BEAN SEED PRODUCTION

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

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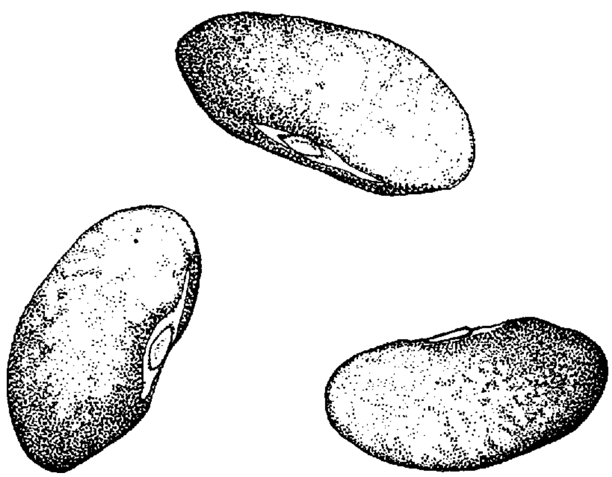

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BEAN SEED PRODUCTION

BOTANICAL CLASSIFICATION

Botanical classification of commonly cultivated species of beans:

Family: Leguminosae (pea family)
- Common bean: *Phaseolus vulgaris*
- Lima or Butter bean: *Phaseolus lunatus*
- Runner bean: *Phaseolus coccineus*

PLANT CHARACTERISTICS

The common bean has the largest number of varieties, and the most culinary uses. The various varieties of common beans are well known for their ability to produce seed coats in a wide array of colors covering nearly the whole color spectrum. In a few cases, the seed coat color is distinctive enough to identify a particular variety of bean, though the color darkens with age. Varieties of beans can be differentiated not only by seed color and size, but also the size, color, and shape of their leaves, the degree of pubescence (plant hairs) on the pods and leaves, and the color of their flowers.

Beans are herbaceous annuals with some perennial tendencies, such as the slightly woody stem found in vining types. Depending on variety, plant height ranges from dwarf (bush plants) to semi-vining (half-runner plants) to vining (pole) beans. Vining varieties have the ability to twine or climb a pole or support, but the degree of twining may vary slightly according to variety. All beans have pinnate, three-lobed leaves. They are usually broad ovate in shape, but certain varieties may have long narrow leaves. The narrow-leaf characteristic is more common in beans which are adapted to hot climates, for example, 'Willow Leaf' lima.

The lima bean (named for Lima, Peru) has a flat broad seed ranging in size from ½" to 1" or larger. Like the common bean, the lima also has a number of color and size variations. There are two subclasses of limas: the small-seeded lima (such as the sieva lima), and the potato lima, which has a thicker seed.

Runner beans are less variable in size and color. Typically, the seeds are various shades of maroon with mottled light-purple streaks, though some may be white or pale green. Unlike other beans, the cotyledons remain below ground when the seed germinates. White-seeded runner beans have white flowers, while colored-seeded runners have scarlet-colored flowers. Runner beans, native to Central America, are perennials that form tuberous roots, but in northern climates they are cultivated as annuals.

Though beans are predominately self-pollinated, various varieties of beans differ in their ability to cross-fertilize. Cross-fertilization does not occur between different species of beans (for example, between a common bean and a lima bean). For that reason, each species may be grown side-by-side without concern for crossing. On the other hand, when growing varieties of the same species, varieties need some degree of isolation from each other in order to maintain purity.

Climate and regional growing requirements:

Successful bean seed production is more dependent on climate than most other vegetable seed crops. Several factors are important here. In hot humid regions, special harvesting and drying techniques (discussed later in this guide) are required to produce high-quality seed. Also two seed-borne diseases, anthracnose and bacterial blight, can be a problem in humid, wet climates. That is why much commercial bean seed production has moved to dry western states.

Beans are considered a warm-season crop, sensitive to temperature extremes. Several days of extended hot weather may cause failure of fertilization and subsequent blossom drop, resulting in lower yields. Cool, rainy weather also has an adverse effect on yield. Lima beans tolerate hot weather better than common beans, and can be grown further south, though some lima varieties may not set seed well when the temperature exceeds 95ºF (35ºC). On the other hand, most limas do not tolerate cool growing seasons as well as common beans. Runner beans, which are indigenous to the cool, humid uplands of Guatemala and southern Mexico will not set seed well in the Mid-Atlantic except at higher altitudes, or during the cooler days of early summer or late summer/early fall.

Beans are fairly tolerant of a wide range of soil types, though have a more limited tolerance of acid or alkaline soil than other vegetables. In the Southeast, where soils are more acidic, proper attention to pH can be helpful for good production. Soil pH should be in the range of 5.8 to 6.5.

