Organic Seed Alliance

Advancing the ethical development and stewardship of the genetic resources of agricultural seed

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Climatic Considerations for Seed Crops: Guidelines and Field Trainings for Organic and Specialty Vegetable Seed Producers

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I. Introduction

The U.S. Northwest (NW) region is a prime location for seed production of many vegetable species and specialty crops. A long growing season, relatively dry summer and fall weather, and winter chilling provide the climatic conditions necessary for growing high quality seed of a diversity of crop species throughout the region. For these reasons, the NW holds a rich history in seed production and is home to several international and regional seed companies. Seed production can be a financially profitable business, either alone or integrated into a diverse production system, often boasting $10,000 and even up to $40,000 an acre. Organic seed production offers a prime business opportunity, as there is more demand than supply to fulfill the seed needs of the growing organic agricultural sector. A growing number of organic farmers are integrating seed production into their diversified farms to ensure access to organic and regionally appropriate seed varieties. Seed crops also enhance the agroecology of the farm by providing pollen and nectar resources for beneficial insects and pollinators during flowering, providing alternative crop species for rotations, and returning abundant organic matter from incorporated residue.

Many growers find seed production rewarding, though seed growing can also be risky, especially if the grower is not familiar with specialized production practices and the climatic needs of the crop.

Seed production is a valuable and profitable addition to a diversified farm. *Photo credit: Organic Seed Alliance*

Seed crops are often more affected by the environment than vegetable crops. There are critical, environmentally triggered responses that must be met to ensure reproductive success in seed crops. Most species have evolved with physiological mechanisms to ensure reproductive success in the geographic region of origin. What this means for a seed grower is that the environmental conditions conducive to reproduction must also be provided for a successful seed crop, either by selecting a crop species well-suited to the local climate, or by modifying the growing environment through horticultural practices.

Climatic advantages of the NW region include moderate spring temperatures conducive to vegetative growth, relatively dry summer and fall seasons for ripening and drying seed crops, and ample cold in the winter necessary to acquire cold chilling (vernalization), but moderate enough temperatures to overwinter biennial crops outdoors in many locations. The diverse climatic influences, from coastal maritime climate, to warm inland valleys, and arid regions east of the Cascade Range, provide a diversity of microclimates conducive to a wide variety of seed crops. The cool, moderate maritime climate of Washington's Skagit Valley makes this region a worldwide supplier of cabbage, table beet, and spinach seed. This region alone produces one-third of the world's table beet seed (WSU, 2012). The dry, arid climate and volcanic soils in several areas of Idaho allow producers to grow certified disease-free, high-quality bean seed. Farmers in the Willamette Valley have produced a wide range of warm weather, dry-seeded vegetable and specialty seed crops since 1910. These include onion, parsnip, parsley, pumpkin, winter squash, table beet, and Swiss chard, a wide range of brassica species, including cabbage, kale, mustard, turnip, rutabaga, and Asian greens such as Chinese cabbage, and bok choy, as well as flowers, medicinal and culinary herbs. Organic seed producers throughout the NW are helping address the growing demand for high-value, organic seed nationally and internationally.

Growing seed successfully requires specialized production knowledge and in some cases specialized equipment. Seed production information is often held by private industry and less readily available from university extension programs. Organic Seed

Alliance (OSA) is a non-profit organization that advances the ethical development and stewardship of seed through education, research, and advocacy. OSA partners with university Extension, university researchers, private industry, experienced farmers (both organic and non-organic), and others to increase access to seed production information nationally. OSA's education programs include workshops, farm-based trainings, webinars, online tutorials, print publications, and the biennial Organic Seed Growers Conference. A series of publications on seed production, including this publication, are available for free download from OSA's website. Publication topics include a general seed saving guide and several specific seed crop guides that cover the basic biological and applied principles of seed production. Visit www.seedalliance.org for more information and educational resources.

In 2013, OSA, in partnership with RMA, delivered five on-farm workshops on organic seed production and climatic considerations across the Northwest. Beth Rasgorshek demonstrates tomato seed cleaning at Canyon Bounty Farm in Nampa, ID. *Photo credit: Organic Seed Alliance*

This guide was produced in partnership between OSA and USDA's Risk Management Agency (RMA). It is intended to help growers minimize risk by providing the basis for understanding important climatic considerations in seed production. The goal is to provide the information necessary to determine which seed crops are best suited to local growing conditions. The basic principles presented apply to seed production in any region, but the recommendations are focused on production in the NW states of Washington, Oregon, and Idaho. Guidelines and recommendations are based on knowledge of historical seed production in the region coupled with information on the biology of seed and specific seed crops. Every farm has a unique microclimate and weather patterns can shift from year-to-year. The true test of success in seed growing comes from experience in the field with a given crop over time. This guide helps inform which crops hold the most promise based on the local climate, but it is recommended that growers begin by testing a new crop on a smaller scale and increasing production based on prior successes.

II. Climatic Considerations in Seed Production

Most modern food crops evolved in regions of the world outside the U.S. Brassica crops (such as cabbage, kale, and broccoli) originated from the coastal shores of western and southern Europe, Solanaceae crops (peppers and tomatoes) are from regions throughout South America, and the wild relatives of many Apiaceae crops (such as carrots) can still be found in Afghanistan and Turkey. These crops have traveled many miles over thousands of years and have been adopted into the agricultural production and cuisine of many cultures worldwide. They have also been selected and bred by humans, but in most cases the physiological process of flowering, fertilization, and seed maturation still reflect the climate where they originated. It is helpful to keep this in mind when considering how the environmental conditions support or hinder seed production of different species.

Environmental Influences on Pollination and Fertilization

The length of season and appropriate temperatures for plant growth are critical to achieving a successful crop, but sometimes a crop will appear to be growing fine and not form seeds. There can be a field full of flowers and ample insect activity and still no or low seed set. This can be one of the most frustrating experiences as a seed grower. In many cases the climatic challenges in seed production are due to the lack of environmental conditions necessary for successful pollination and fertilization of the crop species. Temperature, moisture, wind, and insect activity must all be conducive for the suc-

Many crops either require, or benefit from, visits from insects. *Photo credit: Organic Seed Alliance*

cessful pollination and fertilization needed to produce quality seed. Environmental conditions vary from year to year, and physiological requirements can be subtle and varied from species-to-species.

Climatic Influences on Seed Production

a) Temperature

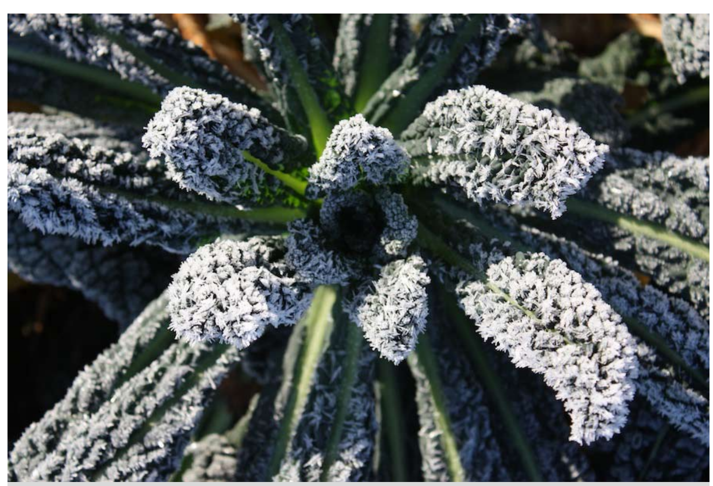
Temperature is a critical factor for many stages of crop seed development. Producers must be aware of the typical minimum and maximum temperatures in the local environment as well as approximately when they occur. Extreme cold and freezing temperatures can cause irreparable damage during both spring growth and overwintering. The extent and duration of cold control the ability of many crop species to transition from vegetative to reproductive growth. Excessively hot conditions during pollination and seed set can affect both pollen viability and the receptivity of plant stigmas. It is important producers are familiar with how these growth stages are affected by temperature requirements of seed crops to achieve a high yield of quality seed.

Minimum Temperatures

Many crops require a period of cold temperatures to transition from the vegetative to reproductive growth stage. This phenomenon is referred to as ***vernalization***. The duration and intensity of cold needed to meet vernalization requirements varies widely among crops and even among varieties of the same species. Some crops require a relatively short period of cold and can fully vernalize and produce seed in a single season (such as broccoli and radish), whereas others must be grown through an entire winter season (biennial) to fulfill vernalization requirements. It is critical to understand the vernalization requirements of a chosen seed crop in order to achieve reliable and quality seed production.

For seed crops that can be grown from seed-to-seed in a single season (spring sowing and fall harvesting) and that require minimal vernalization, it is important not to plant out too early in the spring. This can result in the crop meeting its vernalization requirement before the plants have achieved sufficient growth and are too small to support quality reproductive growth and a good seed set. This can be difficult to judge as seasonal temperatures and environmental conditions naturally fluctuate from year-to-year. Experience and familiarity with both local environment and the seed crop are the best guides for mitigating this issue.

Minimum temperatures dictate which winter annual, biennial, and perennial crops can successfully be overwintered in the ground and which must be dug up and protected in a cellar or cold storage. The seed grower must find the balance that allows the crop to acquire enough cold exposure to meet the vernalization requirement without incurring damage from freezing temperatures. This applies to crops both in the field and in storage. Each crop species, and the varieties within that species, have a minimum temperature, or cold-tolerance, they can withstand before the cold will result in perma-



Lacinato kale with frost in the field during December. *Photo credit: Organic Seed Alliance* nent damage from which the plant cannot recover. This cold tolerance threshold can also vary from crop-to-crop based on the amount of moisture in the environment at the onset of cold, the wind velocity, and the duration of the cold period, as well as other factors if the crop is in the outdoors. Some varieties of Brussels sprouts, European kales, spinach, and leafy chicories can withstand extreme cold, lose some tissue to cold damage, and still continue growing. The critical factor is whether or not the apical growing point, or crown, is damaged by the cold. If damage occurs, the plant will not be able to recover and will likely die. In general, if temperatures below 20°F (-7°C) regularly occur throughout the winter in an area, overwintering many seed crops will be difficult. With these winter temperatures, a different seed crop, cold storage, or the use of protective structures should be considered. Although the amount of cold required varies by both species and variety, a general rule that applies to most biennials for successful vernalization is for the crop to receive a cumulative time of 45 days at or below 50°F (10°C). On the other hand, if the local environment does not provide enough cold to meet the crop's needs then the crop may need to be dug up and stored under refrigeration in order to achieve successful vernalization. If storing the crop under refrigeration or in a cold room of any type then most biennials will require temperatures below 40°F (4°C), with exceptions for bulbing crops like onions. Resources for determining minimum cold tolerance temperatures for specific crops include some gardening books, seed catalogues, and the local Extension service.

Seasonal Fluctuations in Minimum Temperatures

Propensity for, and intensity of, temperature fluctuations in the local environment must be taken into account for seed crops planned to be overwintered. Extreme temperature fluctuations during the winter can be detrimental to overwintered seed crops. Warm periods can encourage the plant to grow, the new growth of which is then vulnerable to damage or death from successive cold periods. Fluctuations in temperature are a challenge for most crops, but some crops that have evolved under conditions of fluctuating temperatures (such as most brassicas and spinach) may be able to tolerate such variable conditions and allow growers to successfully overwinter the seed crop outside. Growers should also be aware of the same phenomenon in early spring when warm periods can be followed by freezing conditions, causing irreparable damage to young plants. To mitigate damage due to these fluctuations, consider using floating row cover or a mulch to minimize temperature variability.

There is little regional information available on which specific crop species are most and least vulnerable to winter (and spring) temperature fluctuations when producing a seed crop. This is due in part to the fact that many of the common winter annual and biennial vegetable crops grown in the U.S. today originated in temperate climates with relatively mild winters and are generally frost-tolerant. Depending on their size, stage of growth, previous exposure to, and duration of, cold, many of these crops will be damaged by temperatures below 29°F (-2°C). Experimentation with a variety of crop species and varieties may be necessary if there is difficulty overwintering a particular seed crop. Variety trials can be very useful for determining which varieties will work in the local environment. Guidance on conducting on-farm trials is available in OSA's publication: *On-farm Variety Trials for Organic Vegetable, Flower, and Herb Producers*. Visit www.seedalliance.org to download this free publication.

Diurnal Fluctuations in Temperature

Another temperature consideration is the difference between day and nighttime temperatures in the area, also known as ***diurnal fluctuation***. Does the temperature drop significantly with the setting of the sun? Or is the heat of the day retained throughout the night? Most heat loving crops don't like cold nights and can incur damage, or fail to set seed, if temperatures dip too low. This is particularly true of the Solanaceae family. They are vulnerable to cold damage if nighttime temperatures are regularly below 50°F (10°C). Tissue damage from cold temperatures above freezing is known as ***chilling injury***. The plant tissues are damaged to the point that they are no longer able to carry on normal metabolic processes even when temperatures rise above freezing.

Lack of seed set in heat loving crops may also result from the fact that pollination and fertilization are challenging under cool nighttime conditions. Pollen may not be produced, or if pollen reaches the female stigma and begins to grow a pollen tube during the day, it may abort and die when nighttime temperatures drop below 50°F (10°C). This can be a challenge for members of the Solanaceae (tomato, eggplant, and peppers), Cucurbitaceae (squash and cucumbers), and Fabaceae (green bean, runner bean, and edamame) crops.

Diurnal fluctuations also affect the overall accumulation of heat units, potentially resulting in slower plant growth and delayed maturation, even with sufficiently high daytime temperatures.

Maximum Temperatures

The timing and intensity of peak heat affects both growth and seed set of crops. Some crops, such as watermelon and eggplant, are heat-loving plants that grow well in high-heat conditions. Others, like cauliflower and spinach, grow poorly at high temperatures. There is wide variation in heat sensitivity and preference among crop species and the varieties within them. Consult *Knotts Handbook for Vegetable Growers* by Donald N. Maynard as reference for optimum temperature ranges for flowering and seed set. Be sure to take into account the prevailing heat conditions in the local area when deciding which seed crops to grow.

Many crops are most sensitive to heat during flowering and are better able to tolerate heat once the seed is set. For this reason certain seed crops may need to be planted earlier than normal for vegetable production to avoid peak heat during flowering to ensure successful seed set. A good example of this is overwintered pea seed production in parts of Idaho. When planted in the late summer to early fall, the pea plants are mature enough in early spring to achieve flowering before heat reaches a critical level where pollination and fertilization are negatively affected. High temperatures negatively affect pollination and fertilization of nearly all crops. Some crops will produce and release reduced quantities of pollen in response to excessively high temperatures. High temperatures can also desiccate (dry out) pollen, causing it to die, resulting in reduced or non-viable fertilization. One of these situations can be a common problem for cool and warm season crops, such as beets, cauliflower, lettuce, and peas, when daytime temperatures reach or exceed 90°F (32°C) during flowering.

Melon seed cleaning at Canyon Bounty Farm in Nampa, ID. *Photo credit: Organic Seed Alliance*

Mitigation Techniques for Temperature

There are three primary ways to manage and mitigate the negative effects of extreme high temperatures on seed crops. First and foremost is to manage the timing of planting, whether direct seeded or transplanted. Planting early (as early as possible, or even overwintering) allows the crop to achieve flowering and pollination before potentially damaging peak heat times. Another option is to use shade cloth or construct a shade structure near or around the crop to protect it from direct heat and create a slightly cooler microclimate. Planting the crop in a known cooler microclimate area in the landscape also helps to minimize heat damage. Conversely, if the local climate is too cool for the seed crop, consider planting into a hoop house, greenhouse, or high tunnel to achieve the temperatures needed for flowering, strong pollination and fertilization, and seed set.

b) Day Length

Day length is a measurement of the number of hours of light and dark in a 24-hour period. The reproductive cycles of many crops are governed by the amount of light and darkness that they are exposed to in a 24-hour period. This physiological reaction to the length of day and night is called ***photoperiodism***. Flower initiation in the crop species affected by photoperiodism is a response to the relative lengths of the light and dark periods, but is generally determined by day length. Many crops have evolved to require increased day length

Hoop house used for carrot production in British Columbia. *Photo credit: Patrick Steiner*

in the spring to initiate flowering. These crops include cabbage, carrot, onion, and spinach. This evolutionary mechanism allows plants to avoid flowering in the cold of winter when pollinators are not present and weather would prohibit successful seed maturation. Day length sensitivity is variable among crops species and the varieties within them. It is important to know how day length affects a crop and whether the local environmental conditions will be conducive to successful production of quality seed.

Onions are an interesting example of varying sensitivity to day length. Onion varieties are classified as long, short, or intermediate day varieties depending on how many hours of daylight they require for bulb formation, flowering, and seed set. When long day varieties are grown in short day climates, they may never flower and set seed because days never get long enough to trigger the biochemical changes that start these processes. If they do manage to flower and set seed in a short day length climate, the timing may be too late to allow for full maturity of the seed before fall. Conversely, if a short day onion is grown in a long day length climate, it may initiate flowering and seed development before the plant has reached full maturity and is able to sustain and support successful seed development. In this case, the plants are too small and immature to produce quality seed. If the plants do manage to set seed, both the seed yield and quality will likely be diminished.

Spinach is another example of a day length sensitive seed crop. The majority of spinach varieties require a minimum of 14 hours of daylight to initiate the transition from vegetative growth into floral development. If spinach is grown for seed in a location that never gets 14 hours of daylight, only a small percentage of plants will likely flower and set seed. However, the seed saved from those plants will result in a more bolt sensitive population. Although this may seem like a good way to produce and retain a new spinach seed source, it is not advised, as a spinach with a propensity toward early bolting will decrease the harvest window and could result in a population that does not grow to full vegetative maturity before transitioning into the floral development and seed production phases. Growing spinach seed crops in northern climates with long days is essential to select for and produce varieties that are not sensitive to early bolting.

Transition from vegetative to reproductive phase in spinach. Early flower development. *Photo credit: Organic Seed Alliance*

Mitigation Techniques for Day Length
Modifying the day length of a region is not likely an economically feasible option in seed production. Producers can extend day length by growing the seed crop under lights in a greenhouse. Field production of highly day length sensitive crops requires appropriate timing of planting to achieve appropriate vegetative growth prior to the critical day length that will induce flowering in the crop.

c) Frost-Free Days
Frost-free days refers to the total number of days with temperatures conducive to plant growth. Seed crops require a much longer growing season than vegetable crops of the same species, and thus require a strategy for a longer period of management in the field. For instance, a head lettuce crop may mature in 45-65 days, whereas twice that time (120 or more days) is needed to mature a quality lettuce seed crop. Frosts and freezing spells in the fall can prematurely halt the maturation of a seed crop. Conversely, spring frosts can delay initial growth and establishment of the crop, which can throw off the timing of seed production or cause the crop to start setting seed before the plants have reached full vegetative maturity. Therefore, it is important to consider the total estimated length of time required for the crop to reach full maturity to know whether it will be possible to produce a seed crop successfully in an area.

Mitigation Techniques for Frost-Free Days
Quality seed crops can still be produced in areas with a short frost-free season, but it may require a combination of season extension tools such as greenhouses, high tunnels, row covers, mulches, and cold storage facilities.

d) Precipitation
Precipitation is the water a crop receives from rain. Precipitation can be both helpful and harmful to the health and success of a seed crop. The timing, duration, and total accumulation of precipitation all affect the crop and need to be factored into and combined with irrigation practices throughout the entire lifecycle of a seed crop. The two most critical stages in crop seed development when precipitation can be most damaging are during flowering and pollination, and final dry down. Both the direct precipitation and the relative humidity it creates can affect the crop.

If it is too rainy during flowering, the activity of pollinating insects may be reduced. Honeybees are especially sensitive to these conditions and will not fly when it is too cool or wet. This is particularly important for cross-pollinated crops that rely on insects for successful pollination. It is also an issue for self-pollinated crops. The pollination of many self-pollinated crops is enhanced by visits from insects who land on and jostle the flowers, encouraging pollen movement within the flower. Rainy and wet conditions can also be detrimental to the pollen movement of cross-pollinated crops that rely on wind for pollen movement. Rain or overhead irrigation can wet the pollen as it is shed by the anthers, either washing it to the ground or rendering it immobile.

Both the amount and the timing of precipitation affect crop growth. As with almost all vegetable crops, most seed crops grow best with watering throughout the season. It is a common misconception that irrigation can be stopped once the seed is set and that this will encourage and facilitate seed maturation. This is not the case. In most climates the crop needs continued irrigation until the seed is fully mature. It is advisable, if possible, to use a drip irrigation system with seed crops as overhead watering can cause damage and encourage conditions for disease on developing seed pods and heads. Precipitation during seed maturation can increase the incidence of disease both externally and internally if the seed is in some sort of a pod, silique, or covering, and cause disease by directly wetting the seed (which can make it vulnerable to fungal and disease infections). Direct wetting of the seed, whether from irrigation or precipitation, may cause the seed to germinate and sprout on the plant, thus ruining the seed crop. If this happens, it may be necessary to harvest early, cover the crop in the field, or move the crop to a protective structure.

Mitigation Techniques for Precipitation
If too much precipitation is present, the crop may be grown in a high tunnel, greenhouse, or other protective structure and irrigated to control watering. If precipitation is limited, irrigation must be applied to ensure adequate water for healthy plant growth. Again, drip irrigation is generally prefer-

able to overhead irrigation to avoid disease susceptibility and damage caused by wetting plant foliage, flowers, and seed.

e) Wind

Prevailing wind conditions are an important consideration for seed crop production. Wind is both necessary and helpful for successful pollination, and can be destructive and detrimental during seed maturation and dry down. Timing, direction, and severity of prevailing wind conditions all affect seed production.

Wind is critical for successful pollination of many cross-pollinated crops such as beets, chard, corn, and spinach, all of which rely on air movement to spread their pollen. Full seed set of these crops can be hampered if they experience repeated days of still air or absence of wind during flowering. In this situation the pollen is only able to travel short distances to neighboring plants, rather than being blown throughout the entire field. The result can be a reduced level of pollination and a decreased level of genetic mixing, which are essential for healthy and robust production in cross-pollinating crops.

Seed crops grown in a greenhouse can suffer from lack of wind and air movement necessary for pollination of self-pollinated crops. In some self-pollinating plants the anthers (male flower parts) are presented in very close proximity to the stigma (female flower part) so that as soon as the anthers release pollen it falls onto the stigma with little or no prompting or assistance. However, others require some sort of external movement to assist in shaking the pollen loose from the anthers and onto the stigma. For many crops, such as tomatoes, peppers, common beans, and peas, wind movement can facilitate this critical pollen movement within the flowers. Tomatoes being grown for seed in a greenhouse may need to be physically shaken by hand or by using strong fans to introduce a stiff breeze during flowering to ensure good pollination and seed set.

Many seed crops are tall and subject to lodging in windy conditions. As plants reach their maximum height in the final stages of seed maturation and dry down, they are susceptible to lodging and their stalks may be weakened. This is something to be particularly aware of if the crop is being taken all the way through full maturity out in the field. Lodging can be especially problematic for lettuce and brassica seed crops that are lightweight when fully dry and vulnerable to being blown about in high wind conditions. The seed pods of brassicas (known as siliques) are vulnerable to cracking open with excessive movement when they are fully dry, which can easily result in crucial seed loss. Tall crops can also be vulnerable to blow down damage if windy conditions prevail during the final stages of seed maturity.

Mitigation Techniques for Wind

Negative effects of wind can be mitigated by planting crops in the leeward side of windbreaks in the field and by staking plants to avoid lodging. Fans may be used to increase airflow, facilitating pollination in low-wind environments such as greenhouses. Plants may also be manually shaken gently during pollination to ensure good transfer of pollen from the anthers to stamen.

A staked cabbage seed crop. *Photo credit: Organic Seed Alliance*

III. Environmental Management

a) Field Selection

The microenvironment of most farms varies across and between fields. Field selection can significantly influence the environmental conditions for seed crops and careful field selection can help increase or decrease temperatures, wind, moisture, and other field conditions. Choosing warm areas of the landscape can help crops and certain species achieve needed heat units without the addition of protective structures. Consider the prevailing wind conditions and their patterns around the landscape to ensure good pollination and help avoid losses due to crop blow downs during the seed maturation and dry down stages. When dealing with a cool weather seed crop (such as lettuce), choosing shady or cooler microclimates in the landscape can help ensure good seed set and minimize losses due to heat damage.

Most landscapes have variable microclimates based on elements, such as orientation toward the sun, protection from wind, and contour of the landscape. Selecting a warm location in the landscape can make a critical difference in the ability of crops to reach seed maturity. Finally, if the local climate is prohibitively cool or has too short a season, the seed crop can be planted in a greenhouse, high tunnel, or other protective structure.

b) Protective Structures

Greenhouses

Protective structures can be used to mitigate and manage the effect of a number of climatic influences and impacts. High tunnels and greenhouses provide many of the same benefits for successful seed production. High tunnels are essentially tall hoop-shaped greenhouses and often have sides that can be easily rolled up to facilitate temperature regulation and airflow. These structures can provide substantially increased heat units and growing days to accommodate heat-loving crops and extend the growing season for the seed crop. Seedlings may also be started in a greenhouse to give field planted crops a jump on the season. Planting into one of these structures in early spring can extend the beginning of the growing season, allowing the seed crop to get established earlier than if it was planted outside. A caution here is to think about how long the seed crop will be in such a structure in relation to the value of the seed produced. Generally tunnel and greenhouse space is valuable and only recommended for the full life cycle of a seed crop if the resulting seed is of substantially high value. An exception to this may be overwintering a winter annual or biennial in such a structure when it would otherwise not be used to produce a crop for market.

Tomato production house at Stone Barns Center for Food and Agriculture. Ability to roll up the sides improves air flow and facilitates insect activity as well as allowing for temperature regulation during the hottest part of the day. *Photo credit: Organic Seed Alliance*

High Tunnels

High tunnels and greenhouses can also be incredibly useful during the final maturation and dry down stages of a seed crop, particularly in areas prone to fall wind and rains. Once the crop reaches full maturity, the plants can be pulled up or cut and moved into a greenhouse or high tunnel for the final dry down to avoid the potential for damaging rains and winds. Overwintered crops grown and selected in the field can be dug up and moved into a tunnel or greenhouse to protect from freeze damage in areas where temperatures are regularly and/or consistently below 50°F (10°C). Greenhouses and tunnels also provide a protected area in which to clean seed.

Greenhouses and high tunnels can be supplemented with additional light and heat to meet seed crop needs. Necessary combinations of additional light and heat may be needed to achieve successful vernalization, pollination, accumulation of heat units (Growing Degree Days) or to bring the crop to full maturity. It may be possible to integrate a seed crop into greenhouse or high tunnel production while maintaining vegetable production in the house at the same time. This can be of great benefit to all crops by encouraging the presence of a diversity of pollinators.

c) Mulches

Seed crops grown in areas that regularly experience extreme cold in the winter may benefit from various mulches to protect them from cold damage in the field. In England, for example, heavy straw mulches are used to assist in overwintering carrots in the field. Many biennial crops, including beets and carrots, are commonly protected by covering roots with a dry soil mulch in the fall. However, care must be taken to avoid covering the apical growing point of the root. In some cases, even a dry snow layer can provide more insulation for plants than those exposed to the cold. Care must be taken to monitor the condition of the crop under the mulch and ensure there are no unintended negative effects. Potential negative effects to monitor for include increased disease incidence and rodent damage.

d) Row Cover

Floating row cover may help extend the growing season in climates with short seasons that are challenged to mature seed crops. A floating row cover, such as Remay, can be used to protect seedlings after direct seeding or transplanting during cold spring or fall conditions. In addition to providing frost protection, row cover increases the temperature under cover, encouraging more rapid plant growth. Row cover also provides protection from pest damage.

Row cover can either be placed directly on top of a crop (as shown) or over hoops to create an in-row protection structure anywhere in the field. *Photo credit: Organic Seed Alliance*

IV. Crop Selection for Seed Production

Dry-Seeded Versus Wet-Seeded Species

Knowing whether a seed crop is *dry-seeded* or *wet-seeded* will help determine what climatic factors may be the biggest challenges to producing quality seed. ***Dry-seeded*** crops have naked seeds, pods, or capsules that are dry at maturity. Examples of dry seeded crops include grains such as quinoa, wheat, and barley, as well as vegetables such as carrots, fennel, lettuce, chicory, broccoli, cabbage, kale, peas, and beans. Dry-seeded crops require a dry environment (or protective structure) during maturation and harvest. These crops are vulnerable to disease during this time if conditions are wet and cold; and do best in dry, low humidity environments.

Wet-seeded crops have seeds that are embedded in the damp flesh of fruits. There are only two vegetable plant families with wet-seeded fruits: the Solanaceae (tomatoes and peppers) and the Cucurbitaceae (melons, squashes, and cucumbers). Certain peppers can be treated as dry or wet-seeded crops, as they can be either processed when they are fleshy (wet), or after they have dried (dry). In general the seed of wet-seeded crops is less vulnerable than the seed of dry-seeded crops because it is better protected from disease while it matures inside the fruit. Many of these crops tolerate and sometimes desire higher temperatures and humidity than dry-seeded crops during maturation and harvest.

Seed Crop Climate Categories

Wet- and dry-seeded crops can be further categorized into cool season, dry seeded crops; warm season dry-seeded crops; hot season, dry-seeded crops; and hot season, wet-seeded crops. These delineations further assist in determining which seed crops are most appropriate and most likely successful depending on location.

Cool Season, Dry-Seeded Crops

These crops do best with a fairly long spring season of cool and wet weather and mild temperatures (less than 75°F (24°C)) during flowering and early seed development. Gentle rains and mild winds in the mid-summer followed by dry conditions in the late summer and early fall are ideal for the maturation and harvest of these seed crops. Examples of cool season, dry-seeded crops include spinach, table beets, Swiss chard, turnips, many mustards, Siberian kale, rutabaga, parsnips, and cilantro.

Warm Season, Dry-Seeded Crops
These crops are very similar to the cool season, dry-seeded crops, but prefer slightly warmer and drier spring weather. They also need warmer summer temperatures during flowering (greater than 80°F (27°C)) for optimal pollination and seed set. Warm season, dry-seeded crops need a slightly longer rain-free period for full maturation and harvesting than their cool season counterparts. Examples of warm season, dry-seeded crops include radish, most kales, collards, cabbage, lettuce, peas, and fava beans. Swiss chard and turnips are fairly flexible seed crops that can be produced in both cool and warm season climates, although in general they will both do slightly better in the warmer season climates.

Hot Season, Dry-Seeded Crops
These crops are at their best with warm spring weather and generally require early irrigation. They prefer hot and dry conditions that persist throughout the summer and fall. During flowering and early seed set they like temperatures to rise into the mid 80s°F (27°C) and after flowering they prefer even higher temperatures, into the mid-90s°F, for full seed development and maturation. Examples of hot season, dry-seeded crops include garden beans, dry beans, lima beans, edamame, carrots, onions, and sweet corn.

Hot Season, Wet Seeded Crops
These crops like it hot. They like warm springs and hot summers with warm nighttime temperatures. Warm spring days that average around 65°F (18°C) and hold their warmth into the night help these crops establish strong early growth and realize high-yielding, fully pollinated fruits. High temperatures, in excess of 90°F (32°C), are easily tolerated during flowering and early fruit and seed set of these crops. Moderate to high humidity conditions are also good for the growth of their wet fleshed fruits. They can tolerate somewhat drier conditions and still produce, but might not yield quite as well as they would with a bit of moisture in the air. Crops in this category include summer and winter squashes, cucumbers, melons and watermelons, tomatoes, peppers (hot and sweet types), and eggplants. However, there are always exceptions and it should be noted that cucumbers prefer slightly cooler peak temperatures (less than 80°F (27°C)) and tomatoes prefer slightly hotter peak temperatures (greater than 90°F (32°C)) than described.

Genetic Diversity and Genetic Selection in Reproductive Success

Genetic diversity is essential to plant success and the continual evolution and adaptability of food crops. This diversity allows food crops to tolerate and thrive under a multitude of stressful and variable environmental and climatic conditions, and is the root of their ability to adapt to new conditions and surroundings. Different genetic combinations confer differing levels of resistance to a variety of diseases, pest pressures, infections, and a multitude of abiotic (physical) stressors. These differing gene combinations are expressed as variations in growth characteristics and qualities (such as plant size, shape, color, taste, and architecture) that result in successful survival and reproduction.

Plant breeding and seed production are essentially human-guided evolution. Humans impose goals and desires on the course of crop development by choosing plants with desired qualities and characteristics and allow them to reproduce and produce

Genetic diversity is key to the continued evolution of our food crops. Pictured here is the Pungent Mustard Mix from Wild Garden Seed. *Photo credit: Wild Garden Seed*

seed for the next generation. In contrast, natural selection is based solely on survival; whether or not a plant can survive long enough to produce and mature seed. Plant breeding directs evolution toward desired goals, be those to increase the size of the edible part(s) of a plant, to produce more succulent and edible leaves, or get bigger berries and fruits. Many of the brassica crops offers an interesting example of the power of plant breeding and goal-oriented selection. European kale, cabbage, broccoli, cauliflower, and kohlrabi were developed from a common ancestor. Differing selection goals resulted in an amazing array of diverse food crops from these early food plants. For instance, selection for edible leaves produced kales, selection for prepubescent and primordial flowering parts produced broccoli and cauliflower heads, and selection for swollen stems resulted in kohlrabi.

Genetic diversity also allows crops to be adapted to regions far from their centers of origin. For example, chili peppers, originally from Central and South America, are now part of the Hungarian and Thai diet. Corn from Mexico fed the native tribes of the U.S. northern Great Plains. This diversity means that some varieties perform better than others under climatic and environmental challenges. There are tomatoes that set fruit sooner than others after a cool spring and there are some kales that survive or even continue to produce through extremely cold winter temperatures. Identifying varieties with the qualities necessary for robust growth and quality seed set are essential to successful seed production.

Selecting Appropriate Species and Varieties for Location

Different varieties of the same crop vary in their responses to crop stresses. This genetic breadth offers an opportunity to enhance crop growth under environmental, pest, pathogen, and climatic constraints by identifying varieties least affected by the prevailing stress conditions of a particular location. Conducting a ***variety trial,*** or series of them depending on the breadth of the needs and interests of the grower, helps determine which varieties are best suited for a particular location.

A variety trial is a scientific experiment in which the hypothesis is that some of the varieties have

Farmers and researchers evaluating an overwintering kale trial in Port Townsend, WA. *Photo credit: Organic Seed Alliance*

more desirable characteristics or genetic traits than the others. The goal of the variety trial is to identify the best varieties for a location, market, or production system. As with any scientific experiment, following a rigorous experimental design increases the likelihood that the measured results will be due to the treatment, in this case of the variety, rather than from an external influence.

Before seeking out varieties and beginning a trial, it is helpful to create as complete a description as possible of ideal crop characteristics, desired crop traits, and trial goals. This will ensure that seed sourcing, trial planning, and experimental design will result in useful information. Consider the primary challenges in producing seed of the chosen crop and what characteristics and traits will be critical for success. Be sure to take into account the prevailing environmental conditions of the location throughout the entire life cycle of the seed crop to ensure that all vernalization, pollination, seed set, and seed maturation requirements can and will be met. Variety trials require time and attention to produce successful and valuable results.

If a desired variety is found, but some aspects of it are dissatisfying, additional trials of that particular variety can be conducted using as many seed sources as possible. The performance of a variety can be strongly dependent on how well it has been cared for and maintained by a seed company, breeder, or seed producer. The same variety from several seed sources can exhibit widely variable performance and yield. This can be especially true for open-pollinated, cross-pollinated crop. Use descriptions in trusted seed catalogues or suggestions and input from fellow local growers in the area when selecting varieties to include in the trial.

For further information and guidance on conducting a variety trial, please refer to OSA's *On-farm Variety Trials: A Guide for Organic Vegetable, Herb, and Flower Producers*. This is available as a free download at www.seedalliance.org.

V. History and Geography of Seed Production in the NW

A century ago it was not uncommon for many farmers to produce much of the seed that they used on their farms. At that time most American seed companies were producing seed mainly in the East and Midwest, and much of the high quality commercially produced seed was still coming from northern Europe. It wasn't until the beginning of the 20th century that American seed companies first discovered the advantage of the seasonally dry climates of many western U.S. valleys for producing high-quality seed. Just as the first commercial seed crops were beginning to take root in the West there was a breakdown in the seed supply from Europe due to the outbreak of World War I. The combination of these two factors then became major drivers in the development of commercial seed investment in Washington, Oregon, and Idaho.

There are several regions in the NW of the U.S. that have a history of seed production, in part because they offer ideal climates for production of specific seed crops. The following information is meant to provide insight and detail on the history and climatic conditions of several of the key seed production regions of Washington, Oregon, and Idaho. The seed crops that have been historically established and regionally successful in each of these states are good crops to consider starting with for those who are new to seed production. It is possible to successfully grow and produce quality seed of the historically "abandoned" crops of an area (seed crops that were once grown in a region but are no longer considered to be crops of economic importance), although the yields may be somewhat reduced in comparison to production of the same seed crop in a more ideal climate. Depending on the scale of your operation and the intended use of your seed crop this may not be an issue or a concern for you.

If you are growing in a region outside of these select areas then the best method to determine which seed crops will be best for your location is to identify which crop climate category you are located in and compare and contrast your conditions to the regions described below. Similar conditions and microclimates are often found outside of these key production regions. For example, the eastern most counties of Oregon and Washington have similar climates to the Treasure Valley of Idaho, and indeed many of the same crops that grow well in Idaho can be produced there. In some cases producing a crop in a region with a similar climate to a major production region, but not within that region, can be advantageous. Growers outside of the major regions of production may encounter fewer pests, disease, and pollination isolation issues than are common within the primary production region of a particular crop.

Washington

History of Seed Production in Washington

Commercial vegetable seed production has existed in the Skagit Valley of Washington for nearly 120 years. In the late 1800s the first commercial cabbage seed crops were grown in the Skagit for limited local sales. This regional market was quite small as most North American farmers were either producing much of their own seed or were buying seed from seed companies in the eastern U.S. Unlike some other western valleys that had started producing larger quantities of vegetable seed by World War I, the Skagit Valley didn't start becoming a major seed production area until the late 1920s.

In the late 1920s the Alf Christianson Seed Company was established in the Skagit Valley to take advantage of the ideal climate for cabbage seed production. Soon after the Skagit Valley also became a major vegetable seed production area for table beets, turnips, spinach, collards, mustard, and rutabaga. The fact that cabbage was the leading leafy green vegetable in North America at this

Cabbage seed field on Whidbey Island, WA. *Photo credit: Organic Seed Alliance*

time was fortuitous for the budding seed industry in western Washington. Spinach, turnips, and table beets were also widely eaten during that time, lending further support to seed production in the region and allowing the number of acres planted to seed crops in the Skagit Valley to increase quite rapidly.

The real boom for the Skagit Valley and many other western seed producing valleys was during World War II years, with Nazi occupation of several key seed growing regions of northern Europe. The demand for American vegetable seed increased dramatically with this development, both for North American use and for many places around the globe that had been customers of the European seed industries. Many of these markets were now open to U.S. seed companies and continued to be long after the end of the war.

Seed production of many of these same vegetable crops is also done successfully in other areas around the Salish Sea maritime region of western Washington. Sequim, located on the northern coast of the Olympic Peninsula, with slightly milder temperatures than the Skagit, is ideal for growing high-quality cauliflower and Brussels sprouts seed crops. Directly south of the Puget Sound, the agricultural land near Chehalis, Washington, offers a great climate for growing many of the cool season crops that are more tolerant of heat, like Swiss chard, turnips, collards, and kale.

Starting in the 1930s, the Columbia Basin Reclamation Project was initiated in south-central Washington to dam the Columbia River to develop agriculture in the rich, fertile soils of the region. By the late 1940s the first irrigation water flowed from the dams and soon after a number of seed companies began growing seed crops in this prime arid agricultural region. The seed crops that have proven to be most successful here over the years include carrot, onion, radish, collards, kale, turnip, kohlrabi, dill, and cilantro. The Columbia Basin has become a major global producer of onion, carrot, and cilantro seed. To the east of the Columbia Basin is the Palouse region of Washington, Oregon, and Idaho, where large quantities of commercial pea seed are grown.

Climate of the Skagit Valley of Washington

The Skagit Valley is an ideal area for growing many cool season, dry-seeded crops. There are many microclimates within the Skagit Valley, so it is vital that growers become familiar with their local climate. On average, spring temperatures range from 48°F (9°C) to 72°F (22°C). Summer temperatures are typically in the low 80s° F (28°C) during late July and early August. These mild summer daytime temperatures that rarely exceed 80°F (27°C) are found in very few agricultural regions on Earth and are what make the Skagit such an ideal climate for these cool season seed crops. Fall daytime temperatures are generally in the mid 50s°F (13°C) to low 60s°F (17°C) and winter temperatures are consistently in the upper 40s°F (9°C) with some pleasant days in the mid 50s°F (13°C). These temperatures

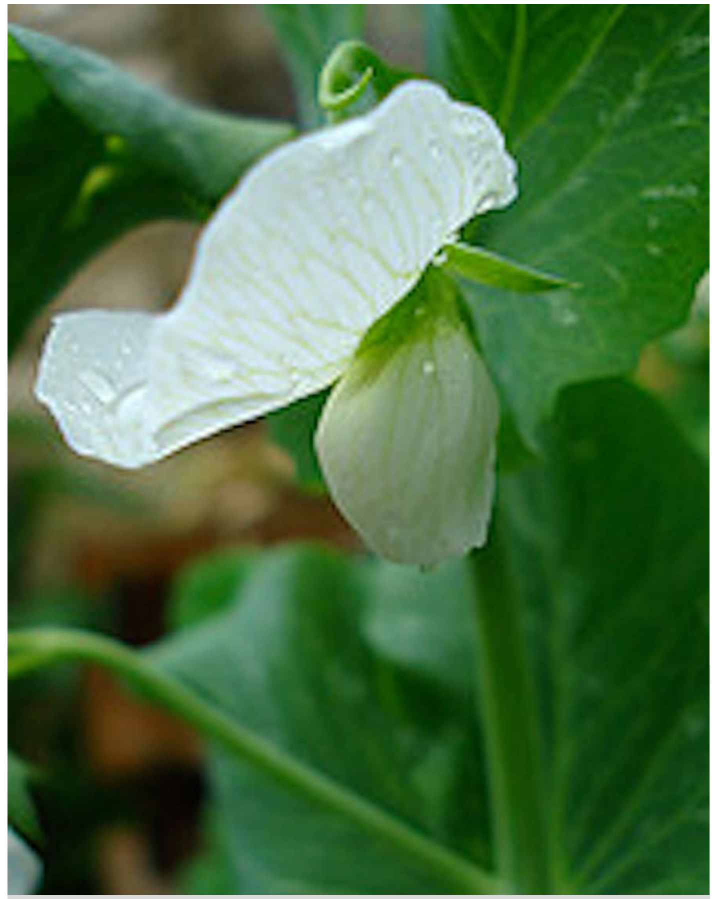
Spinach seed production field. *Photo credit: Organic Seed Alliance* enable a number of the biennial seed crops to continue slowly growing throughout the winter when they are overwintered in the field.

Winter nighttime low temperatures are usually in the 30s° to mid 20s°F (-4°C). However temperatures can dip down into the 10s°F (-9°C), which can cause damage to biennials in the field. Every few years there are dips into the single digits in the coldest parts of the valley, which can wreck havoc on overwintered crops. Some biennial root crops are routinely “pitted,” which entails topping and windrowing the roots on the ground and covering them with 12 – 18 inches (30 – 46 cm) of soil. The soil covering protects the roots and allows them to withstand colder temperatures. Leafy biennials will overwinter most successfully at a smaller frame size (compared to normal, vegetative production size), which increases their tolerance of cold. A small amount of snow is possible in most years and when snow falls before a cold snap it will add an extra layer of protection for any overwintering crops in the field.

The last killing frost in spring usually occurs around April 15th, and the first killing frost in the fall can normally be expected anytime from late-September to mid-October. The average rainfall for the valley is anywhere from 30 to 60 inches (75 – 150 cm) annually, depending on location. The majority of the rainfall occurs between November and late May. Winds in the area are generally out of the West, though the warmest weather patterns often come out of the South and the coldest arctic blasts that cause the hardest frosts in December and January often come from the North.

Climate of the Palouse of Washington, Idaho, and Oregon

The Palouse is an unusual native grassland prairie that encompasses parts of southeastern Washington, north central Idaho, and northeastern Oregon. It is characterized by rolling countryside largely made up of silt dunes that were formed as loess soil was deposited by wind from glacial till after the last ice age. The loess, or wind blown silt soils, of the region are very productive agricultural soils that are used to produce an abundance of dryland wheat and several pulse crops. Pea seed is the primary vegetable seed crop grown commercially in this region, with some other minor pulse seed crops occasionally grown. This region is well suited to growing seed of pulse crops that are most productive under extended cool spring conditions with occasional rain that supports luxuriant growth with ample flowering and pod set that take place before temperatures get hot in mid-July. The warm, dry growing season makes this region best suited for crops in the warm season, dry-seeded climate category.



Peas need to be planted early enough to achieve flowering and pollination before peak heat sets in. *Photo credit: Christian Guthier*

The Palouse region includes many microclimates due to the variable terrain from sloping hillsides to valleys with occasional flat land. This area has large diurnal temperature fluctuations throughout the year making it a challenge for wet-seeded, hot weather crops. It is not uncommon for nighttime temperatures to drop 20° to 40°F (11° to 22°C) below the daytime highs. Springtime temperatures are warm with highs in the upper 40s°F (9°C) in March to the mid-70s°F (24°C) in June, with nighttime temperatures from the low 30s°F (1°C) to the upper 40s°F (9°C) during this time. Frosts can occur anytime throughout the spring and occasionally into June. Summer weather can be hot with high temperatures frequently in the mid-80s°F (30°C) through August, declining to the mid-70s°F (25°C) in September. Nighttime summer temperatures are generally in the mid-50s°F (12°C) and drop into the low 40s°F (6°C) by late September.

The first killing frost can arrive as early as mid-September. Winters can be very cold, making overwintering biennials in the field a challenge. However, the weather can also be mild, depending on the year and your particular location, due to the moderate conditions of Pacific fronts coming across the Cascades to the West. Winter daytime temperatures are frequently in the upper 30°s to mid 40s°F (3° to 7°C). Nighttime temperatures regularly drop into the low 20s°F (5°C). Cold snaps that bring temperatures in the teens (10° to 17°F, -12° to -8°C), and occasionally as low as 0°F (-18°C) are not uncommon in early January. Much of the annual precipitation comes in the winter months between October and May as both snow and rain. Spring rains of up to 2 inches (5 cm) frequently occur in May and June and contribute to healthy robust crop growth under dryland conditions. The annual average rainfall for the Palouse is anywhere from 10 to 25 inches (25 to 60 cm). The months of July through September experience the seasonal dry weather common to the Northwest.

Climate of the Columbia Basin

The term Columbia Basin refers to the irrigated agricultural lands of south-central Washington that stretch northward from the confluence of the Columbia and Snake Rivers at Pasco to Grand Coulee near the northern end of the Columbia Plateau. This productive, fertile agricultural region is irrigated from water held at several dams that adjoin the Grand Coulee dam, which is the largest water reclamation project in North America, supplying an annual flow greater than that of the Colorado River. This region has a desert climate with less than 10 inches (25 cm) of precipitation per year, most of it coming between the months of November and May. The hot, dry summers are ideal for growing many of the warm-season, dry-seeded crops and most of the hot-season, dry-seeded crops.

Spring weather in the Columbia Basin can warm up earlier than other parts of the Northwest with daytime temperatures often in the upper 40s°F (9°C) in March and climbing to the mid-70s°F (24°C) by early May despite a relatively high number of overcast days during the spring season. The last spring frost can be anytime from late April until mid-May depending on the specific microclimate and the year. Nighttime temperatures by late May are consistently in the low 50s°F (12°C) and many of the seed crops are growing vigorously under irrigated conditions. The main hindrance to crop establishment and growth during the spring is the extreme wind events, with wind speeds of 35 – 40 mph (55 to 65 kph) that routinely occur throughout the region.

Summer weather after July 4th can be hot, reaching 90°F (32°C) regularly, with occasional hot spells that can go into the upper 90s°F (36°C) during late July and early August. The juxtaposition of relatively mild but warm springs coupled with hot dry summers is why the Columbia Basin is a favorable climate for both the warm-season and hot-season, dry-seeded crops. Fall weather is also very favorable to the maturation and harvest of dry-seeded crops in most years as the temperatures slowly decline to the mid-70s°F (24°C) by mid-September and closer to 60°F (15°C) by early October. The first frost, and first fall rain, usually occurs in mid-October with some variation based on location and year. The prolonged fall growing season makes this area an ideal location for obtaining very high-quality clean mature seed for high-cash value crops like carrot and onion seed.

Onion seeds heads in the field. *Photo credit: Organic Seed Alliance*

Fall daytime temperatures are generally in the low 40s°F (6°C) by mid-November with hard frosts occasionally getting to the lower 20s°F (-4°C). Therefore, any cultural practices like the hilling of overwintering root crops for seed must occur by this time of the season to protect the crops from the dry cold conditions. Winter temperatures are at their lowest from mid-December through late January when many days hover at 32°F (0°C) and nighttime temperatures can often drop to the low 10s°F (-11°C). On occasion the nighttime lows can drop as low as 5°F (-15°C). This is when there is the greatest threat of losing the onion or carrot plants in the field. A small amount of snow is possible in most years, which can insulate crops if they are well covered by it, but the snow rarely stays on the ground for more than several days.

Oregon

History of Seed Production in Oregon

Commercial vegetable seed production has existed in Oregon for at least 100 years. Like Washington, Oregon has several distinctly different climatic regions that are conducive to a wide range of seed crop production. In the early years of commercial seed production in the Willamette Valley farmers experimented with growing many different seed crops. While some seed crops like carrot, cauliflower, many cabbages, and most melons were not ideally suited to the Willamette Valley, the growers there did find that crops like turnip, parsnip, mustard, Chinese cabbage, squash, and sugar beets gave them world class yields of high quality seeds. Crops like onion and table beet were produced in the valley early on but their production moved as the other seed growing areas across the west sorted out which crops were best suited to which areas. Carrot seed production would find a home in central Oregon and several of the heat loving crops such as onion would eventually be grown in Malheur County on the other side of the state on the Idaho border. Over the past 60 years vegetable seed has also extended to the higher elevation areas in central Oregon, mainly around Madras, and to the hot southern reaches of the Rogue River Valley near Medford.

Climate of the Willamette Valley of Oregon

The Willamette Valley is an ideal area for growing warm-season, dry-seeded crops, as well as some of the hot-season, dry-seeded and wet-seeded crops. There are many microclimates within the valley that make this possible, so it is very important for growers to learn the finer points of their local climate. On average, spring temperatures range from the mid-50s°F (13°C) to the low 70s°F (22°C). Summer weather after July 4th can be quite warm, regularly reaching 80° to 90°F (27° to 32°C) and occasionally into the 100s°F (38°C) during late July and August. The summer high temperatures combined with warm summer nights make it possible to grow both warm- and hot-season, dry- and wet-seeded crops in the Willamette Valley. Fall temperatures are generally in the upper 50°s to low 60s°F (14° to 17°C) and winter temperatures are consistently in the upper 40s°F (9°C) with some pleasant days in the mid-50s°F (13°C). These temperatures enable some biennial crops to grow a bit through the winter when they are overwintered in the field. Winter nighttime low temperatures are usually in the mid-30s° to upper 20s°F (2° to -2°C), however temperatures can dip into the mid-10s°F (-9°C), which can sometimes damage overwintering biennials in the field. A small amount of snow is possible in most years, which can insulate crops if they are well covered by it, but the snow rarely stays on the ground for more than a day or two when it does come.

The last killing frost in spring usually occurs around April 15th and the first killing frost in the fall can normally be expected in mid-October. The average rainfall for the valley is anywhere from 30 to 60 inches (75 to 150 cm) annually depending on

Pictured here is Brightest Brilliant Rainbow quinoa, a variety developed by Wild Garden Seed for production in the Willamette Valley and similar climates *Photo credit: Wild Garden Seed* location, with most of that falling between November and late May. However, frequent light rain and cool temperatures can continue through June with reliably dry and warm weather arriving after July 4th. The fall rains usually return by late September or early October. Winds in the area are generally out of the west, though the warmest weather patterns often come up from the south and the coldest arctic blasts that cause the hardest frosts in December and January often come from the north.

Climate of Central Oregon

The high desert regions of central Oregon are characterized by semi-arid climates with seasonally sunny days and cool nights that are well suited for warm-season, dry-seeded crops. This region includes Deschutes, Jefferson, and Crook counties. They are in the rain shadow on the eastern side of the Cascade Mountains, with most of the precipitation falling in the winter months between November and March, usually in the form of snow. While there is agriculture at elevations throughout this region where ground water is available for irrigation, most of the vegetable seed production is done in the Madras area. While limited vegetable cropping is practiced from Bend northward to Hood River, near the Columbia River, the southern end of this region has higher elevations and a very short growing season where it is possible for frosts to occur any month of the year. The elevation gently decreases as you move northward along this region from almost 3700 feet (1125 m) near Bend to around 2000 feet (610 m) near Madras, and continuing to decline until you reach the Columbia River. Both small and large variations in the topography of this region result in numerous microclimates, so it is important to learn the local climate when considering which seed crops to grow. This high desert terrain, like most mountainous regions of the West has large diurnal temperature fluctuations throughout the year. It is not uncommon for nighttime temperatures to drop 20° to 40°F (11° to 22°C) below the daytime highs. The dry summer and fall growing season make this region well suited to maturation and harvest of dry-seeded crops.

Springtime high temperatures in the Madras area range from the mid-50s°F (12°C) in March to the mid-70s°F (24°C) in June. Average nighttime low temperatures during this time range from the low 30s°F (1°C) to the mid-40s°F (7°C), although frost events can occur anytime through early June. During the summer, July and August temperatures reach into the mid-80s°F (30°C) and then start to decline to the mid-70s°F (25°C) in September. