Organic Seed Alliance
Supporting the ethical development and stewardship of seed
PO Box 772, Port Townsend, WA 98368

# Principles and Practices of Organic Bean Seed Production in the Pacific Northwest

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## Crop History, Lifecycle, and Basic Biology

The common bean (*Phaseolus vulgaris*) is a member of the *Fabaceae* or legume family and is of New World origin. The wild ancestors of the modern common bean come from Central and South America. These ancestral types are found across a range of environments, from moderately hot, arid climates to humid lowland tropics and even into cooler upland areas of South America. The beans of this species grown in North America today are grown in a more limited temperate climatic zone. Modern agricultural varieties of snap beans and kidney beans as well as some navy beans and cranberry beans have a non-climbing (bush-type) habit. Most other agricultural varieties have a vining habit classified as either a type II (upright short vine) or a type III (floppy vine). These types are indeterminate in their growth habit, but are not climbing. Most navy and black varieties are type II, while most pinto, red, and great northern varieties are type III. Older varieties, landraces, and heirlooms are often indeterminate and climbing, and are referred to as "pole beans". The snap bean types, also called string beans, green beans, and garden beans, are grown for a harvest of tender young pods with immature seeds eaten as a fresh vegetable. While immature pods of any common bean variety were once commonly eaten, there are now thousands of varieties developed for fleshy pods with slow seed maturation for a crop that has become a vegetable mainstay in our culture. The term "snap bean" refers to the way in which fresh garden beans are broken or snapped by hand into short segments before cooking. In the bean seed growing regions of the Northwest these are called "garden beans" to distinguish from the more widespread dry beans or field beans. Whether for vegetable or seed, beans are produced as an annual crop maturing in one growing season. Bean seed crops may require a long season to mature (average 90-120 days) and must be planted early enough to mature and dry prior to fall frosts or rains. Commercial bean seed production is focused in the western region of the United States as the dry, long summers and arid climate create good growing conditions with lower disease pressure and a long season for maturation.

## Growing Bean Seed

### *Climatic requirements*

Common bean is a tender, warm season crop that requires warm, well drained soils for germination. Temperatures of 70°-80°F (21°-27°C) are preferred for optimum crop growth. Temperatures above 90°F or below 50°F during flowering may adversely affect pod set and seed yields. Most snap bean cultivars germinate best when soil temperatures are at or above 65°F (12°C.), but germination may be inhibited at temperatures above 95°F (35°C). There are instances when seed growers must plant with soil temperatures below optimum in order to fully mature a seed crop by the end of the season. Cultivars vary considerably in their ability to germinate in cool, moist soils and to resist common root rot organisms that can damage or destroy seedlings. Varieties with green cotyledons in the dry seed and white cotyledons at emergence have what is called the "persistent chlorophyll" or pc trait. Varieties with the pc trait, including most French filet types, green-seeded snap beans, and a number of modern snap bean varieties, are the most sensitive to cool soil conditions. Second in sensitivity are white-seeded dry and snap bean varieties, while colored seeded varieties are the least sensitive to cold and moisture stress at emergence. At Oregon State University, Oregon bush blue lake varieties have been selected for good germination and emergence in cool, wet soils.

## *Soil and fertility requirements*

Soil conditions and types may vary and still produce healthy plants and superior seed, but adequate drainage is essential as beans are sensitive to both moisture stress and water logging. Early plantings for long season varieties are best done on light sandy soils. Soils that easily crust should be avoided and irrigation and tillage managed to avoid crusting as seedling emergence may be impaired. All crop residues should be thoroughly incorporated into the soil prior to planting. Residues on the surface can interfere with seed placement during drilling and result in inadequate coverage of weeds with soil during an early cultivation. Incorporation of residue is additionally crucial in the availability of nitrogen (and other nutrients) to the young bean plants before their development of symbiosis with the *Rhizobium* bacteria. Some growers inoculate their bean seed with *Rhizobium* innoculant prior to planting. This practice can be particularly beneficial when producing on soils where beans have not been grown in the past or that are low in biological activity. It is important, however, for organic producers to use non-genetically modified sources of innoculant.

