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

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

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Table of Contents

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Crop History, Lifecycle, and Basic Biology

Spinach (*Spinacia oleracea*) is a member of the Chenopodiaceae or goosefoot family. It is derived from a leafy, winter annual that evolved in and near the Fertile Crescent of the Middle East. Winter annuals are plant species that germinate in the cool of the fall and grow vegetatively until the cold weather and short days of winter slow their growth. In spring, winter annuals grow steadily until a combination of environmental factors prompts the reproductive (bolting) phase of the life cycle. Spinach bolting is initiated primarily by day length, and the ancestral forms of this crop bolt very early under less than 14 hours of light per day. This allowed the crop to mature seed before the onset of intense heat during summertime in the Middle East. The seed then lay dormant, having evolved to only germinate with the onset of cool, wet weather during fall.

Modern forms of this crop have been selected to produce a lush and robust leafy vegetable that is more adaptive across environments and seasons, but some of the traits of spinach ancestors remain. Many varieties of spinach still produce well as a fall-sown vegetable crop that is harvested in fall, winter, or spring. However, many spinach varieties have been developed to be spring-planted and produce a bountiful crop before the summer day length causes bolting. Most modern European varieties do not initiate bolting until day length reaches close to 16 hours (the length of day in NW Washington near the summer solstice). While spinach seed can still be difficult to germinate when planted in warm soils, the seed is much easier to germinate than seed of the ancestral varieties.

In recent years, the processed spinach market has remained steady while fresh bunching and baby leaf production have dramatically increased. This shift in type of production has led to new production issues and breeding foci.

Growing Spinach Seed

Climatic requirements

Specific environmental conditions are required to produce good yields of high-germinating, large-seeded spinach without high incidences of seedborne pathogens. For this reason, there are few locations where spinach seed can be grown for commercial use. The two main spinach seed production areas worldwide are the Skagit Valley of Washington and a region of central Denmark. Both areas have cool, wet springs followed by dry, cool summers [temperatures usually not exceeding 75°F (24°C)] and relatively dry fall weather for harvest. Summer weather that exceeds 85°F (28°C), especially during pollination and early seed development, can dramatically lower germination rates, seed size, and yields. Skagit and Snohomish counties of Washington State have been major areas of production, with 2,000-3,000 acres of spinach seed crops grown per year at a volume equal to up to 50% of the US and up to 20% of the world production, according to the 2005 USDA “Spinach Seed Crop Profile” for Washington State. However, other areas in the Pacific Northwest, such as the north Olympic Peninsula, the San Juan Islands of Washington, and the islands of British Columbia have an even more moderate climate and are also prime locations for spinach seed production.

Soil and fertility requirements

Spinach grown for seed can be planted on a variety of soils, but the soils must be well drained to avoid root rot problems. Soil pH should be maintained above 6 as spinach is sensitive to acidic soils. In seed crops, the amount of available nitrogen should not be too high in order to avoid excessive vegetative growth before bolting, as this promotes lodging of the plants during seed set. Well maintained soils high in humus and microbial populations will supply adequate nutrients and water over the long seed production season. Spinach is somewhat tolerant of soil salinity and very tolerant of alkaline soils, although foliar fertilizer applications may be needed on alkaline soils to counteract the reduction in availability of micronutrients like manganese under high soil pH.

Planting

Most of the spinach that is grown in the Pacific Northwest for seed is planted in spring between March 15 and May 15. While spring-sown spinach can be planted as early as the ground can be worked, the plants will not put on any appreciable size until the onset of the longer days and warmer weather of late March or early April. Sometimes spinach seed crops are fall-planted and overwintered, but this is not commonly practiced due to increased disease pressure associated with fall-planting. Overwintered spinach develops a fuller canopy early in the spring which, combined with cool and damp conditions, can lead to increased incidence of some diseases, like Cladosporium leaf spot. Overwintering spinach also acts as a "green bridge" providing a vegetative host allowing many diseases to survive through the winter.

