Table 2: Green Manure Crops for Vegetable Farms

Seeding Crop Number	Pounds/Bushel	Quantity of Seed per Acre (pounds)	Desirable Seeding Dates
Nonlegumes			
Rye	60	90-120 (alone) 90 (mixture)	Sept. 1-Nov. 10
Perennial or common ryegrass	24	15-20 (alone) 5-8 (mixture)	Aug. 1-Sept. 15
Sudangrass	40	20-30	May 15-July 1
Field corn	56	50-60	May 15-July 1
Winter barley	48	80-100	2-3 weeks before fly-safe date
Wheat	60	90-120	Hessian fly-safe date
Legumes			
Sweet clover	60	16-20 (alone) 10-12 (mixture)	March 1-April 15 July 15-Aug. 20
Red clover	60	10-15 (alone)	Feb. 1-April 1
Soybean	60	90-100	May 15-July 1
Alfalfa	60	12-18	March-April
Hairy vetch	60	15-20 (mixture)	Sept. 1-Nov. 1
Mixtures			
Rye/vetch		90/15-20	Sept. 1-Oct. 1
Ryegrass/sweet clover		5-8 12-15	July 15-Aug. 20
Sweet clover/orchardgrass		6-8	March 1-April 15

Animal Manures and Composts as Fertilizers

Animal manures and composts can provide significant nutrients to plants. The nutrient content of manures varies among animal species and within each species. Nutrients in composts can vary even more and depend on parent material and processing. Test manures and composts to determine the potential nutrient contributions and application rates. Avoid using composts made of unknown origin or parent material. Improperly made composts, be they of rural or urban origin, can contain heavy metals, inorganic debris, diseases, and insects that are unwelcome on your fields.

It is important to consider the timing of manure and compost applications. Fresh manure has potential to "burn" a crop because it often contains high levels of ammonia, and fresh or casually "aged" manure often contains human pathogens. For these reasons, it is rarely acceptable to apply fresh or "aged" manure to food crops while they are growing. Generally, a fall application is acceptable, ideally to a cover crop, and at least nine months before harvesting the next vegetable crop. Manure that has been properly composted and then protected from contamination is less likely to contain human pathogens and may be used closer to harvest if steps are taken to minimize contact with the food crop. Any use of manure or composts should follow current Good Agricultural Practices (GAPs) or the demands of a particular market, if more stringent. For guidance about current GAPs from the U.S. FDA, see www.fda.gov/food/guidanceregulation/fsma/ucm253380.htm.

Transplant Production

Transplant production has replaced direct seeding for many vegetable crops. One of transplanting's primary advantages is earlier fruit production, allowing growers to capture better market conditions. In addition, the high cost of hybrid seed makes it desirable to use each seed as efficiently as possible. Transplanting also gives the crops a competitive advantage against weeds. This section addresses the special skills and knowledge required for successful transplant production.

Most growers use polyethylene-covered greenhouse structures to provide warmth and protection from the environment. Although cole crops do not need the more moderating conditions a greenhouse provides, they can be grown in coldframes, lean-tos, or covered wagon beds.

The heater is one of the most critical features of a transplant greenhouse. Vegetable transplants must be kept at the appropriate temperatures. However, if heaters are improperly exhausted, the transplants can be stunted or deformed. To prevent heater fumes from returning into the greenhouse, chimneys should extend two feet above the ridge of the greenhouse.

There should be some provision for bringing fresh air into the greenhouse. Some heaters vent fresh air into the greenhouse every time the furnace operates. For others, a hole or holes should be cut in the greenhouse wall and fitted with tubes to feed outside air to the heater. Avoid space heaters that may "spit" diesel or gasoline onto nearby plants. Heated air should be circulated using a perforated "sock" or tube that runs the length of the greenhouse, or fans placed on opposite sides of the greenhouse and blowing in opposite directions. Place thermometers in several locations to measure the temperature at plant level. At least one high-low thermometer is a good investment.

For detailed information about greenhouse structures, see *Greenhouse Engineering* (NRAES-33), available from Plant and Life Sciences Publishing: palspublishing.cals.cornell.edu.

Transplant Containers

A wide variety of transplant containers are available, each with advantages and disadvantages. The most common ones are:

1. Todd planter trays made of Styrofoam (Speedling type).
2. Polystyrene or PVC flats or trays.
3. Peat strips, pots or pellets (e.g., Jiffy).

Peat pot containers have the advantage that the root system need not be disturbed upon planting. Peat pots also are more forgiving of over watering than other containers. If peat pots are planted partially above ground, moisture is "wicked" away from the plant, often resulting in plant death — peat pellets do not have this disadvantage.