## *Planting and Cultivation*

Common beans are frost sensitive. The usual recommendation is to plant after all danger of frost is past. However, it is often necessary to plant a seed crop 7-10 days before the last anticipated frost either to allow time for full maturity and harvest prior to inclement weather in the fall or to avoid the heat of summer during flowering (see *Flowering and Pollination*). Soil temperatures do need to be warm, approximately 65°F (18°C), so the seed germinates quickly and does not succumb to root rots in cool soils. However young plants with fleshy cotyledons are more frost tolerant than mature bean plants and can tolerate a light frost soon after emerging.

Bean seed is commonly planted at an average depth of 1-1.5 inches (2.5-3.8 cm) below the surface of the soil after the press wheel has packed the soil. However, planting depths may vary according to soil moisture and local conditions. In the Willamette Valley of Oregon bean seed is often planted at ½ to ¾ inch depths while in southern Idaho 2-3 inch depths may be required to attain adequate soil moisture. Common beans for seed are routinely grown on 22 inch row centers with an in-row density of 6 to 8 bean plants per foot. Seed may be inoculated with *Rhizobium* bacteria prior to planting to enhance nitrogen availability. This may be particularly beneficial when planting on soils where beans have not been produced in recent years. Prior to planting beans soils are commonly pre-irrigated, allowed to dry to moderate soil moisture, planted, and then not irrigated again until seedling emergence. This avoids soil surface crusting prior to seedling emergence. Alternatively soil crusting is mitigated by a very shallow dragging of soil with a harrow prior to emergence. Post-planting irrigation is not recommended because the sudden shock of cold water causes mechanical damage to seed, leading to reduced germination and emergence.

Weed control is particularly critical in organic bean seed production to achieve optimum growth and prevent weed seed contamination in harvested seed. Control of hairy night shade (*Solanum sarrachoides*) is particularly critical as the berries of this weed are very difficult to remove from harvested seed. Weed management and cultivation practices may vary according to farm equipment availability, planting practices, and local field conditions. However, one successful method that has been used for weed control under organic production is as follows: Plant single rows into hills that are 6-8 inches (15-20 cm) high. After 4 to 5 days, when seeds have sprouted but the epicotyl is still 1 inch (2.5 cm) below ground, cultivate the hills for the first time using a drag harrow. The drag harrow will scrap off the top surface of each hill, exposing the first set of tiny weeds before they can become established in the bean rows. Even if done properly an occasional bean plant is lost, but it is well worth the effort to get the first “within row” weeds.

The next cultivation is done after the bean plant has emerged and has one set of true leaves. Set up two tool bars on a cultivating tractor. The first tool bar should have shanks with chisel points that are set as close to the bean rows as possible. These chisel points will disturb the soil, killing weeds close to the plant, as well as throwing some soil up onto the base of the plant to smother other weed seedlings.

Follow these shanks by a second tool bar with "duck feet" sweeps which will disturb the soil, kill weeds between the rows, and throw soil back onto the hills to rebuild them. Subsequent cultivations are done with knives that cut soil away from the bean plants, and sweeps between the rows to rebuild the hills. In addition to disturbing as much of the soil surface as possible to up-root or bury weed seedlings, it is important to create sufficient hills in order to facilitate undercutting the bean plants at harvest. Cultivation should be done with attention to avoiding major root disturbances as the plants get larger. Many growers do not use the described drag harrow method, but practice several cultivations and additionally walk the field to remove larger weeds once the canopy is closed.

## Flowering and Pollination

Nearly all modern agricultural varieties of common bean grown at higher latitudes are day-neutral in their flowering response. In other words, the length of day does not determine flower initiation and plants flower as soon as they are physiologically ready. Many tropical and some temperate dry bean varieties are day-length sensitive. Many tropically adapted common beans are short day plants and fail to flower until the days shorten in late summer. As varieties vary in flowering response it is recommended to grow a small plot of any new seed crop to see if it matures adequately in the region.

Common bean flowers have the shape and structure of a typical legume flower. Their petals are usually whitish, but may be tinged to deep violet to purple. There are five petals consisting of one large, oval banner or standard petal, two elongate keel petals that are fused together enclosing the stamens, and two wings. There are nine stamen filaments united into a sheath that surrounds the pistil with one stamen filament separate from the fused nine. Unlike other legumes, the style and keel petals of a bean flower follow an approximately 360° spiral pattern. This trait is one that taxonomically separates *Phaseolus* from all other genera.