The temperature range for germination of spinach seed is 45-75°F (7-23°C) with an optimum of 70°F (21°C). Hot weather can suppress germination. Daily irrigation during hot periods can help cool the soil and facilitate germination. Shade cloth or Remay can also be used to cool the surface of the soil during hot periods.

Spinach seed crops are commonly grown with overhead irrigation; however, drip irrigation may reduce disease pressure. In the Skagit Valley of Washington, most spinach seed producers do not irrigate, relying instead on rainfall. In the Willamette Valley of Oregon and other regions of the Northwest irrigation is required.

Spacing

The planting density for spinach seed production requires much wider spacing than for vegetable production. In general, spinach plants should be spaced 8 to 12 inches apart within rows. If the population is to be selected for genetic maintenance or improvement then the initial planting density is anywhere from six to eight plants per foot to allow for multiple selection events from time of emergence to flower initiation (see *Selection criteria*). Standard row centers are normally 22 to 26 inches, but in raised beds, spacing between rows can be dropped to 12 to 14 inches. Wider plant spacing increases air flow through the crop, reducing disease pressure.

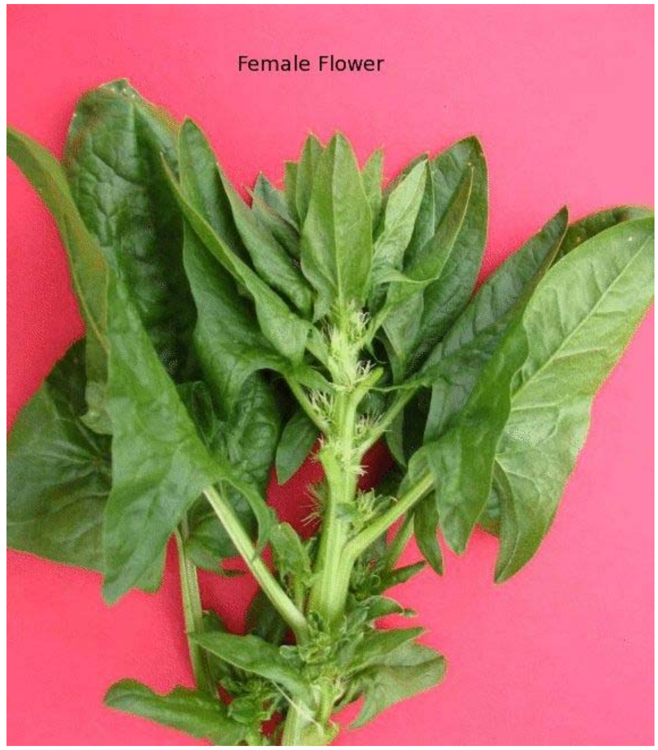
Cultivation

Spinach seedlings grow slowly and do not compete well with weeds. Starting with a stale seed bed is advisable, as well as avoiding fields with high weed pressure. Pre-emergence flame weeding may be effective, but emerging seedlings are easily damaged. Early season weed control is critical for optimum establishment. If plants become leggy due to early competition they will be difficult to evaluate in the selection process, produce lower yields, and be more prone to lodging when full size.

Flowering and Pollination

Spinach is a wind-pollinated crop with extremely fine pollen. It is a dioecious species: approximately half of the plants in a population have only male flowers, while the other half have only female flowers.

Occasionally, there may be monoecious plants in a spinach population that express both male and female flowers on the same plant, but these are less common. Male spinach plants exhibit two basic plant forms. The first males to flower are quite short in stature (often only 4 to 6 inches tall at full development) with suppressed leaf development on all upper nodes, but prodigious in staminate flowers at all nodes. These “extreme males”, as they are often called, only flower for a short period of time, but produce large amounts of pollen ensuring that plenty of pollen is available for early flowering females. The second type of male plant is known as a “vegetative male”, and is more typical in morphology with both male flowers and leaves at all nodes. Vegetative males initiate flowering a week to 10 days after the extreme males. These plants flower over a longer duration, ensuring ample pollen for the female plants throughout the period of pollen receptivity. In the absence of pollen, female plants eventually “revert” and begin producing male (pollen-producing) flowers.