Determinate and indeterminate varieties:

Determinate (bush) varieties have short stems with four to eight nodes on the main stem with short internodes. Semi-determinate (half-runner) varieties have stems two to four feet in length. Indeterminate (pole) varieties grow up to ten feet in length with a twining growth habit, and little branching of the main stem. The internodes of indeterminate varieties are longer and only the length of the growing season limits the number of nodes produced.

Roots:

Bean plants develop taproots, that in good soil can reach a depth of at least two feet within a month, and three to four feet when fully mature. Strong lateral roots also develop, and a fully mature vining variety may have a root zone radius of two feet. Nitrogen-fixing nodules may or may not be present on the roots.

Flowers:

Beans have perfect flowers (male and female reproductive parts are in the same flower). The flowers are typically white in many of the newer varieties of bush beans, but flower color, especially in older varieties and vining varieties, may be white, pink, rose, lavender, deep violet, or sometimes yellow. In runner beans, they may be crimson, or crimson and white. The flower consists of a corolla (united petals) and a keel (the two lowest petals joined at the lower edges, resembling the keel of a boat). Usually there are ten stamens, the upper one free, while the other nine unite into a twisted tube that encloses part of the style and the long ovary. The flowers are borne along a two to three-inch rachis (stem).

Pollination and fertilization:

Pollination is the process of transferring the pollen from the male part of the flower (anthers) to the female part, or stigma (pollen-receptive surface of the pistil). Fertilization is the process of the union of the male gamete in the pollen with the egg to form the zygote, which becomes part of the seed.

Beans are more susceptible to crossing than are peas, and certain bean cultivars are more susceptible to crossing than others. Beans are primarily self-pollinated and self-fertilized, but natural crossing often occurs as a result of pollinator pressure, principally by large bees, such as the bumblebee, and to a lesser extent by the honeybee.

Blooms open in the morning, between 7 and 8 a.m. and never close, though the corolla is shed within a few days of blooming. The stigma is receptive two days before the flower opens and even though the pollen is shed from the anthers the evening before the flower opens, the pollen isn’t transferred to the stigma at this time unless the flower is agitated or tripped by a bee. After the flower opens, the flower can be cross-pollinated by bees. A short time after opening, the stigma retracts into the keel and comes in contact with pollen from the anthers and self-pollination occurs. After pollination, the pollen tube grows toward the ovary and fertilization takes place about 8 to 9 hours later. Pollen tubes from foreign pollen may grow more quickly than self-pollen, leading to a higher incidence of cross-fertilization.

Common beans and limas seem to set a full complement of seeds and pods in the absence of bees, and most studies indicate that bee pollinators do not have a significant effect on yield. Though bees are not essential for seed development and increased yields, they can be a cause of crossing if the flowers are pollinated early in development. On the other hand, runner bean yields can be increased significantly as a result of insect visitation.

Seed and pods (fruit):

The fruit of the bean plant is a bi-valved pod that bears seeds alternately on both sides of the dorsal margin of the placentae. The characteristics of pods differ among varieties: they vary in size, shape, length, and curvature of the pod as well as the width of the cross section, which may be round or flattened. Also varieties differ in the amount of seed within the pod and how well the pod dehisces (splits open) along the dorsal and ventral side.

Most cultivated bean varieties have to be threshed to remove the seeds from the pods, but very old or ethnic varieties have a tendency for the pods to shatter, causing the seeds to be flung out by the pods twisting into a spiral “spring” as they dry.

Seed germination:

The statistics on seed germination in relation to temperature are given in the table below:

Type of bean	**Minimum (°F)**	**Optimum Range (°F)**	**Optimum (°F)**	**Maximum (°F)**
Common bean	60	60 to 85	80	95
Lima bean	60	65 to 85	85	85
Runner bean	60	60 to 85	80	85

In the optimum temperature range, common beans will emerge from the soil in about 6 to 15 days. Lima beans will emerge in about 7 to 20 days, depending on temperature. Though 60°F (16°C) is considered the minimum soil temperature for germination, significantly better emergence occurs when the soil temperature at 8 a.m. is at least 65°F (18°C). When the soil is cool, seeds may rot before they germinate. For early spring planting, dark-seeded bean varieties are recommended because they have a better germination success in cool soil than do light-seeded beans. This is because the pigments in the seed may provide some protection from opportunistic fungi.

ISOLATION DISTANCES

Though bean flowers are perfect and self-pollinating, a considerable amount of out-crossing can occur under certain conditions, and therefore isolation between varieties is required. For an in-depth discussion of the principles and practices of establishing isolation distances in various crops, see the companion manual devoted to this topic. The important point for the seed grower to remember is that isolation distance recommendations need to be understood within the context of the environment in which the crops are grown. This is especially important for organic growers who, as a result of their growing practices, have a larger degree of biodiversity in the environment, and therefore a higher pollination pressure on seed crops.

