



Organic Seed Alliance

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

Principles and Practices of Organic Radish Seed Production in the Pacific Northwest



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Crop History, Lifecycle, and Basic Biology

Radish (*Raphanus sativus*), one of the oldest vegetable domesticates, was originally cultivated in China. The ancestral form of radish was probably closely related to the modern green- and red-fleshed Chinese radishes that are still in favor across Asia today. These older types are true biennials requiring a period of cold treatment or vernalization to initiate flowering (bolting) and produce seed. This is still true of all of the larger types including Winter Radishes, Black Spanish, and Daikon. The modern, small, round- and icicle-shaped types that come in shades of red, pink, white, or violet have had most of their vernalization requirements bred out of them. These types can be grown for seed as annuals if they receive a minimum number of cold treatment hours (less than 100 hours below 58°F/16°C) during the short 30 to 40 days it takes to develop a harvestable radish.

Growing Radish Seed

Climatic requirements

Radish is a cool season vegetable crop. For seed production, superior roots are best formed at temperatures that rarely exceed 80°F (26°C). During seed set and maturation however, radish seed crops may tolerate slightly higher temperatures. Radish seed is successfully grown in Northwestern locations like the Treasure Valley of Idaho, the Columbia Basin of Washington, and the Willamette Valley of Oregon, where summer temperatures often exceed 90°F (32°C). It should be noted that temperatures above this can reduce seed set, as the stigma may dry out causing the pollen to desiccate and not germinate properly. The formation of both the embryo and endosperm may also be affected at these temperatures, reducing the size and percentage germination of the seed.

Soil requirements

Radishes require higher soil tilth and fertility than most other vegetable crops. To insure the development of well-shaped roots that are a true

reflection of a variety's potential, it is best to grow the roots on a lighter soil, preferably a sandy loam, silt loam, or high organic matter soil. These soils, along with adequate moisture and fertility will promote even, unchecked growth. In heavier soils with uneven watering and poor fertility, the roots will often have rougher exteriors with many off-shapes, making selection difficult in breeding programs. As all seed crops are flowering crops, they require adequate phosphorous availability to maximize flowering and therefore reproductive capacity and subsequent seed yield. Soil fertility should be adequate, but not excessive. Radishes need a steady supply of nutrients through both root and flower production, but too much nitrogen will cause excessive vegetative growth, limiting flower production and seed set.

Planting

As with other root crops, radish varieties can only be properly maintained for trueness to type if they are grown using the “root-to-seed method” which allows for selection of the roots before seed production begins. The radish roots, or “stecklings”, are first produced by planting the seed in a “root nursery” in much the same way that a commercial radish vegetable crop is grown. With this method, roots are then pulled from the ground at edible maturity, selected based on root morphological characteristics (appearance) and then replanted (see picture below) in a different field at a wider inter- and intra-row spacing to provide adequate space for the subsequent reproductive stages that lead to a seed crop. It is best to avoid planting before the occurrence of environmental conditions that support vigorous root growth, thereby avoiding “growth checking” which may alter the appearance of the roots.

Alternately, using the “seed-to-seed method” doesn't require pulling the crop and replanting. Simply plant the crop sparsely in the row and thin back the rows to an appropriate seed production spacing (see *Spacing*). This method should only be used if the grower knows that the seed lot that they are starting with is of excellent genetic standing with a high degree of uniformity in all of the important phenotypic characteristics. It can

take as few as two to three consecutive seed to seed generations for some varieties to become irregular and non-uniform.



Small, Round and Icicle Types:

The seed of modern, small, round and icicle types of radishes produced in the Pacific Northwest are planted in mid-spring when temperatures and day length are sufficient to produce rapid root growth and quality roots. The nursery can be planted anytime from mid-March till mid-April depending on location.

Roots should be pulled and selected at maturity (see *Selection*). Once selected the roots may be planted immediately or stored in cool, high humidity conditions. Vernalization requirements, necessary for flower initiation (bolting), are almost always met during the month of growth in mid-spring when they accumulate time of exposure to cool temperatures almost every night and sometimes during the day. In commercial seed production, the roots of these small-type radishes are often stored in a cooler at 35–42°F (2–5°C) for approximately 7 to 10 days. This insures that all of the radish roots in the population receive adequate vernalization so they will bolt swiftly and uniformly upon replanting. This also contributes to the likelihood that all of the plants within the population will cross-pollinate more evenly, as they will flower closer to the same time, and the seed will more uniformly.

Chinese, Black Spanish, and Daikon Types:

Larger Chinese, Black Spanish, and Daikon radishes are true biennials that require more extensive vernalization than the small types; however, vernalization requirements vary by variety. Some may be produced by spring planting early enough (by late March) to acquire adequate vernalization, while others are best seeded mid-summer (late July) and overwintered. In most Pacific Northwest locations, the overwintered roots must be dug up and stored as they will freeze in the winter. Some varieties may prematurely produce a flower stalk before producing a marketable root when spring-planted. If root selection is required, it is preferable to plant these types in mid-summer (late July), dig and select the roots in the fall, store them through the coldest, wettest period of the Northwest fall and winter (November through January), and replant them as the day length increases in February. They will bolt readily as spring arrives and seed will be ready to harvest in mid- to late-summer, well before the first rains of September.

Spacing

Optimum spacing of a radish seed crop is a debated topic. Fully flowering radish plants, even those grown from petite, red types, can produce a plant that can reach 6 feet tall and 3 feet in circumference. Some growers plant at a wide spacing of 18 inches within the row and 4 feet between rows (row centers). This allows the plant to reach much of its seed bearing potential for maximum yields per plant in the field. The wider row spacing may be preferred as this will increase air flow through the crop, reducing disease pressures.

Alternately, some radish seed growers plant radishes as densely as 4 to 6" spacing within in the row and with row centers that are 22 to 26" apart. This tighter spacing can be achieved by transplanting roots at this density from the root nursery in the root-to-seed method or by direct-seeding very sparsely at this row spacing and then thinning the roots in the row to the appropriate spacing for the seed-to-seed method. With these higher density plantings, the yield per plant

decreases but the overall yield per row foot may be comparable overall (or higher) as there are many more plants per row. Denser planting can prevent lodging and damage from wind in areas where this has the potential for being a severe condition at harvest time. The denser row spacing also has the benefit of fitting more roots within a given area, thereby increasing the population size.

Flowering and Pollination

Radish is a cross-pollinated species with perfect flowers. It is pollinated by a variety of pollinating insects attracted to the abundance of flowers over an extended blooming period. As with most other cultivated members of the Brassicaceae family, radish is self-incompatible (i.e., each plant is unable to pollinate its own flowers). Therefore, each pollination event comes from an outcross between two different radish plants of the same population. Initiation of flowering (bolting) in radish is not day-length sensitive, but most radishes do require some degree of vernalization to induce flowering.

Isolation Requirements

As a cross-pollinated species radish can cross easily from one radish type to another. Wild radish, *Raphanus raphanistrum*, is a common weed in the Pacific Northwest and will cross with domesticated radishes. Isolation distances of at least one mile should be maintained from any other radish population if grown in an open landscape with few natural barriers. If barriers in the landscape are present, like forests, hills or large buildings, then it is possible to grow a radish population within 0.5 miles of another radish population with little chance of crossing. Isolation distances for seed production should also be increased if the nearest radish production field is of a completely different type. For example, if growing a round red type while another grower in the area is growing a Daikon type, then the isolation distance should be increased to two miles in an open landscape and one mile in an area with ample physical barriers.

Genetic Maintenance

Population size

The extreme outcrossing (cross-pollination) of radish is ideal for maintaining adequate genetic mixing in a diverse varietal population. It is imperative to keep the level of inherent diversity in each variety intact when producing seed in order to avoid inbreeding depression. Seed should be collected from a minimum of 120 to 200 plants in any commercial radish seed crop.

Selection criteria

The practice of genetic selection of any crop is related to the needs of the farmers in a particular area, the environmental pressures of the production region, cultural practices, and market demands. While breeders normally concentrate on traits for the farmers who will grow the crop as a vegetable, it is also important to remember that it is possible to select for traits important in seed production. Therefore, when developing varieties for organic systems selection criteria should include traits that are necessary for both the organic vegetable farmer and the organic seed producer. Selection should be done at several points in the life cycle, including at the seedling stage, the market or eating stage, and during flowering so as to maximize seed yield.