Flowering is initiated primarily due to day length. Heat can play a role by speeding the metabolic rate of the spinach plant, accelerating the flowering process once flowering has been initiated.

Hybrid seed production

Most commercial spinach varieties including an increasing number of organically available varieties are hybrids. The fact that spinach is a dioecious species is an advantage in hybrid spinach seed production. The female plants are used to develop all female flowering parental lines. This is possible because female spinach plants, if isolated from spinach pollen during flowering will eventually “sex reverse,” subsequently producing male flowers in addition to their female flowers in order to achieve pollination. The subsequent generation will inherit the female genes. This sex reversal enables breeders to increase seed of a female line. During the development of female lines for hybrids the breeder must perform meticulous selection on the female plants insuring that the lines uniformly produce only female flowers for at least five to six weeks before sex reversing. Then, when used as female parents in hybrid seed production, these lines will have adequate time to receive all of their pollen from the male parental line of the hybrid in the field.

Dioecious, open-pollinated populations may also be used as “females” in hybrid seed production, however all male plants must be removed from the population prior to flowering to ensure pollen is received from the intended male parental line. Monitoring and removing male plants is also required when using an all female line as there is always a chance that although predominately female, a male plant may remain in the genetics of the population.

Traditionally, the male parents for hybrid spinach seed production have been populations of spinach varieties with the normal complement of approximately 50% male plants and 50% female plants. The male parents are usually more genetically elastic than their female parental counterparts, in part to maintain their vigor and ability to produce ample pollen, and are therefore referred to as “open-pollinated parents” or “OPs” among spinach seed producers. The male plants in these OPs tend to have the two distinct forms, “extreme males” and “vegetative males” (described above).

As 50% of the plants in the male parent produce ample pollen producers it is not an issue that the other 50% of the plants are female and do not contribute directly to the production of the hybrid. The male rows are usually destroyed several weeks before the hybrid seed is harvested from the female, seed producing rows, to avoid any chance of seed mixing at harvest.

In recent years there has been a trend to develop male parental lines that are monoecious, having both male and female flowers on the same plant. These monoecious male parents are derived through inbreeding and tend to be more uniform in their reproductive characteristics than the traditional dioecious males. Also the elimination of extreme male plants from these monoecious males means there is later flowering of these male parents. This trait is passed on resulting in later bolting in the hybrids produced by these lines. The main reservation with the use of monoecious males at this time is that many of them do not produce as much pollen as the traditional, dioecious males.

Isolation Requirements

Spinach readily cross pollinates, so an isolation distance of at least 1-2 miles between adjacent spinach seed crops is recommended. Distances may be adjusted according to direction of prevailing winds, similarity of neighboring spinach crops (for example savoy vs. flat leaf cultivars) and the presence of wind breaks or barriers. Check with local state extension offices about the use of regional pinning maps to determine the location of spinach seed crops. If pinning maps are used in the area, growers are requested to post the location of the spinach seed crop after checking for appropriate isolation distances from other spinach seed fields in the area.

Genetic Maintenance

Population size

Seed should be harvested from a minimum of 120 plants during selection in order to maintain seedling vigor and avoid inbreeding depression in spinach breeding programs. A larger population, 200 plants or more, is recommended in order to maintain good genetic diversity. The initial population size should reflect the intensity of selection activities. For example, if 50% of the population will be rogued from the field then an initial population of 400 plants or more should be established.

