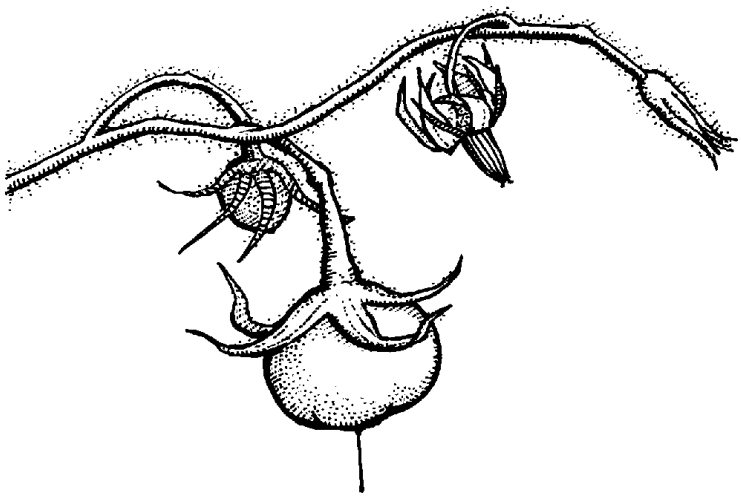
TOMATO SEED PRODUCTION

An organic seed production manual for seed growers in the Mid-Atlantic and Southern U.S.



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BOTANICAL CHARACTERISTICS

Botanical classification of cultivated species of tomatoes:

Family: Solanaceae (nightshade family)
Common tomato: *Lycopersicon lycopersicum* (formerly *Lycopersicon esculentum*)
Currant tomato: *Lycopersicon pimpinellifolium*

The common tomato produces fruits in a large variety of shapes, colors, and sizes whereas the currant tomato, which has not been domesticated to the same degree, produces red or yellow fruit approximately 1/4" to 3/8" in diameter. The common tomato will cross readily with the currant tomato even though the two are different species.

Roots:

Left to grow naturally, tomatoes have a strong taproot which can grow as long as six feet, but because tomatoes are normally transplanted, the taproot is broken and the plant develops a fibrous rooting system. Most of the lateral roots develop 2 to 10" beneath the soil surface. The laterals can grow out a distance of two feet before growing downward to a depth of four feet.

Flowers:

Tomato flowers are borne in clusters that resemble a raceme. Technically they are classified as a monochasial cyme. Indeterminate varieties of tomatoes have a flower cluster that occurs at every third internode along the main axis. Indeterminates grow indefinitely provided that environmental conditions remain favorable. Determinates have flower clusters that occur at every other node, or as frequently as every node. This growth arrangement continues along the axis until a terminal cluster is formed and growth of that particular branch ceases. Determinate plants are short-vined, and are sometimes termed "self-pruning." Because they have a larger number of flower clusters per length of vine, the plant tends to fruit and mature a crop within a briefer period of time.

In most varieties of tomatoes, the number of flowers in a cluster is typically four to five. In the small-fruited cherry and currant tomatoes, the number of flower per cluster can range up to eight to twelve. One of the more interesting varieties is 'Riesentraube' which can have dozens of flowers per cluster, though not all of these bear fruit.

Pollination and fertilization:

Pollination is the process of transferring the pollen from the male part of the flower (anthers) to the female part, called the stigma (pollen-receptive surface of the pistil). Fertilization is the process of union of the male gamete in the pollen with the egg to form the zygote which becomes part of the seed. When the stigma becomes receptive to pollen, anthers do not shed their pollen until about 24 to 48 hours later. During this time, cross-pollination can occur, but after the anthers shed their pollen, the flower is more likely to be self-pollinated. Tomatoes are predominately self-fertilized, but not exclusively. A large amount of cross-fertilization can occur under the right conditions depending on the environment, microclimate, and biodiversity in the growing area.

Pollen germinates (develops a pollen tube) when the temperature ranges from 50 to 100°F (10°C to 38°C). The optimum temperature is 85°F (29°C). Pollen can be killed at 95°F (35°C) or above, depending on the variety. Pollen tube development may also be impaired by high temperatures. Even at the optimum temperature of 85°F (29°C) fertilization has been reported to take as long as 50 hours. Some of the larger-fruited varieties of tomato do not set seed well during periods of extended hot weather, in the mid-90's or above, and especially if the night-time temperatures don't drop below 70°F (21°C). Some of the more well-known large-fruited heirloom tomatoes have difficulty setting fruit in the hot arid Southwest or deep southern states. On the other hand, small-fruited varieties have a significantly better tolerance to both high and low temperatures, and can be more successfully grown at temperature extremes.

Determinate and indeterminate varieties:

Determinate varieties are short-vined plants on which blossoms and fruit develop about the same time. Indeterminate varieties are long-vined plants which bear fruit continuously. They should be caged or staked as noted below. Some varieties are semi-determinate.

Seed:

Tomato seed develops in a mucilaginous gel which has germination inhibitors. During the process of seed extraction and fermentation this gel is broken down. After the seeds are washed and dried, the seeds are normally tan or light brown in color with a pubescent covering (fuzz). Tomatoes are unique among the Solanaceae in that they are the only seed that is pubescent. The number of seeds per fruit typically ranges from about 150 to 300 or more seeds per fruit.

Tomato seed germinates in the range of 50 to 95ºF (10ºC to 35ºC). The optimum range is 60 to 85ºF (16ºC to 29ºC), and optimum germination occurs at 85ºF (29ºC). The Federal standard for germination is 75%.

ISOLATION DISTANCES

The subject of isolation distances in tomatoes has either been ignored in most seed production guides, or the information is incorrect. The issue is also controversial. There are a variety of reasons for the controversy, mostly stemming from a lack of understanding of what factors are important for determining isolation distances. For an in-depth discussion of this topic, see the companion manual devoted to the topic of isolation distances. The most important point for the seed grower to remember is that isolation distances should be understood within the context of the environment in which the crops are grown. The manual on isolation distances helps the grower understand that context. In addition, the basic principles of pollination ecology are explained, along with practices that can be used to modify isolation distances according to your growing conditions. It also contains a chart of recommended minimum isolation distances, and factors to consider when making modifications to the recommendations.

One key to understanding isolation distances in tomatoes is knowing that the tomato originated in South America, largely in the area of Ecuador and Peru where it was (and is) a plant pollinated by wild solitary bees. During the domestication of the wild tomato, it gradually moved out of its original geographic range, and out of the range of native pollinators. For this reason, the tomato came under increasing selection pressure to become self-pollinated. So, although tomatoes have been domesticated to a great degree, and are now mostly self-pollinated, they retain some of their ancestral capacity for cross-pollination, depending on the species and variety.

Traditionally, most seed saving guides indicate that tomatoes are self-pollinated. This is essentially true for modern varieties, but under certain conditions for certain varieties, considerable cross-pollination of tomatoes can take place. Even a small amount of cross-pollination over a number of years can lead to the loss of one or more characteristics unique to a variety. Therefore it is essential that varieties be isolated from each other in order to obtain pure seed.

There are many factors that affect the amount of cross-pollination. These include: (1) variety characteristics such as flower structure; (2) environmental variables such as wind movement, light intensity, day length, and carbon-nitrogen ratio; (3) types of pollinating bees present and their behavior on the blossoms; (4) isolation distance; (5) presence of barrier plants; (6) planting patterns such as row or block planting; (7) number of varieties; (8) number of plants of each variety; and (9) regional or bioclimatic factors. Day length can effect the length of the style, as can heat and low humidity. Long day length, periods of high temperature, and low humidity cause the style to elongate which in turn favors cross-pollination.

Generally speaking, most modern varieties (introduced after 1950) can be isolated from each other by a relatively short distance. This is because most modern tomato varieties have a blossom structure in which the length of style does not exceed the length of the anther cone. This arrangement of flower structure favors self-fertilization. Older tomato varieties, potato-leaf varieties, and large-fruited,

beefsteak-type tomatoes (including varieties with double blossoms) tend to have an "exserted style," meaning that the style protrudes beyond the anther cone, typically by a millimeter or more. This arrangement of reproductive parts favors cross-fertilization by pollinating wild bees. Some garden tomatoes have retained some of the characteristics of their wild ancestors. These characteristics may be found in many cherry tomatoes and currant tomatoes. These types have a blossom structure such that the style protrudes considerably beyond the anther cone

If you are not familiar with the varieties you intend to grow for seed, you should be conservative in establishing isolation distances until you know the variety characteristics. Also when growing different varieties for seed, it is good to get in the habit of examining the flower structure of different varieties so that you can begin to get an idea of the range of variation and the potential for out-crossing.

Isolation distances are determined partly on the intended use of the seed. The chart below shows recommended isolation distances for three different types of tomatoes:

Seed Crop	Minimum for home use	Minimum with barriers	Minimum without barriers	Comments
Tomato, modern variety	10'	35'	75'	Style length, and types and amount of bees are an issue.
Tomato, large-fruited heirloom variety	35'	75'	75-150'	Style length, flower structure, and types and amounts of bees are an issue.
Tomato, wild ancestry	40'	75-150'	>150'	Style length is a large concern, especially if wild bees are common.

These distances can be modified on the basis of variables such as the presence of other pollen sources, or the presence of physical barriers.

Less separation is required if seed is collected only from plants in the center of block plantings. A tall barrier crop such as ornamental sunflowers is recommended. Pollen-producing crops such as squash and cucumbers are useful in providing bees with an alternate source of pollen, though this pollen is available mostly up until mid-day. Borders of perennial flowers are very useful for attracting bees, especially those flowers that have open, exposed nectaries, for example, members of the Composite Family (for example daisies and coneflower).

In making decisions about isolation it is important to take into consideration plantings made in neighboring gardens or farms. If a nearby garden or market garden is a problem for maintaining isolation, consider donating the same seed variety to your neighbor.

MINIMUM POPULATION SIZE

Plants grown for seed can become subject to "inbreeding depression". This is a condition where the genetic diversity of a variety becomes so narrow, or bottle-necked that the variety loses some of its vigor, fitness, and adaptability as a result of too few plants being saved for seed over one or more generations. Generally speaking, inbreeding depression is generally not considered an issue in "selfers" (plants that are self-pollinated). Because tomatoes are predominately self-pollinated they can be treated as "selfers", but even selfers can be subject to inbreeding depression if too few plants are saved for seed.

Because population geneticists have varied responses to the question of the minimum population sizes needed to prevent inbreeding depression, this topic needs more study. Like the topic of isolation distances, the devil is in the details. A fuller discussion of the issues will be covered in a separate manual. The minimum population size depends on the variables involved. That said, there are some general guidelines. For plants such as tomatoes, no fewer than 20 plants should be grown for seed, though for a highly uniform (homozygous variety) as few as 12 plants might be required (but that would be an unusual situation). According to plant breeder John Navazio, as many as 80 to 100 plants should be the minimum population size for most selfers.

If you are growing a fairly uniform variety of an established commercial tomato that is available from a number of sources, 20 plants can be considered the minimum. If you are growing an uncommon or rare heirloom variety that has more inherent genetic diversity, you should be growing at least 40 plants, and perhaps as many as 80, if space and resources allow. The question to consider is: "Who is maintaining the diversity of the stock seed?" If what you are growing represents a small part of a larger genetic pool, the minimum population size can be smaller. The seed company that provides the stock seed may be maintaining seed based on a larger population size or pooled lots of seed or larger grow outs.

CULTURAL NOTES

Sowing seed and handling of transplants:

Sow seeds six weeks (for determinate varieties) to eight weeks (for indeterminate varieties) before the last frost date in your area. The best planting medium is a sterile seed-starting mix. Good drainage and aeration are important for starting seeds. Plant seed ¼" deep in shallow flats or cell packs and maintain soil temperature in the range of 75-85ºF (24-29ºC). Under optimum conditions, most varieties germinate in five to fourteen days, but under less than ideal conditions, germination may take at least three weeks. When the seedlings have produced four leaves (two seed leaves and two true leaves), transplant to 3" pots or large cell packs. Seedlings in plastic pots require much less water than those in peat pots. After transplanting, keep seedlings at a lower temperature at night, 50-55ºF (10-13ºC), to promote earlier flowering in some varieties. Day temperatures should rise to 75-85ºF (24-29ºC) to promote rapid growth. Expose plants to light and air currents as much as possible to harden the plants and promote stockiness. If fluorescent lights are used, keep the seedlings no further than two to four inches below the lamps, otherwise seedlings may become leggy. To keep seedlings stocky indoors, direct a gentle breeze from a low-speed fan toward the seedlings for several hours a day. Water sparingly, but do not allow the growth to become checked. Fertilize with complete, soluble organic fertilizer or fish emulsion if leaves become yellow and/or purple. Leaves with a purple coloration may indicate phosphorous deficiency. Yellowed leaves may indicate nitrogen deficiency. For transplanting to the garden, average soil temperature at 8 a.m. (4 inches deep) should be above 60ºF (16ºC). To facilitate drought resistance and a larger root mass for nutrient absorption, set the plants deep in the topsoil to encourage development of adventitious roots that develop along the stem.

Culture methods (support of vines):

In the Mid-Atlantic and South it is not advisable to grow indeterminate (and some determinate) tomatoes on the ground for several reasons. Ground culture promotes disease by placing foliage in close proximity to soil-borne pathogens; interferes with good air circulation around foliage; promotes fruit-rot (anthracnose); and subjects developing fruits to higher temperatures which could potentially affect seed development. Plants should be either staked, caged, or trellised (for example, the Florida weave system). Caging produces the best results, especially for tall indeterminate varieties. Cages should be 18 to 24" in diameter, and at least 48" tall. Cages can be supported by fastening the cage to metal electric fence posts, or 48" lengths of rebar which can be purchased at building supply stores.

Spacing of plants:

Recommended spacing distances depend on the variety and the support system used for the vines. For cage culture, plants should be spaced 24 to 48" apart within the row. Rows should be spaced three to six feet apart. Most indeterminate varieties are spaced 36 to 42" within the row and five feet between rows. Closer spacing generally produces higher total yields than wide spacing, but spacing which is too close may promote disease by interfering with air circulation. Before determining spacing, you should be familiar with the width and height of the varieties you plan to grow. Certainly soil fertility, water, tilth, and variety characteristics all have a relationship to the final plant size.

Factors affecting yield:

Too much mulch on the soil in the spring may delay growth by preventing the soil temperature from rising enough to support active root growth. Starting at the middle or end of June, apply a deep

mulch around plants to help conserve moisture and increase yield. High levels of phosphorus are necessary to produce good yields, but too much nitrogen added after transplanting will delay flowering. Pruning and staking increase earliness to fruiting at the expense of yield. Pruning of determinate varieties should be avoided or kept to a minimum.

Diseases:

Early determinate varieties generally have poor disease resistance, however disease is not usually a problem until mid-season. Thus disease resistant varieties should be planted for a sustained harvest. Leaf blight diseases such as early blight and alternaria begin to appear about mid-July, and plants are more susceptible once fruit production begins. To reduce or prevent disease problems, use resistant or tolerant varieties and rotate tomatoes to different parts of the garden each year, using a minimum three-year rotation. Tomatoes should not be grown in soil which has previously been used to grow peppers, eggplants, or potatoes during the previous three years. Fusarium wilt, a disease caused by a soil fungus, is common in the Mid-Atlantic region, during mid- to late-season. Where fusarium wilt is present, a minimum six-year rotation is recommended. Do not plant eggplants, peppers, or potatoes in wilt-infested soil during the rotation period. Use resistant varieties if space does not permit a six-year rotation or if there is a history of fusarium in the soil. Avoid planting tomatoes near walnut trees to avoid "walnut wilt." Early blight and anthracnose are common in the Mid-Atlantic region, and are favored by hot, humid conditions. Late blight is more common in inland regions at higher elevations, especially during the spring and fall. Blossom-end rot is prevented by ensuring an adequate level of soil calcium and steady moisture. Do not use fungicides. Fungicides may mask important information about variety performance. When fungicides are absent there is a good opportunity to identify and select plants which have greater resistance to disease.

Greenhouse and solar greenhouse notes:

Greenhouse-grown tomatoes require pollination for good fruit set: vibrate the blossoms with an electric toothbrush or tap the flower cluster several times with a pencil. Fans can be used in the greenhouse to vibrate the blossoms during the wintertime when greenhouses are not vented. The daytime greenhouse temperature should not exceed 90°F (32°C), and night temperatures should drop below 70°F (21°C), but not lower than 55°F (13°C). The optimum night temperature is 59-68°F (15-20°C). At 40°F (5°C) some tomato varieties show tissue damage not readily visible to the eye. Greenhouse tomato pests can be controlled with insecticidal soap up to one day prior to harvest. Whiteflies, winged-aphids, and leaf miners are attracted to and trapped by sticky yellow traps.