Some of the variables that influence the degree of outcrossing are the following: (1) variety characteristics such as flower structure, (2) environmental factors such as wind and temperature, (3) types of pollinators and their behavior on the blossoms, (4) isolation distance, (5) presence of barrier plants, (6) planting patterns such as row or block plantings, (7) number of varieties, (8) number of plants of each variety, (9) presence and type of other pollen sources, and (10), regional or bioclimatic factors.

Because beans have such distinctive colors and patterns in the seed coat, it is tempting to conclude that crossing has occurred when a change in the seed coat is observed. While this may be true in some instances, the absence of such a change does not constitute evidence of seed purity.

Following are some data summarized from pollination literature regarding the amount of outcrossing in beans planted in adjacent rows: (1) common bean (*Phaseolus vulgaris*) - 1 to 25%; (2) lima bean (*Phaseolus lunatus*) - 1 to 89%; and (3) runner bean (*Phaseolus coccineus*) - at least 32% cross-pollination reported in one study, but runner beans cross more readily than lima beans and cross-pollination may exceed 90%.

The extent of crossing is highly dependent on the microclimate and biodiversity of the region in which the beans are grown for seed. As a beginning seed grower it is important to be very conservative in establishing minimum isolation distances until an understanding has been gained about the dynamics that can affect crossing in beans.

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

Seed Crop	Minimum for home use only	Minimum with barriers	Minimum without barriers	Comments
Common bean (*P. vulgaris*)	20-25'	50-75'	150'	Bees prefer flowers other than legume flowers.
Lima bean (*P. lunatus*)	50'	75-150'	150-300'	Easily cross-pollinated by bumblebees and honeybees. A tall barrier crop or other pollen sources are recommended to divert bees.
Runner bean (*P. coccineus*)	75-150'	300-450'	600-1200'	Cross-pollinated by bumblebees, honeybees, and other pollinators. Other pollen sources and barriers are essential at shorter distances.

These distances can be modified on the basis of variables such as the presence of other pollen sources throughout the flowering season, or the presence of tall, dense, physical barriers. If you are a beekeeper and a seed grower, it is best to grow only one variety of lima bean or runner bean because bees can easily forage ¼ mile or significantly further. Under extremely high pollinator pressure, lack of other pollen sources, and no barriers, the isolation distances for lima beans and runner beans may need to be increased if you are growing "registered" or "elite" seed.

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. 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 (such as daisies and coneflowers).

If necessary, bush beans can be caged to exclude pollinators. The simplest solution is to build a spun-polyester hoop house. Though there is an initial expense, the components for cages can be re-used year-after-year, except for the polyester which may need to be replaced every two or three years. A hoop house can be constructed by inserting one-foot lengths of rebar, electrical conduit pipe, or PVC (½" inside diameter) pipe into the ground at two-foot intervals along both sides of a double row of beans. To make the hoops, purchase flexible black plastic water-supply pipe (¾" inside diameter). This is available in 100-foot rolls at building supply stores. Cut the pipe into sections about five or six feet long, bend into a hoop, and then insert the loose ends over the upright metal bars. The hoops are then covered with spun polyester. Edges of the polyester can be held down by boards, soil clips, or buried in the soil. The hoop house not only excludes pollinators, but also may exclude Mexican bean beetles if constructed early in the season (and if set up where Mexican bean beetles are not likely to emerge from the soil). One caution regarding this technique: beans grown under spun-polyester row cover may be subject to higher temperatures which may have an effect on seed set.

Evidence of crossing:

If crossing has occurred within a flower, the results of the crossing will not be visible in the seed derived from that flower. The seed coat color and pattern will be the same as the parent seed. Evidence of crossing will not be visible until the second generation, when evidence of crossing can be seen as individual variation within the population of plants, and the seed collected from those plants. Changes in seed coat color are a good indicator that crossing has occurred, but not all crosses show up as a change in the seed coat color. Therefore, stability of seed coat color is not a reliable indicator of seed purity.

If you have discovered that crossing has occurred, both the seed from your current crop and the seed used to produce that crop is impure and unsaleable. Therefore you will need to discard the seed from both your current crop and the previous crop, and start over with pure seed from a previous pure generation.

To understand the origin of seed coat color, it is important to know what tissue is responsible for seed color. In beans, the seed consists of both embryo and maternal tissue. The embryo is the result of either self- or cross-fertilization, and therefore is the next generation. So if crossing has occurred, it will be expressed in the embryo, not the seed coat, which is maternal tissue. The embryo has two large cotyledons which are the food storage organ of the seed. Though the cotyledons of the embryo can have a distinctive color characteristic of the variety, the cotyledon color is not usually visible underneath the seed coat of the dry seed (though conceivably, it could in a rare instance, affect seed coat color). It is the testa (seed coat) which is derived from maternal tissue that gives rise to the seed color. Therefore you can't determine by looking at the seed, whether a cross has occurred, until you grow out the seed and observe its progeny.

MINIMUM POPULATION SIZE

The subject of minimum population size is controversial and needs further study, and depends on the type of crop, the context, and the intended use of the seed, in the same way that minimum recommended isolation distances are determined in relation to a number of factors.

Common beans and lima beans are naturally inbreeding plants. Runner beans are not so easily classified, though perhaps they can be considered naturally inbreeding, with outbreeding tendencies. For all intents and purposes common, lima, and runner beans can be treated as "selfers" and therefore not subject to inbreeding depression, characterized by a loss of vigor and genetic variability.

Part of the answer to the question of minimum population size for "selfers" depends on an understanding of how much variation exists within the population of beans to be grown for seed. Many modern commercial varieties are highly uniform and have little heterozygosity relative to some heirloom varieties which can be somewhat variable. An example of a non-uniform variety is the heirloom pole bean, 'Turkey Craw', which appears to be uniform with regard to foliage and seed coat color pattern, but has two slightly different types of pods. The difference in the pods can be seen when they are dried: one is more wrinkled than the other and there appears to be a slight difference in threshing characteristics in that the wrinkled pod retains the seed more easily.

So how many plants are the minimum required to maintain genetic diversity? My recommendation is that for highly uniform common beans, 10 to 20 plants saved for seed will cover most (95% or more), if not all, of the genetic variation in a variety – though ideally the goal is 99% or better. For a variety that is non-uniform, 20 plants saved for seed is probably adequate, but 40 to 80 plants may be needed to retain at least 99% of the genes in the population. In theory, as many as 190 to 200 plants are required to maintain the genetic diversity of most selfers. The greater the tendency for natural outcrossing, the larger the population size needed to maintain genetic diversity within a variety. Thus for runner beans, the minimum population size should be higher, perhaps 40 or more plants. For some insight on this, it is useful to refer back to the section on isolation distances where it is noted that outcrossing tendency of runner beans is greater than that of limas which is greater than that of common beans.

SELECTION AND ROGUING

One form of selection that can be practiced by the grower is roguing. Roguing is the process of removing off-type plants. Varieties are never static and are always changing. For that reason there is no such thing as "variety maintenance". Selection is always happening, whether we have a hand in it or not. There are environmental factors (climate, weather, soil, diseases, pests, occasional crosses, etc.) and genetic factors (mutations, genetic drift due to population size) which are continually changing the variety. Thus you have to practice roguing to maintain desirable variety characteristics.

Roguing is done throughout the growing season, from seedling stage through fruiting stage, whenever the need occurs. If possible, plants should be rogued before flowering so that the undesirable traits don't pass into the seed.

Roguing is done by inspecting the entire plant, not just the fruit or seed. When roguing plants, pay special attention to earliness, foliage color, leaf shape, flower color, growth form, trueness-to-type, vigor, and disease and insect resistance. When pod production begins consider for example, productivity, size, color, shape, and eating quality. Your focus should be on the whole plant, not on individual pods. Finally, roguing can be done again on the seed itself. If you find off-types at this stage you may have to evaluate the purity of your seed crop.

CULTURAL NOTES

Soil preparation:

Successful bean production depends on careful preparation of the seedbed. Once the seedbed has been prepared, it is helpful to pre-irrigate (which is preferable to irrigating after planting) so that the soil is uniformly moist. If the soil is not pre-irrigated, it is important to lightly firm the soil over the beans in the trench so that the soil is in close contact with the seed, otherwise germination may be slower and more erratic. If the soil is not moist, the crop should be irrigated immediately after planting. If the soil is prone to crusting, it may be necessary to irrigate again to help the seedlings emerge through the heavy soil.

Beans do best in a soil which has good aeration and drainage, such as a sandy or clay loam, but do not thrive well in heavy, cold, clay soil. The soil should be well worked and supplemented with organic matter to improve soil tilth, nutrition, and to encourage beneficial microorganisms. Green manure should be turned under at least four weeks before planting. Soil pH should be in the range of 5.8 to 6.5.

Sowing:

Common (bush and half-runner) beans: Beans are very frost tender and need a minimum average soil temperature of 65°F (18°C) to germinate well. Sow after the last frost-free date. Dark-seeded bean varieties resist rotting in cool soil, and can be planted when the soil temperature is as low as 60°F (16°C). Plant seeds ¾” to 1” deep, spaced 2 to 3” apart within the row and thinned to 3” apart. Bush varieties can be spaced in rows 18” apart. Though close spacing helps suppress weeds, too close spacing makes it more difficult to work the crop and to scout for bean beetles, and therefore minimum row spacing of 20 to 24” is recommended for most bush varieties. Semi-runners will need wider row spacing, at least 36” apart depending on the variety. The sowing rate for bush and half-runner beans ranges from 45 to 95 pounds of seed per acre depending on the variety and location.