Selection criteria

The practice of genetic selection of any crop is related to the needs of the farmers in a particular area, environmental pressures, cultural practices, and market demands. When producing seed from stock seed (seed that has already been genetically refined) or under contract from a seed company, minimal roguing or selection may be required. Seed company guidelines should be communicated and followed regarding timing and extent of roguing activities. However, more intensive selection is an effective tool for improving cultivars over time and may be particularly useful in adapting a cultivar to local, organic growing conditions. While breeders normally concentrate on traits for the farmers who will grow the crop as a vegetable, it is also possible to select for traits important in seed production, a crucial component in adapting cultivars to organic systems. Selection should be done at several points in the life cycle. Planting six to eight spinach plants per foot in the initial stand before selection establishes a population large enough to select, or rogue, intensely and still maximize crop yields.

Spinach populations are commonly selected based on the following criteria:

Seedling vigor:
Seedling vigor and early robust growth are important traits in all production systems, and can be improved over several cycles of selection. This includes not only selecting for the quickest germinating plants, but also recognizing based on shape, size, and color, the ability of seedlings to grow under less than optimum conditions. This is done soon after emergence and is best coupled with an initial hoeing of the field.

Leaf shape:
There are various stages at which leaf size can be selected depending on the leaf shape desired by the vegetable market served by the spinach cultivar. As an example, much of the modern "baby leaf" is selected for rounded leaves. Alternately, some prefer a lobed or arrow-shaped spinach leaf for shape variation. Leaf textures are characterized as savoy (crinkle-leaf), semi-savoy or flat, and are selected along with leaf shape. Leaf texture varies with the stage of growth.

Leaf color:
Color variation exists in spinach and may be selected. Darker leaf color is commonly preferred. Darker leaf color is also attributed to higher nutritional value. Select at various growth stages for color.

Plant stature:
The ability of the plant to hold its leaves in an upright position is very important in vegetable production in general, especially for harvest of leaves cut for salad mix. Upright foliage also lessens the amount of soil trapped in the underside of leaves and can reduce the amount of fungal and bacterial pathogens splashed onto leaves from rain or irrigation.

Disease resistance:
Diseases should be monitored and identified accurately for proper field management and for selection purposes. Routinely selecting for non-diseased plants can help develop partial or horizontal disease resistance. This requires familiarity with the symptoms of various diseases, and selecting the plants that exhibit the least severe symptoms (specific diseases of spinach are covered in the *Disease* section below). Horizontal resistance is a durable form of resistance that combines multiple disease resistance genes into the population. Although this type of resistance may still incur some level of disease in the crop,

the concept is to reduce the incidence of disease to a tolerable level.

Early flowering:
The earliest flowering males (usually "extreme males") are also the earliest flowering plants in spinach populations. If all "extreme males" are selected out of the population along with the earliest flowering females then it is possible to shift the spinach variety to a longer-standing, more bolt-resistant, variety.

Cold tolerance:
There is usually minimal cold weather pressure on overwintering spinach populations in NW Washington. However, there have been several very cold winter episodes in the past decade that have resulted in considerable damage to overwintered spinach crops. Above 18°F (-8°C), damage is usually minimal. Below 15°F (-9 to -10°C), damage can be severe and crop loss can occur. In the temperature range of 15-18°F (-8 to -10°C) damage is variable, allowing for selection of the least damaged individuals. Hardier varieties that are more adapted to Pacific Northwest winters can be developed through several cycles of such selection.

Seed Maturation and Harvest

One of the most difficult steps in successfully growing a seed crop is judging the maturity of the seed. If a crop is harvested before the seed is fully formed, the seed may be immature, have low germination, and lack seedling vigor. If the crop is harvested too late, there is the risk of losing seed to shattering, predation, or inclement weather. Prolonged exposure to wet weather can also promote bacterial or fungal diseases that may degrade the quality of the seed.

Spinach seed, as with all members of the Chenopodiaceae, is formed and matures in an indeterminate growth pattern, beginning on older, lower branches and continuing up the flower stalk through the season. Due to this sequential maturation, only a portion of the seed continuously being set will reach maturity by the end of the season. In most cases only about 75% of the seed on any given plant will reach maturity by harvest. One method of gauging the maturity of a spinach seed crop is to make a visual assessment of the percentage of seed on most plants that has turned a tan-brown color, typical of mature spinach seed, and then harvesting the crop when 60 to 80% of the seed has become this color. However, this is an unreliable method of judging maturity due to the considerable effects of genetic and environmental variation. Environmentally, the seed may prematurely lighten in color in the presence of the Stemphylium/Cladosporium leaf spot disease complex. Genetically, some spinach cultivars have much greener seed, even at full seed maturity.