SELECTION

Selecting the plants:

There is usually no need to rogue plants, provided the seed crop is being grown from well-selected stock seed. However, in dealing with ethnic or heirloom varieties it is not unusual to see more variability in a seed crop. Many ethnic groups and gardeners maintaining family heirloom seed do not place the same premium on uniformity valued by the commercial seed trade. Variability in ethnic and heirloom varieties is not necessarily bad. In fact the variability may be an important source of genetic diversity. So, in general, you may expect to see more variability in ethnic and heirloom varieties, but plants that are obviously off-type should be rogued. If you are growing seed of an ethnic or heirloom variety that is new to the seed trade, the seed company should provide you with some idea of what type of variation to expect.

Selection of seed plants begins at the seedling stage and continues before the plants have flowered. Remove any weak plants or those with any off-type foliage before these can pollinate with any other plants. Pay attention to the foliage of the plant and be aware of any increased or decreased susceptibility to disease, insects, or environmental conditions. If you see a plant with some unusual or potentially useful characteristic, you may want to transplant it and isolate it for future evaluation.

Once the plants begin to bear fruit, examine each one for trueness to type. Instead of focusing on each individual fruit, you should look instead at the overall performance of each plant. Does each plant have typical fruit color, shape, size, and internal fruit characteristics? If a significant number of

fruits on a plant fail to meet overall performance requirements, the plant should be pulled, otherwise it is too late for roguing plants once the fruit has been picked.

Selecting fruit on the plants:

In selecting fruit for seed, choose fruit which are true-to-type including typical color, shape, size, and internal fruit characteristics. In other words, do not use off-type, misshapen, or diseased fruit. Fruits which are bruised, or fruits which have small cracks are useable for seed, but plants which have a lot of cracked fruit should be rogued before fruit is harvested, otherwise you may end up selecting for cracking. It is okay to harvest both early and late fruit, but don't attempt to harvest fruit from plants which are obviously in stress or decline. During seed processing, keep an eye out for fruit which has undesirable internal qualities.

WHEN TO HARVEST SEED

Tomatoes should be harvested at the "dead-ripe" stage, but they should not be left on the vine so long that there is evidence of decay. They should have developed full color, and the fruit wall will have softened enough to have a slight "give." During very hot weather, I recommend harvesting tomatoes about two days before they are dead ripe so that they can continue to ripen off the vine in the shade. If your growing season is shortened prematurely by frost you can harvest the fruit and allow it to ripen off the plant. Interestingly, seed harvested from immature fruit at the “breaker stage” (when it shows the first blush of color) will often germinate well, but such seeds will not retain their viability as well as seed harvested from fully mature fruit. If you do harvest seed from slightly immature fruit, it should be labeled as such.

In the southeastern U.S. daytime temperatures can climb into the high 90’s. Once fruits are harvested they should be kept in the shade because the effect of direct sunlight on the fruits for long hours could potentially raise internal fruit temperatures high enough to damage the seed. When tomatoes are grown for seed in the Deep South it may be useful to partly shade the plants from intense afternoon sun. This can be done by growing them near a line of trees that have a large canopy with few branches on the lower trunks.

Fruits ripening on the vine at temperatures above 90^{o}F (32^{o}C) may produce lower germination seed. This problem most likely occurs in varieties that do not have good foliage cover. Normally, this is not a severe problem and doesn't require corrective action, but may explain lower germination of seed extracted during periods of hot weather.

METHODS OF SEED EXTRACTION

There are basically three methods of seed extraction: (1) juice and seed extraction, (2) acid extraction which is not recommended, and (3) extraction by fermentation, which is the preferred method. Fermentation is the preferred method because it is a natural process that is least harmful to the seed and can destroy bacterial canker and other seed-borne diseases. Fermentation should be a controlled process. Though not difficult to do, it can be done incorrectly, in which case the ferment produces a bad smell and an overgrowth of white fungus which can stain and damage the seed. Details of the proper procedure are described in the section below.

FERMENTATIVE EXTRACTION
The preferred method for producing commercial-grade seed

The best quality seed is obtained by fermentative extraction. The process basically consists of breaking or mashing up the fruit into pulp, seeds, and juice, and then pouring the mixture (“mash”) into a large container where it ferments for a period lasting usually three days. After fermentation is complete the seed is separated by washing, and then the seed is dried. Though the process is quite simple there are some important details for performing the process properly.

Methods for mashing the fruits:

The first step in extracting the seed is to reduce the fruit to a coarse mash. Before starting this it is sometimes useful to core the tomatoes first because the cores are heavier, they don't break down well during fermentation, and they don't wash away easily during the washing process. Tomatoes that have dirt or other debris stuck to the skin should be rinsed off before processing.

There are all sorts of methods that can be used for mashing the fruits, some more fun than others. Be creative. There are lots of possibilities, and if you develop a new method let me know. Some suggestions include the following:

- **Bucket and masher method (preferred method):**
  This is the method that I now use routinely. Cut the tomatoes into wedges or sections and add them to 5-gallon plastic buckets, filling the buckets no more than two-thirds full. Lids are recommended to keep out fruit flies which can become a nuisance when fermentation is done indoors. Five-gallon plastic buckets are available at most building supply stores. Larger containers such as feed troughs are available at farm supply stores. You may also want to purchase a hand mortar mixer which looks like an oversized potato masher. This is useful for mashing up the cut-up sections. Alternatively you can mash up the sections by squeezing them through your hands. If this seems too gross you can use the mortar mixer to mash them. This secondary mashing method isn't always necessary if the tomatoes break apart easily, but the fermenting mash will get a better start and will be more uniform if the fruits are well broken down at the outset. The advantage of this method is that it is probably the easiest method for producing small lots of seed ranging from two ounces to a few pounds. Make sure that you label the bucket with the tomato variety, and remove old labels when the buckets are cleaned.

  Wheelbarrow method:
  This method was used by Glenn Drowns, one of our former growers, who used it for extracting seed of sweet peppers. Fill a wheelbarrow about half-full and chop the tomatoes with a hoe. Make sure the wheelbarrow is on level ground. The disadvantage of this method is that the tomatoes may not be equally chopped. This method is for soft-fruited, medium or large tomatoes: you can't chop cherry tomatoes with a hoe. The advantage of this method is that if you are allergic to tomatoes you don't have to handle them directly. Though rare, some people can develop rashes or allergies from frequent contact with tomato fruit and vines. After the tomatoes are chopped, transfer the mash to a fermentation container.

- **Swimming pool method:**
  I have not used this method, but suggest it as a possibility to explore. This method has been used successfully by a grower for a small southwestern seed company.

  Fill a plastic swimming pool one-third full of tomatoes and step on the tomatoes as though they are grapes to be smashed into wine. At the end of fermentation, water can be trickled into the pool at a slow rate (so as to not agitate or float the seeds on the bottom). The water will clarify, but pulp will need to be scooped or picked out. Alternatively, the mash can be transferred to 5-gallon buckets or other large containers. This extraction method can be a great activity for kids. The disadvantage is that the kids will need to wash their feet and legs thoroughly before moving on to the next variety, and the pool will need to be thoroughly cleaned. Without thorough cleaning, seeds and diseases of different varieties can be mixed.

  I used a variation of this method when my son was younger. He enjoyed stepping on tomatoes in 5-gallon buckets. I have since learned that it is not necessary to have a fine mash for the tomatoes to ferment properly, but it does keep the kids entertained and involves them in the process.

- **Hardware-cloth grater method:**
  Build a wood frame using two-by-four lumber and mount 1/4", 3/8" or 1/2" hardware cloth on the frame. (The frame can serve double-duty as a soil sieve.) Place a large tub or basin under the frame. If the tomatoes are soft, you can rub or grate tomatoes over the

hardware cloth. It may be necessary to cut the tomatoes first, halfway between the blossom and stem end.

- **Other methods (for processing small seed lots):**

  The following are other variations to consider, though for small seed lots I find it easy enough just to cut tomatoes into sections, break them up, and ferment them in quart or half-gallon jars.

  Zip lock bag method:
  This method comes courtesy of grower Merlyn Niedens who uses this method for processing small amounts of seed. Purchase heavy-duty, freezer-quality, quart or gallon-sized zip lock bags. Write the name of the variety on the side of the bag. Place the tomatoes inside the bag and crush them. The bag or bags are placed inside a large basin or 5-gallon bucket. These bags are massaged or squeezed at least twice daily to stir the ferment. After squeezing the bag several times, partially open the top of the bags so that gas can escape. Be sure to position or support the bag so the ferment doesn't spill. When fermentation is complete the contents are placed in the bottom of a bucket to be washed. When done, wash out the bag and hand upside down to dry.

  Food processor method:
  This doesn't offer an advantage over other methods, except that it can be useful for cherry or currant tomatoes. It does reduce the mash to a finer texture, but the fine texture is not necessary for good fermentation.

  Use a food processor (not a blender) with a blunt plastic blade and set on a slow setting, or process with a quick turn on/off motion. This is a very fast and efficient method for processing small amounts of fruit. Be sure your food processor is equipped with a 1/8" dull square-edge plastic blade. Do not use a metal blade which will damage the seed. Cut tomatoes into wedges; drop into the food processor until about half full, and process at a slow speed until the wedges are broken apart. Caution: although the method works well and gives good results with little apparent effect on seed germination (when done correctly), it is not recommended for seed production without first testing to see what effect it has on germination.

  Squeezo® strainer method:
  Two products are produced by this method: the juice and the "pumice" which consist of "dry" pulp, skin, and seeds. The seed is separated from the pumice by washing the seed with water until the seed is clean. The advantage of this method is that you can save the juice to drink, but the disadvantage is that it is a slower process, and fermentation isn't used (unless you save some of the juice for fermentation). There is a possibility seed may be bruised by this method, so if this method is used, compare the germination of seed extracted this way with seed (of the same lot) processed by the bucket and masher method. Be sure to clean the strainer thoroughly between processing varieties. Seed may become stuck in small crevices.

  Corona grain mill method:
  The Corona grain mill can be used to pulp tomatoes that have been cut into sections. The important point to remember is that the milling plates have to be set far enough apart so that they do not grind or abrade the seed. A disadvantage of this method is that seed can become stuck in crevices of the mill plates or grinder and need to be cleaned out, a concern if you are processing more than one variety.

Adding water to the mash:

If bacterial canker is a problem, it is best to not add water to the mash because dilution of the mash reduces the effectiveness of controlling canker (see section on Control of Seed-Borne Diseases). If canker is not a problem, it doesn't hurt to add a small amount of water, usually not more than 10 percent of the volume of the mash. Adding water makes it easier to stir the mash, and allows more

circulation of ingredients since the mash is less dense and the rising bubbles have an easier path to the top of the liquid.

The fermentation process:

After the fruits are reduced to a mixture of sections, pulp, juice and seed, the next step is fermenting the mash. This happens naturally without any intervention. The combination of naturally occurring yeast and sugars in the mash is enough to start the process. Fermentation has begun when small gas bubbles are seen rising from the mash, usually within twelve hours. Fermentation is complete when gas production slows or stops, when the mucilaginous material around the seed is digested, and seed has settled to the bottom of the container. A very important step, often not mentioned in seed-saving literature, is that the mash should be stirred at least twice, and preferably three times a day. This helps the ferment to work evenly, helps release the seed from the pulp and its mucilaginous coat. More importantly, stirring prevents the growth of a white scum on top of the mash. This white scum, often accompanied by a bad smell, indicates the overgrowth of a fungus which can injure or discolor seeds. If you see this overgrowth you need to stir the mash more frequently.

Fermentation temperature:

The speed of the fermentation process is largely dependent on the temperature. If the temperature ranges between 75 to 80ºF (24 to 27ºC), fermentation should be complete within 48 to 72 hours. To control bacterial canker, the fermentation should last 96 hours (4 days). This requires a temperature of about 65ºF (18ºC). This long fermentation can cause injury to the seed, such as premature sprouting. Therefore as a compromise, tomatoes should ideally be fermented at close to 70ºF (21ºC) as possible. This may be difficult to achieve in practice during the summer unless fermentation occurs in an air-conditioned environment or cool basement. At a minimum keep the fermentation temperature below 80ºF (21ºC) because a fermentation temperature (temperature of the liquid) in the high 80's can cause a 50% loss of germination in 48 hours. A fermentation temperature in the 90's will cause a loss of germination in the majority of the seed. If fermentation occurs outside, make sure that it is done in the shade.

When fermentation is complete, the mash has lost its frothiness when stirred, the good seeds have sunk to the bottom, and much of the pulp has floated to the top.

Washing:

When tomato seed is processed on a large commercial scale, the seed is washed in a shaker washer or flume. In small-scale seed production where seed is fermented in containers such as buckets, the first step in washing is to stir the fermented mash, let it settle, and then scoop off much of the pulp floating on top. Next, water is poured into the mash so that the volume is approximately doubled. If you don't add enough water, the specific gravity of the mash may be too high to allow some of the good seeds to sink. Adding water lowers the specific gravity. This also clarifies the liquid so that you can see the seed more easily. After water has been added, the mix is allowed to settle again. The good seeds will sink to the bottom. After the mix has settled, the container is tilted and the pulp and other debris are poured off the top. The pouring continues until most of the mash is poured off. Lighter, low-density seeds of poor quality can be poured off with the liquid. This washing process is repeated until the water turns clear. Typically it takes anywhere from three to six washings. When the water comes clear, the contents are then poured into a large strainer (held over another bucket). Excess water is expressed by pressing on the seeds with a large spoon while the seeds are in the strainer. Next the strainer is flipped upside down over a cloth towel or rag. The seeds fall out into a pile, and the pile is then spread and flattened with a large spoon until the patty is no thicker than ¼ inch. The towel itself is usually spread over a screen so that air can reach the patty from the bottom as well as the top. The purpose of the towel is to wick water away as quickly as possible. The patty of seeds doesn't need to be turned or stirred provided there is a steady stream of air flowing over the seeds.

Drying:

Once the seed has been washed and made ready for drying, it should be dried as quickly as possible without heat. A fan is useful for this purpose. If the seed is not dried quickly it can sprout or

mold. The seed should be relatively dry to touch within 24 to 36 hours. Drying should take place at a temperature of less than 90ºF (32ºC). Once the temperature reaches 95ºF (35ºC) damage to the seed can occur. For this reason, seed should not be dried in the sun when the air temperature is much over 80ºF (27ºC). Seed is best dried in an air-conditioned room with air circulated by fans.

Curing:

Curing is a continuation of the drying process. After the seed has been dried set it aside in a dry environment with good air circulation to cure for two to four weeks. During this time the moisture content of the seed is gradually reduced. Seed should be thoroughly cured before being placed in an airtight container. If curing outdoors, make sure that mice cannot get into the seed.

Milling:

It is usually not necessary to mill seed after washing and drying since there will be little foreign material with the seed. It may be helpful to screen the seed for size in order to discard small seed.

Seed yield:

Calculating seed yield is an optional step that can be useful for determining seed yields of different tomato varieties. This is important information if you are a seed grower planning to sell small lots of seed to seed companies. This only needs to be done the first time you grow a variety for seed, provided that your growing conditions remain relatively the same from year to year and place to place. To calculate seed yield, weigh the total lot of tomatoes to be extracted for seed, and then record this information. After you have extracted, washed, and dried the seed, weigh the dry seed and calculate how many pounds of fruit are required to produce an ounce or pound of seed. You will also want to keep a record of the number of plants required to produce a given weight of seed so that in the future, if you want to produce a pound of seed you will know approximately how many plants you will need.

An acre of tomatoes raised for seed may yield an average of 35 to 160 pounds of seed depending on the variety, the density of the planting, the amount of crop saved for seed, fertilization efficiency, and growing conditions. One hundred pounds of tomatoes will yield approximately 4 to 10 ounces of seed, but this number is strongly influenced by the fruit size, variety, and growing conditions. Seed size and weight varies depending on variety, and averages about 11,480 seeds per ounce. The Federal germination standard is 75%.

Labeling:

It is easy to lose a good batch of seed if you have not labeled your seed at every step from extraction through drying. Never assume that you will remember which variety is which. The label should travel with every step of the process from start to finish.