Common beans are highly self-pollinated as the anther sacs are borne directly adjacent to the stigma (the receptive part of the female flower) and the pollen is normally released the day before the flower opens. Under most conditions the seed is self-pollinated before the flower opens and is accessible to insect activity. However, there are several situations that can lead to out-crossing between bean plants including: 1) When growing beans adjacent to areas with biologically diverse habitats for insects there is usually a higher and more diverse number of insect pollinators present. These pollinators may be able to get into flowers before they fully open either because the flowers are not completely closed (a genetic trait) or the insects may be able to pry the flowers open in search of nectar or pollen; 2) Variety differences of floral structures exist and some (particularly pole bean varieties) have longer pistils which extend further out of the flower making cross pollination more likely; 3) An increase in rate of crossing can occur due to a combination of excessively hot weather and the fact that some bean varieties are more sensitive to heat than other varieties. The pollen of many bean varieties can be damaged and non-viable if temperatures are too high at the time of flowering while the stigma will usually remain unaffected. There is genetic variation for this condition among bean varieties and the pollen of one variety may loose viability while another does not under similar conditions. If multiple varieties are being produced during a hot period it is possible that pollinating insects may move pollen from a fertile variety to another variety lacking fertile pollen and create unwanted crosses.

## Isolation Requirements

Isolation requirements can vary depending on location and type of production. If conditions are conducive to an increased rate of cross pollination (see *Flowering and Pollination*) then isolation distances should be increased. The common recommendations for isolation are that little or no isolation is necessary, and under most situations even with heat and ample pollinators there is only a small percentage of outcrossing that occurs. In commercial production a break of 10–15m (30–45ft) is recommended with a taller crop barrier, such as several rows of corn or sunflowers, to deter pollinator movement. For foundation or stockseed where genetic purity is critical this break should be increased to 50m (150ft) with a tall barrier crop as well. Vining or “pole” varieties of common bean are more prone to outcrossing than bush varieties and the recommended isolation distance should be doubled.

## Genetic Maintenance and Improvement

### *Population size*

Common bean is a self-pollinated species that has evolved to tolerate inbreeding. As such any commercial seed crop is ample in scale to avoid inbreeding depression. Population size becomes an issue however from a genetic conservation perspective when saving seed from a small population or conducting a selection within a larger population. In addition to the importance of genetic preservation diversity is important when breeding or selecting varieties for adaptation to varied environmental conditions. While maintaining diversity may be desirable in these instances, it must be remembered that routine selection, therefore narrowing the population’s diversity, is critical in order to avoid unwanted off-types and maintain integrity of a commercial variety (see *Selection criteria*). Diversity will naturally arise in a population that is not routinely selected and may include undesirable traits such as fibrous and stringy pods resulting in an inferior commercial product. The following recommendations are intended as a guide to ensure preservation of desirable traits for conservation and breeding purposes.

Most modern bean varieties are derived from a single elite plant that exhibits all of the characteristics of the breeder’s ideotype. Seed multiplied from this single plant is what plant breeders call a “pure line” and the subsequent variety is a “pure line variety.” A variety derived in this way has very little inherent genetic diversity and therefore seed saved from less than 10 true-to-type plants is sufficient to ensure all of the variety’s genetic diversity is conserved.

When reproducing an older bean variety, the question of genetic diversity needed to maintain the genetic breadth of a variety is more complex. The older commercial bean varieties from the 1920s through the 1970s have now been around long enough that they have probably widened their genetic variability since they were first released as pure line varieties. For this reason it is wise to save seed from at least 50 representative plants whenever reproducing an older commercial variety.

Lastly, there are also older farmer varieties, land race varieties, and heirlooms. These populations often have more genetic variation than commercial varieties. As this variation may be very important in the environment or the cultural context in which these varieties are used, it is important to maintain this potential genetic breadth by saving seed from at least 100 representative plants (200 if the variety is a highly variable land race).

### *Selection criteria*

Selection, or roguing, refers to removing unwanted off-types in the population. Routine selection is critical to maintain a variety's trueness of type and avoid the appearance of undesirable traits. In commercial seed production, selection should be toward the seed company's variety description or the breeder's original vision of the variety. Selection in all varieties should include quality traits such as tender pods in snap beans. Additionally, it is critical to select against disease in bean crops in order to produce quality seed, minimize risk of seedborne diseases, and select for or maintain a cultivar's disease resistance (see *Disease*).