Common (pole) beans: Pole beans bear later than bush beans and give higher yields. Pole beans grown commercially for seed in western states are grown on the ground without support, but in the Mid-Atlantic and South they should be grown on poles or trellised to reduce disease and insect problems. Poles should be at least eight feet high, and 36” apart. If poles are used, they should have a rough surface so that the vines can climb without sliding down the pole. Sow six to seven seeds, ¾” to 1” deep, about 6” out from the base of each pole. Pole beans can also be grown on tripods made of poles eight feet long. These are spaced about four feet apart center to center. Trellising is another option. Trellises are constructed by placing metal or wood posts eight feet apart with heavy-gauge wire strung between the tops of the posts. Trellis material is then suspended from the wire. If trellis material isn’t available, a twine trellis can be constructed by stretching twine between the posts about 6” above the ground. Twine is then woven, zigzag fashion between the top wire and the bottom wire. To prevent slippage of the twine toward the center, the twine must be lashed to the wire and bottom twine. Alternatively, the twine can be tied to the top wire and hung straight down and then tied to the bottom horizontal twine. The sowing rate for pole beans ranges from 20 to 40 pounds of seed per acre depending on the variety, location, and cultural method.

Lima beans: Lima beans need a growing season of about 3-1/2 to 4 months. Culture is similar to common beans, but the root system is more extensive and the plants need a wider spacing. Lima bean seed should not be planted until the soil temperature is at least 70°F (21°C) and preferably 75°F (24°C), or typically two to four weeks later than common beans. Avoid planting limas in soggy soil. Irrigating seeds after planting can cause considerable rotting of seeds. Highest yields of limas are obtained when spaced at 3” apart in the row. When sowing pole limas, sow five to six seeds at the base of each pole, about 6” out from the base of the pole. The sowing rate for lima beans depends on the variety, the thickness of the stand desired, the size of the seed, the location, and the culture method. Average sowing rates are as follows: bush limas, 40 to 60 pounds per acre; small-seeded bush limas, 60 to 90 pounds per acre; and pole limas, 30 to 40 pounds per acre.

Runner beans: Runner beans (both bush and pole types) are grown in a manner similar to limas, except they can be started earlier in the season. The sowing rate typically averages 60 pounds of seed per acre, but like limas, variety, location, growth habit, and culture method all affect sowing rate.

Cultivation:

Areas between bean rows can be weeded and tilled fairly deeply when the plants are several inches tall. Later tilling of the soil should be shallow to avoid disturbing the roots, and once the pods have formed, hoeing or tilling is not recommended, nor should it be necessary. A loose layer of straw mulch between the rows encourages predators such as spiders, and helps retain soil moisture. If the crop is irrigated from above, it should be done early enough in the day so that foliage is dry by evening, otherwise moisture on the leaf surface may encourage bean rust.

HARVESTING

Bean seeds are ready to harvest as soon as the pods are brown and dry. Most commercial bean seed production is done in the dry western states where pods can be left on the plant to dry until harvest, without fear of disease. Bean seed growers in the Mid-Atlantic and South are not so fortunate and have to pay special attention to the weather and the timing of harvest. Weather permitting, the pods are left on the plant to dry, but most growing seasons the weather is too humid or rainy to allow the pods to remain on the plants. Extended wet weather may cause the pods to become moldy, soggy, and useless and beans may sprout within the soggy pods. Any seed that is salvaged under these conditions will often be discolored, moldy, and of low viability. You might as well throw the seed out.

If you are fortunate to have dry weather, the pods can be left on the plant to dry, but if wet weather threatens the pods must be harvested before the rain. A single thunderstorm may not be a problem, but several consecutive thunderstorms over several days may be enough to cause problems with the seed. To avoid problems, I recommend harvesting pods as soon as they turn from green to yellow, or yellow-brown. During this stage the pod should be somewhat flaccid with no more than 10 to 15% green color present.

The partially dry pods are then brought under cover or indoors to complete the drying process where conditions can be controlled. The pods are spread out in a thin layer about 1 to 2” deep on tarps, sheets, screens, trays, or other suitable surfaces. At this point, the goal is to dry the pods as quickly as possible. Ideally, this should be done indoors in an air-conditioned environment, but this is not always feasible. If not possible to dry indoors, a shed or garage with good ventilation is another possibility. If a fan can be used to ventilate the space, all the better. The pods may need to be turned periodically. Once dry, the pods should cure for another two to three weeks. If drying in a barn or shed you will need to watch for rodents and take whatever preventative or control measures necessary.

At the end of the growing season, if frost threatens the crop, the entire plants can be pulled and hung upside down in a warm area so that the pods continue to dry. This allows the beans and pods to mature for several more days. Not all the pods will be salvageable, but a considerable portion of the harvest may be saved.

THRESHING AND WINNOWING

Beans should be fully cured before being threshed. During the curing process the pod appears dry, but the seed continues to lose water. The seed gradually changes from a rubbery consistency (when it can be bent and dented with a fingernail) to a hard object that can be shattered or broken. Though beans should be hard before being threshed, they are, nevertheless, a live organism subject to damage. Threshing is the process of using a mechanical force to release the seed from the pods. Threshing is a skilled art, whether done by machine or done by hand. Seed which has been subject to improper threshing may appear intact and normal, but may have small cracks or internal damage that produces seedlings with developmental disorders that ultimately lead to seedling death or stunted growth. Properly cured seed will be seed that has a moisture content high enough to prevent small cracks upon threshing, but low enough to prevent internal damage to the embryo.

Methods for threshing bean seed:

Following are some threshing methods that can be used for threshing several pounds to a hundred or more pounds of beans. There are a number of possibilities for threshing. The method of choice is related to the volume of seeds to thresh and the equipment available. Also choose a dry day to do the threshing: the lower humidity will increase the efficiency of the process.

- **Feed sack method:**
  The dried pods are placed in a large feed or grain sack and the opening is tied shut with a piece of twine. The sack is then placed on the floor or a cement slab where you can jog in place, twist, or dance on top of the sack. Turn the sack and shake the contents occasionally to redistribute the contents. Soft-soled shoes should be used for this because stomping on the seeds with hard-soled shoes could damage the seed. The idea is to apply just enough pressure to separate the seeds from the pods. You can also vary the routine by swinging the sack against a brick wall or down on a driveway. After most of the seed is threshed you can massage and twist the sack with your hands to break up the pods further.

  A commonly recommended method that I have not tried is to hang the sack from a tree branch and swing at it with a baseball bat.

- **Canvas ground cloth method:**
  A canvas ground cloth or plastic tarp can be used, but canvas is more durable. You can find a large canvas tarp in the painting section of many large home improvement stores. Simply dump the pods onto the tarp and jog around on them until the pods are broken up. Alternatively, you can beat the pods with a flail, but jogging on the pods might cause less seed damage.

- **Hand threshing method:**
  Threshing by hand is a good method for processing small amounts of seed. The pods can be either split by hand or placed in a plastic tub and wrung through your hands, in which case you'll want to wear gloves.

Methods for cleaning and winnowing seed:

- **Screening:**
  Most of the chaff can be removed from the seed by screening. Screens can be constructed from hardware cloth which comes in three-foot wide rolls available at hardware and home-improvement stores. Hardware cloth is available in 1/2", 1/4", 3/8", and 1/8" size mesh. The latter two sizes may be harder to find, but may be specially ordered. Hardware cloth can be mounted on a square made of furring strip, 12" on the side, which is the standard size for small seed-cleaning screens. For processing large batches of seed, hardware cloth can also be mounted on three-foot square, 2 x 4" frames. Beans and chaff are poured through the screens. Large chaff is left behind on the large-mesh screen and small chaff will pass through the small-mesh screen leaving the beans on the screen. Start with the 1/2" mesh screen to remove the rough chaff, and then progress to a smaller mesh size, as necessary. The 1/8" mesh screen is used to remove the "fines" (the small chaff), though winnowing will serve the same purpose.

- **Winnowing:**

  Winnowing is the process of removing chaff from the seed, chaff that is often the same size as the seed. It can be done several different ways. Regardless of the method used, it is often useful to spread a large tarp under the winnowing area so that seed accidentally blown out with the chaff can be recovered.

  - **Vacuum cleaner hose discharge method:** Some small hand-held vacuum cleaners (Hoover, for example) allow the user to mount the intake hose on the discharge side of the vacuum. This allows the user to direct a strong stream of air toward a large container of seed and chaff. A large stainless steel mixing bowl, 16" in diameter works well. This size bowl is deep and wide enough to hold several pounds of seed and the sides shallow enough to allow chaff to blow over the edges when air is directed over the seeds. It helps to stir the seeds with one hand while directing the hose with the other hand. While stirring the seed, the lighter chaff will float to the top and will be blown out by the air stream.

  - **Box fan method:** Seed can be winnowed by pouring seed from one container into another in front of a variable speed fan. A variation on this method is to spread a tarp in front of the fan and pour the seed slowly and directly onto the tarp. The fan will need to be elevated a couple of inches above the tarp. The light chaff will blow off the far end of the tarp and the seed and heavier chaff will blow to separate zones at different distances from the fan.

  - **I-Tech Seed Winnower:** This device is ideal for small-scale seed cleaning but is no longer being manufactured commercially. Fortunately the University of California at Davis maintains a Web site that offers plans for constructing seed winnowers and other seed processing equipment. This information may be viewed at http://agronomy.ucdavis.edu/ltras/itech. The electric seed winnower is the easiest to make: the only materials that are needed are plastic pipe and a squirrel cage blower. I would suggest modifying the device by running the fan motor from a variable speed rheostat so that you can control the fan speed.