INSECT PESTS

An important thing to remember about insect pests is that just because an insect is feeding on a plant doesn't necessarily mean that there will be an adverse effect on yield. Some plants can withstand quite a bit of defoliation without serious consequences, so a zero-tolerance policy is not advocated. Instead, a policy of damage assessment based on cost-benefit is more ecologically sustainable. Cost-benefit analysis involves awareness of what role the pest is playing in the ecosystem. Generally speaking, if you have created a growing area with rich biological diversity, your pest problems are likely to be minor.

Tomato hornworms (*Protoparce sexta* and *Protoparce quinquemaculata*):

Tomato hornworms can be controlled by *Bacillus thuringiensis*, though in most cases it is not necessary to use this unless the outbreak is severe. Handpicking hornworms early in the season often provides sufficient control. Incorporate biological diversity into the growing area. This encourages the activities of small parasitic wasps to lay their eggs on hornworms. As the wasp larvae develop inside the hornworm, the hornworm becomes lethargic or immobile, and shortly thereafter, the young wasps

emerge from the caterpillar. Hornworms with the white egg cases of parasitic wasps on their backs should not be destroyed because the wasps will hatch out and parasitize other hornworms in the garden. It is worth noting that hornworms hatch out into night-flying sphinx moths which are important pollinators of some flower and herb crops.

Fruitworm (*Heliothis armigera*):

Fruitworm, also known as the corn earworm can be controlled by *Bacillus thuringiensis.* Tomatoes with thick skins, especially cherry tomatoes are much more resistant to fruitworm than varieties with a thin skin.

Flea beetles *(Epitrix cucumeris*):

Flea beetles are rarely a serious problem. A simple control measure is to keep flats of tomato seedlings several feet off the ground because the flea beetles have a more difficult time reaching the plants.

CONTROL OF SEED-BORNE DISEASES

Tomatoes are prone to a number of diseases, many of which affect yields noticeably. There are over 20 bacterial and fungal diseases which can affect tomatoes, plus others caused by insects, or non-parasitic diseases, also called physiological diseases (for example, blossom-end rot). Sometimes more than one disease may be present at a time. As a seed grower, the diseases that are of most concern are those diseases which can be carried in the seed or on the surface of the seed coat.

Basic sanitation and prevention is always the first step. To control seed-borne diseases, it is important to practice crop rotation, to clean up and compost all plant residues, to maintain adequate nutrition, and to select and wash fruit before collecting the seed. Seed crops should be planted early in the season, rather than late. By planting early in the season a seed crop may be produced before the onset of warm humid conditions which favor fungus diseases. Plants which show disease should be rogued as quickly as possible to minimize disease spread. Seed should be collected only from healthy plants. Fruit which shows obvious signs of discoloration, fungus growth, mosaic patterns, or other abnormal conditions should not be used for seed (unless there is a risk of losing the variety). The ground should be mulched under the plants. This prevents rain from splashing disease spores onto the plant.

Seed growers should be aware of several seed-borne diseases which may be carried on tomato seed. The most important diseases for the Mid-Atlantic and Deep South are those listed below:

Bacterial canker (caused by the bacterium, *Corynebacterium michiganense*):

This bacterial disease is not widespread but can be destructive, and it is more common in southern states. As a seed producer, you should be familiar with the symptoms. Fruits infected with canker will show "bird's eye" spots. These are dark rough spots (usually tan or brown, about 3/16" (3mm) in diameter), surrounded either by a water-soaked area, or white halo. Symptoms on foliage are evident as an upward curling of leaves which turn brown and wither but do not fall off. Cankers may develop at leaf nodes and spread downward. The cankers first appear as light streaks which darken and crack; later small cankers may form along the length of the crack. The pith of the stem may appear yellow and mealy. Canker disease can be eliminated by extracting the seed with fermentation. To destroy canker by fermentation keep the temperature at or below 70°F (21°C) for a minimum of 96 hours. Canker may also be destroyed by acetic acid treatment. Moist, just-extracted seed is soaked for 24 hours in a 0.8% solution made from pure acetic acid (1 ounce acetic acid per gallon of water). If dried seed is being treated, use ¾ ounce acetic acid per gallon of water. If acetic acid is not available it may be possible to obtain a 0.8% solution of acetic acid by diluting white cider vinegar (5% acid strength) with 5-¼ parts water. (Note: I am not certain that white cider vinegar is as effective as pure acetic acid diluted to 0.8%.) After acetic acid treatment rinse with water and dry as soon as possible.

Tomato (tobacco) mosaic virus:

Tomato mosaic is most often seen on greenhouse-grown tomatoes and sometimes field-grown tomatoes. The most common symptom is a mosaic or mottling of the leaves which shows as irregular patches of yellow or light green mingled with green. Leaves may be distorted, blistered, curled, dwarfed, or elongated like shoe strings, depending on the strain of the virus. Infected fruit may not show any symptoms, or may show some internal browning or discoloration. Tomato mosaic virus may be prevented by keeping smokers out of the garden (cigarettes may carry the virus), by dipping your hands in milk each time you handle another plant (milk inactivates the virus), and by using disease-free seed. I never let smokers into our seed gardens or into our seed packing facility – no exceptions!

Tomato mosaic virus doesn't get into the seed embryo but is carried on the seed coat and is difficult to remove or inactivate. Seed harvested from infected plants may produce up to 3% infected seedlings. The virus can be attenuated or inactivated by storing dry seed at room temperature for several months to a year. Seed which has been stored several months will usually produce normal seedlings, though the virus may still be present in the seed coat. In addition to dry storage, the virus may also be inactivated by treating seed with 10% trisodium phosphate for 10 minutes followed by 3 water rinses lasting 5 minutes each. Planting the seed directly without later transplanting will also reduce the incidence of the disease.