The most important trait to monitor in gauging the maturation of spinach seed is the relative maturity of the seed endosperm. The endosperm and embryo, which mature concurrently, must be fully developed to produce vigorous, vital seed. The endosperm, which is primarily comprised of starch, is easily monitored by cracking open or squeezing the seed to visually inspect the stage of endosperm development. Appearance of the endosperm will transition from translucent or milky early in development to what is described as "flinty" with a grayish, waxy appearance at the midpoint of development. At these stages, the endosperm can be squeezed out of the developing seed for inspection. When seeds in the middle of the stalk are at the "flinty" stage, irrigation may be stopped to speed the maturation and drying process. This can be important if there is risk of maturation extending into the wet, disease-conducive conditions of fall.

At a mature stage of development, the endosperm turns a starchy, white color which can be observed by cracking open the seed. When the endosperm turns to this true, solid white color and is firm, the seed is mature and ready to harvest. When the majority of the plants in the field have at least 75% of the seeds at this advanced, starchy white stage, it is time to cut the plants near the base of the stems to stack into windrows. This should be done preferably during a warm, dry period. The windrowed stalks will be ready to thresh in 4-10 days, depending on the weather. Rotating stalks in the windrows facilitates uniform drying of the seed. Cutting or windrowing the crop in wet weather should be avoided. If a crop is ready to cut and an extended wet weather pattern is forecast, cut the crop and bring it into an airy, dry shelter to cure (see OSA-RMA publication *Weather Related Risk Guidelines* for additional info on harvest in adverse weather). Once dried, seed stalks are usually combined or threshed and then cleaned by screening and fanning.

Diseases of Spinach Seed Crops

Several fungal diseases are prevalent in spinach seed production in the Pacific Northwest, particularly those that are favored by the wet conditions of the region. Due to the commercial demand for clean, disease-free seed, growers must pay particular attention to management of seedborne diseases. In organic production, the restriction of available pesticides and fungicides necessitates preventative management and non-chemical control measures. Spinach leaf spot diseases, including anthracnose, Cladosporium and Stemphylium leaf spot, and downy mildew are key fungal diseases which thrive in cool to warm, wet conditions, may be seedborne and are prevalent in the Pacific Northwest. They may occur individually or as a disease complex. Fusarium wilt, another fungal disease, has the greatest impact on spinach production in the spinach growing regions of the Pacific Northwest. Although favored by warmer temperatures, the pathogen thrives in moist conditions, can be seedborne, and is long lived in the soil. For this reason, growers must practice long rotations (5-17 years) from spinach and related host plants. Preliminary research suggests that *Fusarium oxysporum* f. sp. *spinaciae*, the causal agent of spinach Fusarium wilt, is favored by lower pH (acidic) soils, so the addition of lime to soils prior to planting may aid in suppression of Fusarium wilt.

Cultural controls, particularly important in organic production, play a large role in disease prevention. Cultural recommendations to prevent an array of spinach diseases include managing irrigation to minimize splashing and the durations of leaf wetness; destruction of field inoculum by incorporating infested residues into the ground; crop rotation; row orientation, staking, and increased row spacing to increase air flow in the field and reduce relative humidity; planting pathogen-free seed; and the use of disease-resistant cultivars. Spring planting rather than fall planting is also commonly recommended in the Pacific Northwest to reduce disease pressure. Fall-planted spinach has a fuller canopy in the early spring when moist, cool conditions and lack of air flow can increase disease pressure. Additional disease-specific recommendations along with disease descriptions are listed below.