When approximately 80% of the roots in the root nurseries are of marketable size, the roots should be pulled and placed neatly on the beds for evaluation. Once the roots have been pulled for

selection, it is best to keep them out of direct sun until replanted. Root selection on a cloudy, cool day is ideal. Selecting roots is best done with good knowledge of what the “norm” is for the phenotype (appearance) of each variety. Selection to a standard varietal type is the major objective in commercial production of established varieties. If a variety is adequately uniform at the outset of your seed production endeavor, then you can expect to discard ~20% of the roots at this stage in order to simply maintain varietal quality. If, instead, the variety is not uniform due to lack of prior selection, then expect to select out at least 50% of the roots as off-types (see picture below). Selection for improvements is always best done at the market stage.



Radishes are commonly selected based on the following criteria in the course of seed production:

Seedling vigor:

Seedling vigor and early robust growth are important to organic growers as these traits affect weed competition, disease resistance, and overall plant health. These traits can be improved over several cycles of selection. Beyond selecting for the quickest or earliest germinating plants, early selection should include recognition of shape, size, color, and ability of the seedlings to grow under less than optimum conditions. This early selection should occur soon after emergence, and is best coupled with initial hoeing and thinning of the plot.

Leaf size and shape:

While many growers do not pay attention to the leaves of radish, uniformity and quality of leaf in a radish variety tends to make more attractive bunches. Radish tops can range from 4 to 8” tall in both round and icicle types (even taller in winter types) so it is important that selection for height be done routinely. Radish tops can also vary between strap leaf and the lobed, cut leaf forms.

Root size and shape:

Each radish variety has a distinct shape that is often somewhat different from other varieties and should be maintained. Select against off-type shapes and roots that are significantly smaller or larger. Shape can be quite fluid in radish, and off-types (see picture below) will appear in each generation and must be selected against to maintain a good planting stock.



Root color:

Color variation in roots can be caused by previous outcrossing with a different colored variety, or because of inherent genetic variation. Regardless, roots should be selected for uniform color if the variety is to be maintained true to type. The ability to deepen the color is also possible, although this requires growing a large enough population to find a couple hundred roots of a darker hue to start a new vigorous population strain.

Harvesting and Cleaning

Seed maturation and harvest

Radish seed crops mature in approximately 150 days depending on variety, climate, and planting date. Radish seed is ready to harvest when about 60 to 70% of the seed pods turn from green-yellow to brown and lose their fleshy appearance, becoming papery thin and light. Plants are first cut above ground either mechanically with a drape-like swathe or by hand with a machete.



The plants are then placed in a windrow to cure in the field for 10 to 14 days. Unlike many other Brassicaceae crops radish pods do not shatter easily and only slight losses of seed occur during swathing and windrowing of the crop. The pods do not crack open readily and should be allowed to dry thoroughly to become brittle before attempting to thresh them. Combines or stationary threshers with rollers that can be set to effectively crack, but not crush, the pods are most efficient. (See photo of seed thresher in right column.) Threshing can be done without machinery on a small scale by stomping on or driving over the pods.

Seed cleaning

Once threshed, radish seeds may be separated from the pods, chaff, and debris by screening and winnowing the seed. Seed cleaning screens are numbered by number of 64ths of an inch size holes. Seed of most varieties may be separated by using a 9 or 10 size screen which allows the seed

to pass through the screen while removing larger chaff. A 5 or 6 size screen may also be useful to retain the seed and allow smaller debris to be removed. If the chaff is adequately dried, much of it should be lighter than the seed and may also be removed by winnowing (separating by weight), by either dropping the material in front of a fan by hand or using a gravity table.



Diseases

Several fungal and bacterial diseases are prevalent in radish seed production areas in the Pacific Northwest, particularly those that are favored by the wet conditions west of the Cascades Mountains. Due to the commercial demand for clean, pathogen-free seed, growers must pay particular attention to management of seedborne diseases. In organic production, the lack of approved pesticides and fungicides necessitates preventative management and non-chemical control measures. Routinely eliminating any exceptionally diseased plants in the field is important, not only for reducing incidence of infection, but for maintaining or improving the overall horizontal (or non-race specific) resistance to particular pathogens. 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 lead to improved resistance over time.