  - **Clipper Office Tester and Cleaner:** This desktop-size machine is used by seed companies, seed growers, seed stores, and university labs for cleaning, sizing, and grading small amounts of seed. It retails for about $1500. Details are available at http://www.clipperseparation.com/clipperofficetester.htm, or by contacting the A.T. Ferrell Company Inc., 1440 South Adams St., Bluffton, IN 46714, or by phone at (800) 248-8318.

  - **Final inspection and hand-picking:** The last step in seed processing is to inspect the seed and to hand-pick any seed which is misshapen, stained by fungus, split, cracked, partly sprouted, or off-type. For a good batch of seed this step goes very quickly, but when seed is grown under wet conditions, considerable hand-picking is needed to remove stained seed. If the seed has been threshed too roughly there will be a number of seed with splits and cracks.

Seed yield:

Yield is dependent on variety, density of the planting, fertility of the soil, microclimate, weather, and other factors. An acre of beans raised for seed yields on average about 1,300 to 1,500 pounds of seed. A very good yield is 2,000 pounds. An average yield for an acre of lima seed is 1,950 pounds, up to 2,500 pounds for a very good yield.

Seed size and weight varies depending on variety and type of bean. An ounce of common beans contains 100 to 125 seeds per ounce, and limas 25 to 75 seeds per ounce.

The Federal germination standard for commercially grown common beans and limas is 70%, and 75% for runner beans. I set the standard for my own seed growers at 80% because I expect the seed to hold its shelf life through the next growing season.

Interestingly, I have found that many of the older varieties of beans seem to germinate slightly better than modern varieties when raised for seed under the same conditions. Curious about this, I contacted an official at the Virginia State Seed lab during the early 1990's and mentioned this. I was told that the germination standard for common beans was lowered at one point from 75% to 70% to allow for the lower germination of more modern varieties. In point of fact, I have a copy of the 1966 Virginia Seed Law which gives a standard of 75% for a list of older varieties and a standard of 70% for other newer varieties.

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.

SEED TREATMENT FOR BEAN WEEVILS

Seed that is not threshed and cleaned in a timely fashion may be ruined by bean weevils (*Bruchus obtectus*). Seed should be cleaned and threshed as soon as it is ready because it is easier to detect weevil damage in cleaned seed than when the seed is still in the pod. Weevils can be killed by freezing the seed for three days. Because the bean weevil is so prevalent in different areas of the country, this should be a routine precaution. Once seeds have been frozen they should be stored (see below) in airtight containers or in an environment free of weevils.

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 at least two weeks before threshing, and at least 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.

INSECT PESTS

Mexican bean beetle (*Epilachna varivestis*):

The Mexican bean beetle (MBB) is one of the most troublesome insect pests of beans. Here in Virginia I have learned to look for their emergence usually around the first week of June. At that time I begin scouting the crops looking for adults or larvae. Timely and frequent scouting is key to controlling this insect. MBB is easily controlled by a small parasitic wasp (*Pediobius foveolatus*) native to India, now raised in insectaries for control of MBB. Pedio wasps are introduced as soon as MBB larvae are spotted. If properly released, they control MBB the entire season. The Pedio wasp makes its entire living on MBB and can detect it from at least a mile, based on experiences with my own releases. Unfortunately it doesn't usually overwinter, though it did overwinter one year in Virginia. I order MBB from an insectary as soon as a dozen or so larvae are spotted on the plants. The locations of MBB are also flagged so that they can be released near the hot spots. The MBB can reproduce faster than the Pedio wasp when temperatures are cool, but by mid June and later, the temperatures are high enough for the wasp to significantly overtake the MBB. The only time I have not had good success was during one cool summer when the Pedio wasps were released later than they should have been. When the wasp (about the size of a pin head) parasitizes the MBB it lays its eggs in the larvae. Shortly thereafter the larvae become immobile and turn brown. When I see these on the underside of the leaves I know that the infestation will soon be under control. Of course no attempt should be made at this point to control the MBB larvae, but you can control the adults: larvae should be left alone because they may be parasitized. Depending on the source, the Pedio wasp costs about $20 per 1,000 wasps plus FedEx delivery. Some insectaries sell the mummies, the brown parasitized larvae of MBB. These are placed around the plants for later emergence of the adult wasps. I seem to get better control using the adult wasps. Adult wasps should be released either early in the morning, or at about dusk. In either instance, the foliage should be dry. The key to the success of this approach is early detection of MBB and timely release of the Pedio wasp.

The Mexican bean beetle can be controlled with pyrethrum and rotenone; however, I no longer use these natural pest controls on beans. Pyrethrum and rotenone are regulated materials for certified organic production: check with your certifier for specific regulations.

Bean weevil (*Acanthoscelides obtectus*):

Bean weevils lay their eggs on bean seed, producing larvae which develop and emerge through a small hole in the seed. Bean weevils can quickly destroy a batch of stored seed if the seed has not been inspected for a while. Beans can become infested in the field so it is important to harvest and process the seed promptly. Threshed seed should be bagged and stored promptly. For organic control see Seed Treatment for Bean Weevils above.