Hot water seed treatment has been shown to reduce the infection of *Cladosporium variabile*, *Stemphylium botryosum* and *Verticillium dahliae* in spinach seed. However, the specific temperature and duration of hot water treatment must be controlled carefully to avoid damaging the seed and reducing germination. Research at WSU by Dr. Lindsey du Toit demonstrated eradication of *C. variabile* from spinach seed treated with hot water at 40°C for only 10 minutes, and *V. dahliae* at 55°C for 30 minutes or 60°C for 10 minutes without reducing germination. *S. botryosum* was eradicated from a lightly infected seed lot treated at 55-60°C for 10 minutes without reducing germination, but could not be eradicated from a heavily infected seed lot, even by treatment at 60°C for 40 minutes. Hot water treatment can affect longevity and germination rates in seed, so the procedure should be used with caution. Experiment with small batches at a time. Directions for hot water treatment procedures are available from Ohio State University (see publication by Miller, S.A. in **References**).

Some cultivars with single-gene disease resistance have been bred for control of particular diseases such as downy mildew; nevertheless, rapid development of new races of the pathogen necessitates continual breeding efforts to create cultivars with resistance to the new races. Breeding cultivars with horizontal or durable resistance holds much promise for organic prevention of many spinach diseases, but few commercially available cultivars with this type of resistance currently are available.

Fungal Pathogens

Downy mildew (*Peronospora farinosa* f. sp. *spinaciae*) – Seedborne

Downy mildew is a wide-spread disease in spinach in many regions of the U.S. The disease is favored by cool, wet conditions, and can be devastating in spinach seed or vegetable production. The disease is characterized by slightly yellow, irregular, chlorotic lesions on leaves that may progress into expanded necrotic patches. There is evidence that downy mildew can be seed-transmitted, but the rate of seed transmission and impact of seed inoculum is unclear. Fungal spores spread readily by wind and splashing water. Heavily infected leaves may become curled and distorted. Incorporation of infested crop residue into the ground is recommended as the pathogen overwinters on spinach debris and weeds, but is not a soilborne pathogen, i.e., the pathogen does not survive once the crop residues have been decomposed by the soil microflora/fauna.

Anthracnose (caused by *Colletotrichum dematium* f. sp. *spinaciae*) – Seedborne

Anthracnose is characterized by small, circular, water-soaked lesions on young and old leaves which can enlarge and become chlorotic or necrotic. Black fruiting bodies called acervuli form in lesions and distinguish the disease from other leaf spot diseases. The fungus thrives in wet, cool conditions and is dispersed by splashing water and on infected seed. Incorporation of crop residues is recommended as the disease overwinters on infected spinach debris and seed.

Cladosporium leaf spot (*Cladosporium variabile*) – Seedborne

The disease is characterized by small, distinct, leaf spots, each of which develops a narrow, darker colored margin. The fungus thrives in moist, cool conditions. Spores are produced in leaf lesions under moist conditions and are dispersed by wind and splashing water. Destruction of volunteers is important as the pathogen overwinters on infected volunteer plants and seed. Orienting rows and increasing spacing to improve airflow is recommended, along with spring- rather than fall-planting. As the disease can be seed transmitted, starting with pathogen-free seed is important. Hot water treatment can be effective for treating infected seed (see recommendations above).

Stemphylium leaf spot (*Stemphylium botryosum*) - Seedborne

The disease is characterized by distinct spots on leaves that begin as a grey-green color, turn tan, and then expand rapidly and become dry and papery. The fungus thrives in moist, warm conditions and is more aggressive on spinach in the presence of pollen. Spores are produced in lesions on leaves in moist conditions. The fungus is dispersed by wind and on infected seed. Incorporation of infested seed crop residues is recommended as the pathogen overwinters on infested residues left on the soil surface, and on infected seed. Orienting rows and increasing spacing to improve airflow are recommended, in combination with planting pathogen-free seed. Hot water treatment may be effective, or partially effective, for treating infected seed (see recommendations above).