There are very few stages in snap bean growth in which differences within a variety are apparent. If the seed is planted into uniform soil tilth and moisture then it is possible to perform early selection for speed of emergence, uniformity of the stand, and overall vigor, which are essential traits for organic production. By routinely roguing out late emerging, low vigor seedlings there will be improvement over cycles of selection for these traits. For some traits, like leaf shape, color, and plant stature it is possible to evaluate the plant and rogue it to type before flowering has begun. Vining plants in a non-climbing, bush variety should be selected against. Flower color, placement, timing and duration of flowering can all be selected during flowering. Pod characteristics such as color, shape, and length are also notable and should be selected.

For snap beans it is particularly important to select against plants with off type pods. Off-types may have altered pod shape (oval rather than round), increased pod fiber, or the presence of strings in a stringless variety. Pods need to be examined at the green pod stage. High fiber pods are often recognizable because they are smaller, oval in shape and curved. Stringy pods can be identified by pressing on the "spur" (the remnants of the style). "Hardpoint" spurs indicate strings while soft, flexible spurs are associated with stringlessness. Off-type and normal pods may be found on the same plant, so it is important to examine all of the pods on every plant.

## Harvesting

Proper timing of harvest is important in order to produce high quality bean seed that is fully mature, has a high germination percentage and has maximum storage potential. Each variety has its own specific harvest timing and while this makes overall recommendations for gauging cutting, curing, and threshing difficult, there are basic signs that indicate maturity. The initial signal that the crop is ready to cut is the relative maturity of the pods and their color at or near the time when they are breaking, or when they first turn yellow, mahogany, or "buckskin" in color but haven't gone to the tan, papery shade. Maturation to the brown, papery stage increases danger of seed shattering during harvest. Pods should generally be yellow at harvest in order to mature properly in the windrow, but the exact desired color may be variety-specific. The crop should be cut when approximately 70 to 80% of the pods on the crop are of the desired color and point of breaking. Typically, the stems of the crop are undercut mechanically just below the soil surface during the early morning when there is dew on the plants, and may be left in place for a day before windrowing. The next day the plants are raked into windrows, preferably with some dew on the plants to prevent shattering or damaging the pods.

Alternately, some modern machinery can mechanically cut and windrow in one pass. Depending on weather conditions the windrows should cure in the field for at least 10 days to two weeks, with a possible turning of the rows near the halfway point. Threshing of beans is best accomplished during the heat of the day when the pods are brittle and easily cracked. Seed should then be further cleaned to separate it from any plant debris that may be moist. If the seed is not sufficiently dry it may require additional drying before being stored for a final cleaning and conditioning. Physical mixing of seed varieties can be a source of variety contamination. Care should be given to thoroughly clean out harvesting and cleaning equipment between working with varieties.

## Diseases of Bean Seed Crops

The most challenging and important diseases for seed growers are the seedborne diseases that may transmit the destructive pathogen via the seed to the next generation of the crop. It is important to manage non-seedborne diseases, but identifying and eliminating the seedborne diseases is crucial to maintain disease free seed stocks. Routinely eliminating any exceptionally diseased plants is also important for maintaining or improving the overall horizontal (or non-race specific) resistance to each particular pathogen. Although it may take a number of cycles of selection to significantly increase the level of resistance in a variety, this slow methodical approach can show improvement over time.

Common beans grown in the Intermountain Northwest are routinely monitored for six seedborne diseases. Four of these seedborne pathogens are bacterial, two of which are caused by two pathovars (pv.) of *Pseudomonas*; halo blight (*Pseudomonas syringae* pv. *phaseolicola*) and bacterial brown spot (*P. syringae* pv. *syringae*). Both thrive in wet, cool conditions and have become increasingly troublesome in the past decade. Both of these pseudomonads can be devastating to bean producers in more humid parts of the country so it is imperative that seed be clean of these pathogens. The other two bacterial seedborne pathogens are bacterial blight (*Xanthomonas campestris* pv. *phaseoli*) which is more prevalent in warmer environments and bacterial wilt (*Curtobacterium flaccumfaciens* pv. *flaccumfaciens*) which can become a problem under warm to hot, dry, drought conditions.