DISEASES

There are a large number of diseases that affect beans, though their prevalence is related to location (certain areas of the country), climate, weather, and types of insect vectors. Many of the disease problems can be controlled or reduced by practicing a three-year crop rotation. Only the diseases which are more serious in the Mid-Atlantic and southeastern U.S. are covered here.

Anthracnose (caused by the seed-borne fungus *Colletotrichum lindemuthianum*):

This disease may be common and widespread in the eastern and southern U.S., especially during periods of cool, humid, rainy weather which favors disease development. The plant can be attacked at any stage of growth and the disease spores are carried by wind, soil-splash from rain, gardening tools, and farm implements. The disease is characterized by black sunken lesions up to ½" in diameter (with diffuse margins) on the stems, pods, and cotyledons. Leaf veins on the under side of the leaf may turn black. During wet weather the spots may be covered with a salmon-colored ooze. The fungus overwinters in bean seed and residues of diseased plants. For this reason, proper cleanup of the gardens or field, and prompt composting of crops residues is important after harvest.

Rust (caused by the fungus *Uromyces phaseoli typica)*:

Bean rust is most common on mature plants and is characterized by white spots or flecks on the underside of the leaf which turn into rust-colored lesions after several days, followed by yellowing and drying of the leaf which later falls off. The symptoms mostly affect the leaves. The fungus overwinters on diseased plants left in the field. The disease can be controlled with sulfur dust but the disease can also be minimized by use of crop rotation and avoidance of overhead watering in late afternoon or evening. (Sulfur dust is an allowed material for certified organic production; however, check with your certifier for specific regulations.)

Powdery mildew (caused by the fungus *Erisphe polygoni*):

Powdery mildew usually appears late in the season and is common in the southern states and along the coast. Symptoms first appear as small, grayish-white powdery spots which later coalesce to cover the entire leaf. Young leaves may curl, yellow, and drop if the disease is severe. The disease spreads most rapidly when humidity is high. Though the disease can be controlled with sulfur dust, a small amount of disease on the leaves is not harmful. Avoid irrigating plants from above on overcast days or late in the day so that moisture has an opportunity to evaporate from the leaves.

Bacterial blights (caused by four different bacteria):

There are four different bacterial blights that affect beans. They all have somewhat similar symptoms and all are favored by wet weather. Most blights start as water-soaked areas on the leaves and stems. The spots later turn brown and coalesce and finally kill the leaf and injure the pod. The bacteria are spread by rain, wind, infected crop residues, and diseased seed. The four blights (listed in order of importance) are: (1) common blight (*Xanthomonas phaseoli*); (2) halo blight (*Pseudomonas phaseolicola*); (3) fuscous blight (*Xanthomonas fuscans*); and (4) brown-spot blight (*Corynebacterium flaccumfaciens*). Of the four blights, common blight is the most serious, and is favored by warmer temperatures: it is especially a problem in the Mid-Atlantic and South. Some bean varieties have tolerance to common blight, but none have a high level of resistance to this disease. In contrast, a number of bean varieties have resistance to halo blight and their use is recommended where possible. It should be cautioned though, that disease studies can be difficult to interpret: investigators often report differences in their own tests from year-to-year.

The most effective means of control is using seed from blight-free areas where fields are surface irrigated and rains are infrequent. Few areas of the country meet this requirement, for example areas of California and the Snake River Valley of Idaho. Another effective means of control is use of resistant varieties, but resistance to disease is often a matter of degree rather than an all-or-none phenomenon. For regional seed production based in the Mid-Atlantic and Southeast, it may be difficult or impractical to implement the first two control measures. Therefore, for our region, the first line of defense includes recognition of diseases symptoms, use of a three-year crop rotation, and timely removal of crop residues. If the residues are infected they should be buried. Crop rotation in itself may or may not provide the desired results, but is strongly recommended as a common cultural method. Additional control measures include the following: (1) avoid overhead irrigation if possible; (2) maintain air circulation around plants through use of weed control and wider plant spacing; and (3), don't work among wet plants. As a last resort, application of copper and sulfur-containing sprays can be effective in controlling bacterial blights though there may be a reduction in crop yield. These are allowed but regulated substances for organic seed production: check the OMRI listing for specific regulation details, and discuss your disease control plans with your certifier.

Mosaic (caused by three different mosaic viruses):

All three mosaic viruses are spread by aphids. Symptoms of mosaic are typified by some form of yellow and green mottling of the leaf between the veins which remain green. The infected leaves may be puckered, deformed, and rough in texture, and the shoot tips may die back. The disease is spread by contact of the leaves with each other, farm implements, and handling healthy plants after working with diseased plants. Aphids, which spread the disease, seem to be more of a problem where the aphids have become resistant to crops sprayed with agrochemicals. In an organic system where ladybird beetles flourish, aphid populations may not reach such high levels.