Fusarium wilt (caused by the fungus, *Fusarium oxysporum f. lycopersicae*):

This fungal disease is fairly widespread in occurrence, and more prevalent in southern and warm coastal states. Wilting is the most obvious symptom. Typically one stem may wilt, yellow, and die back at the top, presenting a flag-like appearance, or yellowing and wilting may occur only on one side of a leaf midrib. The infected stem may die back or wilt severely before other stems show infection. If you suspect fusarium wilt, it can be confirmed by cutting the stem in cross section. The vascular tissue of the stem will be discolored, typically showing as a brown ring. Plants showing fusarium wilt should be pulled and the vines should not be composted. Instead they should be discarded in the trash or a location far away from the growing area. The disease is fairly persistent in the soil, and plants in the tomato family (Solanaceae) should not be grown in fusarium-infested soil for at least six to eight years. Control measures include paying strict attention to crop rotation and growing wilt-resistant varieties. Hot water seed treatment can be an effective treatment in some instances.

Anthracnose (caused by the fungus, *Colletrichum phomoides*):

This fungal disease is a fruit rot found on uninjured ripe tomato fruits, and is common in the Mid-Atlantic and southern states. Another name for this disease is called "ripe-rot". In the early stages of infection, lesions on the fruit appear as small, sunken, circular spots that appear as water-soaked indentations in the skin. These gradually grow larger, up to about ½" in diameter, and develop a dark center because of the black fungus under the skin. The disease becomes more prevalent, especially in August during hot and rainy weather. The disease organism is prevalent in the Mid-Atlantic and grows best at 80ºF (27ºC), but it doesn't grow above 95ºF (35ºC) and for that reason isn't as much a problem in the Deep South. Tomato varieties that are subject to defoliation by other diseases are also more susceptible to anthracnose. Lesions also appear on the stem and foliage, but are easily overlooked. These stem and leaf lesions may serve as infection sources for the fruit. This is why it is important to remove plant debris at the end of the season. A crop rotation of at least four years is recommended.

Early blight (caused by the fungus, *Alternaria solani*):

Early blight is fairly common in the Mid-Atlantic, especially during periods of frequent rain. Infection can occur in the seedling stage, but is most commonly observed on the older leaves of established plants, frequently after fruits begin to set. Symptoms develop as dark spots with concentric rings. The rings spread to surrounding tissue and as the infected leaves die, they become dry and papery. In addition to causing a decrease in yield, the disease can be carried on the seed. The disease is promoted by heavy dews and frequent rainfall. Maintaining good air circulation around the plants can be helpful, as well as mulching the soil to prevent soil splashing of spores onto the leaves. A minimum two-year rotation and removal of crop residues is helpful in controlling the disease. The disease may be seed-borne, but proper fermentation of harvested seed helps to control the disease.

SEED DISINFECTION

In most cases no seed disinfection treatment is recommended for disease control. Proper fermentation of extracted seed will destroy canker and some other fungus diseases. Long-term dry storage will attenuate tomato mosaic virus. If you find it necessary to harvest fruit from plants affected by diseases such as wilts, blights, etc., and are concerned about the possible transmission of disease you can use the following general seed treatment. Prepare a 10% solution of commercial bleach and soak thoroughly dried seed for 10 minutes with frequent stirring. Pour off the bleach solution and follow with three, 5-minute water rinses. Dry the seed as soon as possible. This treatment may have a small adverse effect on germination. Note: any seed which has been treated with a chemical, no matter how mild, should be labeled to that effect. In fact, Federal seed law requires that if seeds are treated with any substance they must be labeled as such. Also, any seed which you suspect might be a carrier of disease should be labeled. This is especially important if you exchange seed with others or grow seed commercially.

Seed disinfection and organic certification:

Seed can be disinfected by hot water treatment. The process involves immersing the seed in water hot enough to kill the pathogen, but not so hot that it damages the seed. This process is discussed in a separate manual dealing with control of seed-borne diseases. Check with your certifier to assess the different seed disinfection options available.

SEED STORAGE

Details of seed storage are available from many sources and are the subject of another manual in this series. Just the basics are covered below.

Long-term storage:

It is very important that seed be thoroughly dry. Freshly harvested seed should be cured for a minimum of three to four weeks before placing in long-term storage. At least one week before the seeds are placed in airtight containers, they should be transferred to an air-conditioned or heated room or other low humidity environment before being placed in a jar with a rubber-gasketed lid. Thereafter the seed may be transferred to the refrigerator or other cool environment. Before opening the jar, always allow the jar to warm up to room temperature. Try to do this on a dry day so that humid air is not introduced to the jar. Note: never store seed in a closed container unless the seed has been dried thoroughly first .

Short-term storage:

For short-term seed storage, it is not necessary to store seed in airtight jars. Seed can be stored in large envelopes, paper bags, cloth bags, or other non-airtight containers. Porous containers are not recommended for storing seed for long term unless the surrounding air remains cool and dry. Zip lock bags and most plastics allow water vapor to pass through and therefore these materials are for short-term seed storage only.

SHIPPING SEED

Just the basic information is included here. Before seeds are shipped, there should be labels on both the inside and outside of the seed containers. Paper bags should be triple bagged. If a seed container breaks open and mixes with other seed, the seed will be worthless. Any shipment of seeds should be able to withstand a minimum ten-foot drop without damage to the container or its contents.

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COMMONS DEED

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