The primary viral disease that can be transmitted via seed is bean common mosaic virus (BCMV) and bean common mosaic necrosis virus (BCMNV). BCMV has been known to affect common bean for more than 100 years while BCMNV has been known since the 1960s. Both viruses have spread worldwide. While affected plants are usually not killed (other than in the case of the I gene described below in the disease description), this virus can significantly reduce yield and quality of the vegetable and seed crop. Although BCMV does not cause visible symptoms on the seeds, 1-3% of seeds from infected plants can carry the virus to the next generation.

Anthracnose, caused by *Colletotrichum lindemuthianum*, is a key fungal disease known to be seedborne on common bean. This disease becomes established and is spread during wet periods with high relative humidity and moderate temperatures of 62° – 80°F (17° – 27°C). It is not particularly problematic in the seed growing regions of the western United States, but is a recurring threat in eastern and northern regions.

Common preventative measures that should be followed for management of all diseases of beans include the following: 1) A minimum of 3 year crop rotation from all legume crops is recommended in bean seed production. Crop rotation is important for all diseases as they may overwinter on crop residue, but particularly crucial for those that may be soil borne. 2) Use wide row spacing and orient rows in the direction of prevailing wind to maximize air movement through the canopy, which reduces the humid field conditions favoring many diseases. 3) Bean seed crops should be regularly monitored for disease and all diseased plants carefully removed from the field and destroyed to prevent spread of the disease. Removal of these infected plants should be avoided early in the morning or at other times when foliage is wet. 4) Similarly, avoid cultivation when the crop is wet as this may readily spread disease, or when the crop foliage is tall enough to be mechanically damaged, thereby increasing susceptibility to infection. 5) Overhead irrigation should be avoided when possible to avoid disease development and spread. If overhead sprinklers are used then time the irrigation set to end by mid-morning which allows the canopy to dry with the afternoon sun. 6) Maintain clean equipment to prevent spread from one field to another. 7) Harvesting early pods as vegetables and reserving later pods for seed harvest is inadvisable as disease pressure tends to increase on later maturing pods. Additional crop specific recommendations are mentioned below with descriptions of the diseases, and when possible plant varieties with resistance to one or more diseases.

There is a well-established bean seed industry in states such as Idaho and Eastern Washington in part due to the arid climate and low disease pressure. In Idaho, bean seed is certified as meeting certain quality standards. Growers follow specific guidelines to produce certified seed which insures certain disease management and varietal purity protocols are followed. For more information about seed certification in Idaho visit the Idaho Crop Improvement Association at www.idahocrop.com.

## *Fungal Diseases*

Anthracnose (*Colletotrichum lindemuthianum*) – Seedborne
Early stages of infection on plants are observed as elongated dark brown areas on the petioles and along veins of leaves. Infected pods have small (1/8”) round, dark spots (cankers) with sunken centers. Infected seed may or may not have visible symptoms depending on the stage and degree of infection. Advanced symptoms on seed may include shriveling and discoloration. As the disease is harbored under the seed coat, it is difficult to treat with seed treatments. Infection is favored by cool, wet conditions. Spores are produced in the centers of lesions and are dispersed by rain or splashing of irrigation water. *C. lindemuthianum* overwinters on crop residue or seed. The disease is prevented by maturing and drying the seed crop in a warm, dry environment. Multiple races of the pathogen exist, and some commercial cultivars have been developed with resistance to individual races.

White Mold (*Sclerotinia sclerotiorum*) - Seed lot contaminant
Although not seedborne, white mold can be devastating to both vegetable and seed crops of beans. The disease is observed as a progressive rot of stems, pods and petioles usually accompanied by a white, cottony fungal growth over the surface of infected tissues. Affected plants may wilt due to girdling of infected stems. Long leaf wetness periods and moist soil surface conditions promote infection, with the bloom being the most critical period for disease initiation. The disease is primarily soil borne and overwinters in the soil as sclerotia, which are long-lived resting structures that germinate to produce spores. Crop rotations of at least 5 years are recommended in fields with a history of white mold. Culturally, allowing the soil surface to dry between irrigations and avoiding overhead irrigations, especially in the afternoon, results in slower disease development. Because of improved canopy air flow, bean cultivars with an upright architecture tend to show fewer symptoms.