Polystyrene and Todd planter flats are both designed so that transplants must be "popped" out of the trays, thus disturbing the root system. This is particularly true if the roots are allowed to grow into the ground beneath the tray. Avoid this problem by raising the flats off the ground. Both the polystyrene and Todd planter flats must be watered with care. Todd planter flats have a pyramidal design that forces roots downward to an open bottom where the roots are air pruned. Some polystyrene containers have open bottoms — tube types have open bottoms, groove types have small drainage holes.

In general, peat type containers are the most expensive, followed by the Todd planter type, then the polystyrene type.

The number of plants in a tray depends on the cell size for each plant. Vegetables are commonly grown in trays with 30 to 300 cells. In general, larger cells lead to greater early yield in fruiting crops. Larger cells are also easier to manage because the greater soil volume holds more water and nutrients. Due to the expense of building and maintaining greenhouse space, many growers have moved to smaller cell volumes so more transplants can be grown in the limited space available. Some growers use two different cell sizes: a larger size for crops they expect to harvest earlier, and a smaller size for crops they expect to harvest later.

Seeding and Growing

Most vegetable transplants are sown one seed per cell. As a general rule, plant vegetable seeds at a depth two times their diameter. Vegetable seeds temperature requirements vary; most vegetable seeds germinate in the 70°F to 90°F range. The time from seeding to transplanting varies from three to four weeks (e.g., cantaloupe) to 10 to 12 weeks (e.g., celery).

Vegetable seed may be ordered with special features, including seed priming and pelletizing. Primed seeds have been partially hydrated, then dried down, resulting in earlier germination and better uniformity. Priming may be useful for hard-to-germinate seed such as triploid watermelon. Seed may be pelletized to make it easier to handle. In this process, varieties with small seeds, or irregular seeds (such as lettuce) are coated to make the seed larger and uniform in size and shape. This process makes mechanized planting easier.

The growing mix should be well-drained and free of disease-causing organisms (pathogens). Most commercial mixes fit this description and perform well. These mixes are often referred to as "soilless mixes" since they are composed primarily of peat or coconut coir, perlite or vermiculite, and sometimes bark or ash. These mixes usually come in bales or bags and have been pasteurized (sufficiently heated to kill soil microorganisms capable of causing disease problems). It is advisable to test the mix before using it to make sure the pH is within an acceptable range (between 5.5 and 6.5) and to determine the initial nutrient content of the mix.

Most mixes include a small amount of fertilizer, but transplants usually benefit from additional regular nitrogen (N), phosphorus (P), and potassium (K) fertilization once true leaves appear. Depending on the initial nutrient level in the mix, including calcium (Ca) and magnesium (Mg) in the fertilizer solution may also be advised. Soluble synthetic fertilizers (21-5-20, 20-10-20) and liquid organic fertilizers (fish emulsion) are commonly used. The best rate, frequency, and method of fertilization will depend on your potting mix and watering practices. Common alternatives include a 50 to 200 ppm N solution applied at every watering, or a 300 to 500 ppm N solution applied weekly.

To make a 100 ppm N solution, use 0.42 pounds (6.6 ounces) of a 20 percent nitrogen fertilizer for every 100 gallons of water. Over-application of ammoniacal N can be detrimental to transplants. This problem can be minimized by not over-applying N, and by using fertilizer in which most N is in the nitrate form. Check the bag label.

Transplants that are too tall and tend to fall over are often referred to as "spindly," "shanky," or "leggy." Such transplants may have low survival rates in the field. Spindly transplants are produced under low light conditions, high fertilizer rates, and/or over watering. Cloudy weather or greenhouse structures that don't let in adequate light could be the culprits. Artificial lights could be helpful during inclement weather, but may be cost prohibitive.

Under such conditions, use a fertilizer containing a lower percentage of P. For instance, try 21-5-20 rather than 20-20-20. It is important to provide adequate P, but not too much. Under fertilization with P will produce short plants, but yields also will suffer. Hot days and cold nights favor leggy transplants. If night temperatures are equal to or higher than day temperatures, stem elongation will be reduced. It may be sufficient to lower the temperatures for a two-hour period starting at dawn.

To prepare transplants for the harsher environment of the field, it is necessary to harden them off. Transplants may be hardened off by withholding water and lowering temperatures moderately during the last week or so of growth. Some growers place transplants in wagons and wheel the transplants outside on appropriate days to get the plants used to field conditions. The transplants are wheeled back inside at night and during especially harsh weather.

After transplanting, plants should be irrigated as soon as possible. Some transplanters are equipped to irrigate plants at the time of transplanting. Otherwise, arrange to irrigate soon. Applying a small amount of starter fertilizer in the transplant water is often beneficial. If transplants are held in the greenhouse to replace those that don't survive, remember to avoid using transplants that have begun to vine or flower.

Diseases

Diseases that are likely to affect vegetable transplant production in the Midwest fall into two types: damping-off diseases (caused by soilborne fungi) and transplant diseases (usually associated with fungi, bacteria, or viruses that survive with seed or plant residue). These diseases can cause extensive transplant loss.

Damping-off may occur before or after seedlings emerge from the soil. Preemergence damping-off occurs when fungi infect seeds as they germinate. As infections progress, seeds rot and eventually disintegrate. Poor stands become apparent after several days or weeks.

Postemergence damping-off is usually observed in seed flats or among transplants. Fungi infect stems at or near the soil surface. The affected area of the stem takes on a water-soaked appearance and sometimes becomes constricted. Eventually, the stems are unable to maintain the structural support of seedlings, which usually collapse and die within 24 to 48 hours.

Several soilborne fungi cause damping-off on vegetables. *Fusarium, Phytophthora, Pythium,* and *Rhizoctonia* species are well known causal agents of pre- and postemergence damping-off. Control measures to prevent damping-off diseases Include:

- Using uncontaminated soil mix. Use a commercially prepared soilless growing mix sold in 3 to 4 cubic foot bales or bags. A common mistake is to open a bag of "clean" soil mix and place it on a dirty floor or some other unclean surface prior to planting. Remember that your soil is only as clean as the dirtiest surface it has contacted.
- Planting seeds shallow and in warm soil.
- Using soil mixes that drain well.

Seedborne and residueborne diseases affect most vegetable crops. The pathogens (disease-causing microorganisms) survive in or on seeds or plant residues, not in soil mixes. Outbreaks of these diseases often show up as clusters of diseased plants, and symptoms often include brown lesions with yellow halos on leaves. By contrast, environmentally induced problems often occur uniformly throughout the seedlings or only in one location (for example, close to an outside wall).

Several different fungal, bacterial, or viral pathogens may be introduced into a transplant facility via contaminated seed or transplants (Table 3). Once introduced, these pathogens may continue to cause problems year after year if proper precautions are not taken.

Table 3: Common Seedborne Diseases of Vegetable Crops Frequently Grown as Transplants

Vegetable Crop	Disease
cabbage	black rot
	Alternaria leaf spot
cantaloupe	anthracnose
	gummy stem blight
cucumber	angular leaf spot
pepper	bacterial spot
squash	squash mosaic (squash mosaic virus)
tomato	bacterial canker
	bacterial speck
	bacterial spot
watermelon	anthracnose
	gummy stem blight
	bacterial fruit blotch

Several measures should be taken to minimize or prevent introducing seedborne or residueborne pathogens into a transplant facility:

- Avoid saving seed unless you are specifically trained and equipped for seed production.
- Inspect seedlings frequently while they are growing.
- Separate seedlots from one another. Save all information regarding seed purchases.
- Irrigate in the morning to ensure soil and leaf surfaces dry.
- Check fungicide and bactericide labels for specific mentions of greenhouse use when treating transplants (see Table 14 for liquid pesticide conversion table).
- Practice good sanitation. Plant pathogens often survive in soil and plant residues. Therefore, sanitation is as important for a greenhouse as it is for a kitchen. Greenhouse floors should be as free of soil and residue as possible; plastic or cloth floor coverings provide a barrier between dirt floors and transplants. Transplant trays and flats should be new or cleaned and disinfected before each transplant generation.

More detailed information about disease prevention and control in the greenhouse is available in Preventing Seedling Diseases in the Greenhouse (Purdue Extension publication BP-61-W), and *Commercial Greenhouse and Nursery Production: Sanitation for Disease and Pest Management,* available from the Purdue Extension Education Store (HO-250-W), www.edustore.purdue.edu.

A few chemicals are labeled for disease control in greenhouse vegetable crops. Restricted use pesticides can only be used by certified pesticide applicators who have the greenhouse certification on their applicator licenses. Restricted use pesticides are identified prominently on the label.

If a pesticide is not restricted use and is labeled for the crop in question, check the label. If it does not mention greenhouse use, then it may be used in greenhouses. Otherwise, the label may explicitly prohibit greenhouse use. Thus, a specific label for greenhouse use for some products is not required; but you must carefully read each label to be certain the greenhouse use is not prohibited. Apply according to labeled rates and timing.

Products that may be used in the greenhouse are listed in tables 16 and 17 on page 45.

Seed Treatments

Seed treatments are useful for preventing damping-off and some other root diseases in vegetable crops. Seed treatments can also eliminate certain pathogens carried in or on the seed.

There are two general types of seed treatment: eradicative and protective.

Eradicative seed treatments kill disease-causing agents on or within seed and are useful in controlling certain seedborne diseases.

Protective seed treatments are applied to the seed surface and protect the seed against decay and damping-off caused by soilborne organisms.

For more information, see *Hot Water and Chlorine Treatment of Vegetable Seeds to Eradicate Bacterial Plant Pathogens*, Ohio State University Extension Fact Sheet HYG-3085-05, ohioline.osu.edu.

Hot Water Treatment

When properly used, hot water treatments kill most disease-causing organisms on or within seed. This treatment is suggested for eggplant, pepper, tomato, cucumber, carrot, spinach, lettuce, celery, cabbage, turnip, radish, and other crucifer seed. Improper treatment can injure seed. Hot-water treatment can severely damage cucurbit seed.

Warm seed in a loosely woven cotton bag (not over half full) for 10 minutes in 100°F water. Place the warmed seed in a water bath that will constantly hold the water at the recommended temperature (see Table 4 below). The length of treatment and temperature of the water must be exact. After treatment, dip bags in cold water to stop heating action, and then spread seed out to dry. Always apply a protective seed treatment fungicide to hot-water-treated seed.

This treatment can injure old seed. Always test a small sample of any seed lot more than a year old by treating it, and testing for germination to determine the amount of injury, if any, that might occur.

Table 4: Water Bath Temperatures and Treatment Lengths

The water bath temperatures and treatment lengths should be followed exactly.

Seed	Temperature (°F)	Minutes
Brussels sprouts, cabbage, eggplant, spinach, tomato	122	25
Broccoli, cauliflower, cucumber, carrot, collard, kale, kohlrabi, rutabaga, turnip	122	20
Mustard, cress, radish	122	15
Pepper	125	30
Lettuce, celery, celeriac	118	30

Chlorine Treatment

Chlorine treatment effectively removes bacterial and fungal pathogens on the seed surface. Chlorine treatment is recommended for pepper, tomato, cucurbits, and other vegetables if the seeds have not been treated by another method.

Agitate seeds in a solution of 1 quart of household bleach, 4 quarts of water, and 1 teaspoon of surfactant for 1 minute. Use 1 gallon of this disinfectant solution per pound of seed and prepare a fresh solution for each batch. After placing seed in this solution, remove, and rinse thoroughly in running tap water for five minutes. After that, spread out seed to dry. Dust the seed with Thiram 75WP® at 1 teaspoon per pound of seed.

Treat the seed near planting time, as viability may be reduced over time. Before you treat all seed, we recommend that you test a small sample of each seed lot first. Treat 50-100 seeds and see how they germinate. If they germinate well, treat the rest of the seed lot.

If you treat coated seed or seed treated with fungicide with hot water or bleach, always dispose of wastewater in an environmentally sound manner.

For more information, see *Hot Water and Chlorine Treatment of Vegetable Seeds to Eradicate Bacterial Plant Pathogens*, Ohio State University Extension Fact Sheet HYG-3085-05, ohioline.osu.edu.

Fungicide Seed Treatment

Thiram is the most common seed-protectant fungicide. Other fungicides are recommended for specific crops. These fungicides are often combined with insecticides, and these combinations may be superior to fungicide treatment alone. Purchase treated seed, or dust seed lightly with fungicide according to label directions.

Do not use treated seed for food or feed.

Using Plastic Mulch

Black plastic mulch laid before planting helps control weeds, reduce root pruning, and give profitable increases in early yields of warm-season crops. Wavelength-selective and clear mulches typically lead to greater early yields than black plastic, but weed growth under these mulches may be a problem. This is particularly true for clear mulch. Because leaching is retarded, less fertilizer is lost, and nitrogen sidedressing is often unnecessary with the plastic mulch. If nitrogen needs to be added, it can be applied later through the irrigation system.

Try to lay plastic mulches as early in the season as possible. Mulches should be laid as soon as the ground can be worked after a heavy rain. Irrigate the field if soil moisture is not adequate prior to laying the mulch. Plastic mulches should be laid over moist soil. If the plastic is laid over dry soil, it will actually delay subsequent transplant growth. It is better to lay out plastic at midday so it can be stretched tight. However, do not overstretch the plastic because cool nights may actually cause it to tear.

The seedbed should be as fine as possible in order to get a good covering. The plastic is laid by burying about 6 inches of each edge. Black plastic mulch is most effective in warming the soil when it is in direct contact with the soil.