equipment. The farm also will need an office space that has both phone and internet access. Offices can be established in the home, a packing shed or farm shop; anywhere it is convenient and easy to access.

Table 1. Equipment Required and Costs (for a small 5 - 15 acre vegetable farm)

Equipment	Description	Average Cost -- Used	Average Cost – New
Tractor -general	55 hp, diesel	\$12,000	\$30,000
Disc Harrow	9 foot- transport	\$1,800	\$3,600
Field Cultivator	Perfecta II-8 ft.	\$3,000	\$4,000
Cultipacker	8 ft, non-transport	\$500	\$1,200
Rotary Mower	5 ft.	\$500	\$1,000
Tractor-Cultivator	Farmall C, 30HP, 2 row. Newer model is 30 hp modern cultivating, offset	\$4,000	\$22,000
Attachment Sweeps	1 set sweeps, 1 set finger discs,	\$1,000	\$1,200
Vegetable Transplanter	Mechanical , 1 row, with water attachment	\$1,500	\$2,000
2 row precision direct seeder	Monosem, vacuum, addl. plates	\$4,000	\$6,500
8 ft drill	Conventional, 7 inch row spacing	\$2,000	\$8,000
Raised Bed Mulch Layer	4 ft, drip attachment, 8-10 inch bed	\$2,000	\$4,200
Water wheel transplanter	1 row, 3 pt hitch, water attachment	\$1,100	\$1,600
Wagon	4-wheel, 18ft	\$2,000	\$2,600
Wagon	4-wheel, 18ft	\$2,000	\$2,600
100 Harvestings lugs	Plastic, perforated with handles	\$300	\$500
Packing Line	16 inch, 4 unit packing line with rotary packing table	\$2,000	\$3,000
Total		\$39,700	\$94,000