## *Bacterial Diseases*

Halo blight (*Pseudomonas syringae* pv. *phaseolicola*) - Seedborne
Symptoms are diverse, but usually begin with water-soaked spots on leaves, stems, and pods in the early stages of infection. Later a yellowish green halo-like circle (approximately ½ inch in diameter) develops around the spots. Seeds from infected pods may appear shriveled and/or discolored; however, seeds may be infected and not exhibit symptoms. Multiple races of the disease exist and resistant varieties have been developed for both race specific and general (horizontal) resistance. Red Mexican and Pinto classes of dry bean are generally considered more resistant. Varietal selection and development of resistant varieties have potential as a disease management strategy.

Bacterial brown spot (*P. syringae* pv. *syringae*) - Seedborne
Symptoms can appear similar to halo blight especially in the early stages of infection with small, water-soaked spots that are particularly visible from the underside of young foliage. Spots may also develop a similar greenish-yellow border, but as they develop become more of a brown spot. The brown spot may fall out of the leaf as dead tissue leaving holes on the leaves. Infected pods may appear twisted and have brown water-soaked spots. Leguminous weeds and cover crops (vetch) can serve as inoculum reservoirs. Bacterial brown spot is more of a problem in lima beans than in snap beans.

Common bacterial blight (*Xanthomonas campestris* pv. *phaseoli*) - Seedborne
Symptoms first appear as small water-soaked spots on leaves between leaf veins, on leaf margins or on pods. Spots eventually dry, become brown and may extend across the leaf surface causing leaves to tatter in the wind. Lesions on pods may turn reddish-brown and contain a slimy exudate. Dried exudate leaves a glazed appearance. Infected pods may shrivel and seed may be either shriveled, discolored or non-existent. The disease overwinters in seed or plant residue and persists for long periods on seed. The pathogen is spread readily by wind, rain, irrigation splashing, feeding insects or contact with contaminated machinery. Seeds may be infected either through vascular colonization or from external lesions. Infection and development of the disease is favored by wet, warm weather. Crop rotations are recommended as well as incorporating or destroying crop residue. Several cultivars of kidney beans are highly susceptible to this pathogen.

Bacterial wilt (*Curtobacterium flaccumfaciens* pv. *flaccumfaciens*) - Seedborne
Infected plants wilt readily during periods of drought stress due to the pathogen blocking water transport in the vascular system. Symptoms may also include interveinal necrotic lesions with yellow borders. These symptoms may be confused with common bacterial blight, but appear more irregular. Favored by hot, dry, drought conditions the pathogen may also spread readily by hail damage to leaves. The disease was more prevalent in the 20th century up until the 1970s, and has more recently re-appeared in portions of the Midwest and Northern regions including Nebraska, North Dakota and Western Canada. Resistant varieties exist, but starting with disease-free seed and practicing 2-3 year crop rotations are recommended.

## *Viral Diseases*

Bean common mosaic virus and bean common mosaic necrosis virus (BCMV & BCMNV) - Seedborne
Both viruses were originally thought to be different strains of the same virus, but they are now known to be genetically distinct. While BCMV co-evolved with bean in the New World, BCMNV is indigenous to Africa, with bean becoming a host when introduced into the continent about four centuries ago. On susceptible plants with both viruses, infected leaves exhibit a light green-yellow and dark green mosaic pattern and leaves or pods may be malformed. Infected leaves may also be cupped, puckered, blistered, distorted and curl downward. Young plants infected may be stunted and spindly. The viruses are seed-transmitted and spread during the

growing season primarily by aphids. Necrotic symptoms in the form of black root may occur on varieties possessing the I gene. Certain BCMV strains may cause black root when growing temperatures are above 90°F (30°C), whereas BCMNV can cause black root at any growing temperature. While varieties with the I gene succumb to black root, the virus cannot replicate or be transmitted in these plants, thus, I gene varieties cannot condition seed transmission of the viruses. For management purposes in seed certification programs, both viruses are treated in the same manner. BCMV and BCMNV are widespread occurring worldwide anywhere beans are grown. Management of aphid populations is recommended. Resistant varieties exist. These diseases are targeted in certified seed programs.

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## Authors

Completed 2007
Dr. John Navazio, Organic Seed Alliance
Micaela Colley, Organic Seed Alliance
Matthew Dillon, Organic Seed Alliance
PO Box 772, Port Townsend, WA, 98368
(360) 385-7192

Pictures courtesy of Matthew Dillon (OSA), Judy Brossy (Ernie's Organics) & Dr. James R. Myers (Oregon State University)

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