Critical seedborne and seed transmitted diseases which should be carefully monitored in radish

seed crops grown in the Pacific Northwest include the fungal diseases Alternaria leaf spot (*Alternaria brassicae*, *A. brassicicola*, and *A. raphani*) and black leg (*Leptosphaeria maculans*, anamorph *Phoma lingam*), and the bacterial diseases black rot and bacterial leaf spot (*Xanthomonas campestris* pv. *campestris* and *X. campestris* pv. *raphani*). Starting with seed free from these pathogens is the first step in disease prevention. As all of these diseases are favored by moist conditions prevalent west of the Cascade Mountains in the Pacific Northwest, avoiding overhead irrigation aids in prevention or in minimizing spread of these pathogens in the crops. Orienting rows and increasing row spacing to increase air flow through the canopy can also reduce disease development by reducing humidity and allowing the foliage to dry out quicker after rains or irrigation. Burying crop residue and controlling cruciferous volunteers and weed species are important as many foliar diseases persist and overwinter on plant tissue and debris. The pathogens listed above are not true soilborne pathogens, i.e., the pathogens will only persist in or on soils in host residues. Incorporating residues into the soil will promote more rapid decomposition of the residues than if the residues are left on the soil surface, reducing the duration of survival of the pathogens in the soil. Other diseases caused by true soilborne pathogens, i.e., Fusarium wilt and Verticilium wilt, necessitate even longer rotations. For this reason, a minimum 4-year rotation from all brassica crops is recommended. Additional disease-specific prevention or treatment measures are mentioned below, with accompanying disease descriptions.

Fungal diseases

Alternaria leaf spot, gray leaf spot or black leaf spot (*Alternaria brassicae*, *A. brassicicola*, and *A. raphani*) – Seedborne

Alternaria leaf spot is caused by any of three *Alternaria* species, all of which cause similar symptoms on radish. The host is susceptible at all stage of growth, with cycles of infection favored by frequent and long periods of leaf wetness. On seedlings, stem lesions (dark spots) can result in seedling death. On leaves, lesions are tan, brown,

or black spots of variable size; as they expand, lesions may be surrounded with a yellow halo, and lesions centers may show sooty black, concentric rings resulting from spore production. Symptoms usually show first on lower, older leaves. Lesions on flower stalks and pods are typically elongated compared to the rounder lesions that occur on leaves; infections on flower stalks also may allow bacterial soft rot to enter the stem, causing it to die prior to seed formation. Diseased pods may be distorted and dry prematurely, or be prone to shattering. Seeds in diseased pods may not form, or may become shriveled or blemished. Seedborne *Alternaria* can occur as mycelium growing under the seed coat, or as spores on the surface of the seed. Removal of infected leaves may slow progression of the disease. Burying crop debris is important as the pathogen overwinters on exposed plant tissue. Hot water treatment of seed can be an effective seed treatment.

Black leg (*Leptosphaeria maculans*, anamorph *Phoma lingam*) – Seedborne

The disease is caused by *Phoma lingam*.

Symptoms are light-brown, oval to round spots that enlarge to become grayish-tan, frequently occurring near the bases of stems. Small black dots (fungal fruiting bodies called pycnidia or perithecia, depending on the stage of the fungus that is developing) form in the centers of spots (lesions); identifying these fruiting bodies is important for diagnosis of this disease, as this disease can readily be confused with ring spot, another pathogen of crucifer crops caused by *Mycosphaerella brassicicola*. Black leg affects both foliar and crown tissues; wilted leaves are often a secondary symptom of severe stem and crown lesions. The fungus overwinters in crop debris or infected seed, with dissemination of spores occurring through splashing rain, irrigation, or wind. The fungus can survive for up to three years in the soil and can be seedborne. Disease development is favored by moist conditions, with greater severity in years with frequent rainfall in late spring and early summer. Avoid planting next to a field that has had crucifers in the past year; remove cruciferous weeds; incorporate crop

debris; and avoid composts that may carry the pathogen as the disease may persist in the soil in decomposing host residues. Choose planting sites with good drainage. Hot water treatment can be an effective seed treatment.

Black root (*Aphanomyces raphani*)

The disease appears as brown to bluish-black discoloration in cracks or wounds on the side or top of roots. Root growth slows as symptoms progress; diseased roots become increasingly black and may cause girdling of the entire root. These black areas of discoloration extend inward in radial streaks. Choose planting sites with good drainage and avoid over-watering. Practice good field sanitation. Varieties vary in susceptibility, with ‘White Icicle’ being very susceptible. *A. raphani* is not seedborne, but resting spores of the pathogen can be moved in mud on tires or other equipment, and in trash or dirt in poorly cleaned seed.

Cercospora leaf spot (*Cercospora cruciferarum* and *C. atrogrisea*)

Cercospora leaf spot on radishes causes circular to angular grey or off-white lesions with darkened (brown to red-brown) margins on cotyledons, leaves, and petioles. The disease may eventually result in defoliation, particularly on younger seedlings. The pathogen survives in crop residues and can infect cruciferous weeds and volunteer plants. Tufts of spores are produced in the center of leaf spots and on overwintering crop residues. Rain or overhead irrigation is the most important mechanism of spore dispersal. Conditions for disease development are optimum in spring and late summer (temperatures 55-65°F (13-18°C) and infection is promoted by long periods of leaf wetness. Deep cultivation and removal of all cruciferous weeds/crops, along with crop rotations, may reduce incidence.

Fusarium yellows or Fusarium wilt of radish

(*Fusarium oxysporum* f. sp. *raphani* = *F. oxysporum* f. sp. *conglutinans* Race 2) – Possibly seedborne

Fusarium yellows has recently (2002) been identified in a radish stock seed crop in the

Columbia Basin of central Washington, causing complete crop failure. Although the disease had not previously been an identified problem in radish seed production in the Pacific Northwest, additional confirmed diagnoses of this disease causing severe losses to radish seed crops in the Willamette Valley of Oregon and the Columbia Basin of Washington, warrant careful monitoring and management because *F. oxysporum* has an extended period of viability in the soil (at least 10-15 years in some soils), the pathogen may be seedborne, and the disease can have devastating effects on a crop. *F. oxysporum* f. sp. *conglutinans* is host specific to crucifers, with several races identified. Race 1 infects a wide range of crucifers, including radish. Race 2 is able to infect radish and some other brassicas, but not *B. oleracea* crops like cabbage, cauliflower, and Brussels sprouts. Race 2 has also been designated as *F. oxysporum* f. sp. *raphani*. Symptoms appear as wilting and dieback of plants, often starting on one side of the plant or even one side of the leaf, accompanied by dark vascular discoloration. Root symptoms appear as a dark discoloration and rot. Severely infected roots readily become infested with cabbage maggot (see **Insect Pests** below). Crop rotation is critical as the pathogen is soilborne.

Sclerotinia (*Sclerotinia sclerotiorum*) - Seed can be contaminated with dormant survival structures (sclerotia) of the pathogen:

The disease causes necrotic, light to bleached lesions on leaves, petioles, and seed stalks. Continuous expansion of a lesion on the stem can girdle the stem, causing wilting and premature plant death of the plant above the lesion. A white cottony mold is commonly associated with the expanding lesions. Macroscopic, black survival structures called sclerotia are formed on and in diseased tissues. Sclerotia of *S. sclerotiorum* can survive in the soil for up to five years. Germination of sclerotia leads to production of airborne spores and/or fungal strands that infect crown and foliar tissues. Symptoms typically are first observed on petioles of the flowers that have fallen and become trapped in the canopy (petioles serve as a source of nutrition for the fungus), and

on leaves closest to the ground where the relative humidity is higher. Small sclerotia inadvertently harvested with seed, can contaminate seed lots and act as an inoculum source for future plantings. Rotate fields with non-hosts crops, such as grasses, for at least 4 years. Irrigate early in the day to provide sufficient time for plants to dry thoroughly in the afternoon sunshine. Remove infected plants prior to seed harvest.