Fusarium wilt (*Fusarium osysporum* f. sp. *spinaciae*) – Seedborne

Fusarium wilt is characterized by a general wilting of plants, a flaccid, off-green color, and blackened roots externally and within the vascular tissue. The disease can occur at all stages of growth. It is favored by warm conditions when the transpirational demand of the plants is greater but the vascular tissue is compromised because it is blocked by the fungus. The pathogen can survive in the soil in the absence of a host for many years. Crop rotations of five to seventeen years from spinach, beets, and chard are recommended. The duration of the rotation depends on cultivar susceptibility and the amount of field inoculum. Preliminary research suggests that *F. oxysporum* f. sp. *spinaciae* is suppressed in high pH soils, so the practice of liming soils prior to planting may be beneficial for control of this disease. Recent research has demonstrated promising potential for the use of Brassica cover crops high in glucosinolates (natural biofumigants) for suppression of Fusarium wilt (see **References**). Planting pathogen-free seed is important.

Verticillium wilt (*Verticillium dahliae*) – Seedborne
Verticillium wilt was first identified in spinach seed crops in the Pacific Northwest in 2004, and is becoming a disease of increasing concern in the region because the fungus readily infects the developing seed. Symptoms include interveinal chlorosis and eventual necrosis appearing first on older leaves. Wilting occurs as the disease progresses and can be confused with Fusarium wilt. Symptoms typically occur after bolting. The pathogen is systemic, highly seedborne, readily seed-transmitted, and has a broad host range (although the particular host range of the specific strains that are pathogenic on spinach remains to be clarified). The fungus is also soilborne and can persist in soil for many years. Crop rotation from susceptible crops is recommended. Non-host crops include grains, ornamental bulbs, and broccoli. Hot water treatment can be effective to treat infected seed (see recommendations above).

Damping off and root rots (*Pythium aphanidermatum* and other species, *Rhizoctonia solani* and other species, and *Fusarium cochlioides* and other species) – Seedborne
Damping-off is a prevalent soilborne disease in spinach caused by various pathogens, primarily species of *Pythium, Rhizoctonia* and *Fusarium*. These pathogens are not seedborne, except for some of the *Fusarium* spp. Damping-off symptoms include lesions, water-soaking, and/or girdling of the roots and crowns that result in wilting and death. The disease is favored by wet conditions and only affects seedlings and young plants. Avoiding overwatering is important in prevention of the disease, particularly for *Pythium* spp. (water molds). Although disease resistant cultivars are not commercially available, there is evidence of some resistance in cultivars suggesting the potential for development of horizontally resistant cultivars.

Viral Pathogens

Cucumber Mosaic Virus (CMV) – Seedborne
A virus, CMV causes a disease of spinach also referred to as spinach blight. Symptoms range from light to severe chlorosis and mosaic patterns of the leaves, and can include narrowed crown leaves that become curled, wrinkled, and roll inward; yellowing of leaves that may die; and stunted plants. The pathogen is aphid-vectored and overwinters in perennial weeds and vegetables (especially cucurbits). Some strains are seedborne and seed-transmitted. Managing aphids and avoiding planting near cucurbit crops is recommended. Roguing symptomatic plants in the field can help prevent spread of the disease.

Beet Curly Top Virus (BCTV)
BCTV is a virus that affects many plant species and is vectored by leaf hoppers. The disease is characterized by thickened, rolled leaves that may be yellow, brittle, and stunted. Affected plants appear compact and stunted, and may die. Control of leaf hoppers and not planting near other Chenopodiaceous crops is recommended.

Beet Western Yellows Virus (BWYV)
BWYV is a virus that has a very broad host range, is particularly prevalent on brassica weeds, and is vectored by aphids. Symptoms of infection include interveinal and marginal yellowing, appearing first on older leaves; red-brown spots between veins that have a bronze cast; thick, leathery, brittle leaves; and poor root growth. The disease is readily confused with symptoms of nutrient deficiencies (e.g., nitrogen, iron, or magnesium). Managing aphid populations is recommended.

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