White Rust (*Albugo candida*) – Seedborne
Symptoms first appear as light green spots that turn white and eventually develop into white, raised spore masses called pustules. Pustules, which may appear on upper or lower sides of leaves, contain white, wind-dispersed summer spores that can lead to additional infections. Some infections can become systemic, leading to the formation of galls, especially if the tissues of plants are very young. In flowering radish crops, *A. candida* causes bizarrely distorted seedpods, termed ‘stagheads’ (galls on infected seedpods). Stagheads significantly reduce seed yield and quality. Overwintering, resting spores of the pathogen (oospores) are produced in diseased tissues including the stagheads. Small pieces of stagheads can contaminate harvested seed and act as a source of inoculum. Oospores can also be seedborne. Disease progression is slowed by extreme hot or cold temperatures and by dry weather. In contrast, the disease increases quickly during mild periods with intermittent rains, heavy dew, and/or fog. Destroy crop residue and cultivate fields prior to planting to destroy all volunteer plants. Avoid planting in fields near other cruciferous crops. Hot water can be an effective seed treatment.

Bacterial Diseases

Black rot (*Xanthomonas campestris* pv. *campestris*, *X. campestris* pv. *maculicola*, *X. campestris* pv. *raphani*) – Seedborne
Radish is susceptible to all three pathovars of *X. campestris* that can infect crucifers. This can be a very serious disease of crucifers, including radish. Symptoms vary greatly depending on the age of the plant when infected, as well as the pathovar and the particular strain of the pathovar. *X.*

campestris pv. *raphani* and *X. campestris* pv. *maculicola* attack the leaves and petioles, causing small tan to white spots with narrow, yellowish, water soaked zones on the leaves. The spots on the leaf petioles are black, sunken, and elongated. Severe infection results in defoliation and, in extremely severe cases, death may occur. *X. campestris* pv. *campestris* can cause angular, V-shaped yellow lesions that typically develop along the leaf margin, because the bacterium readily enters the leaf where the veins end at the leaf margin and form an opening called a hydathode. The veins in these yellow lesions may turn black. The lesions can dry up and turn brown. Severely infected leaves drop off the plant. Infection can turn systemic, i.e., the pathogen moves from the leaf into the petiole, the branches, and the main stem. If so, the vascular tissues turn black. Different races of the pathogen have been reported. In seed crops, infected plants may be symptomless, but systemic infection can lead to movement of the pathogen into the pods and seed.

The causal organism is carried over the winter in the crop residue and in infected seed. Once a plant is infected, further spread occurs via insects and splashing rain or irrigation water. During warm spring days, lesions are visible four to five days after infection. In cooler periods development is slower. The bacterium will grow between temperatures of 41-94°F (5-35°C), but is favored by temperatures between 80-86°F (27-30°C). Practice crop rotation for at least 2-3 years (longer for seed crops because infested stem tissues take a long time to be decomposed in the soil), and incorporate crop debris. Use seed that has been tested to be pathogen-free, or has very low levels of the pathogen. Seed treatment with hot water or chlorine can help reduce the amount of pathogen on the seed. Remove symptomatic transplants.

Insect Pests

Cabbage maggot (*Delia radicum*)

Adult cabbage maggots are small (¼ inch long) flies that lay their eggs on the soil surface near the radish crown. The larvae that hatch are ¼ inch maggots that tunnel into roots, causing wilting

and stunting of plants. Maggots feed for up to four weeks, pupate in the soil, and emerge as adults. Pupae overwinter in the soil and begin emerging in late March. Multiple generations may occur in a season. Planting early will help avoid the first generation of flies. For extreme infestations, floating row covers will prevent flies from laying eggs. Cabbage maggots prefer moist, cool weather.

Cabbage seedpod weevil (*Ceutorhynchus obstrictus*)

The insect damages developing seed pods, reducing yield and providing entry for fungal pathogens. Adults are 1/6 inch long grayish weevils with a pronounced snout. Larvae are small white grubs that feed on developing seeds. One to two eggs are laid on the pods. These hatch within a week and the larvae tunnel into the pods. Larval development takes about 6 weeks. Adults feed on pollen and overwinter in leaf litter, ditches, etc. Populations may be reduced by colder winters with little snow cover.

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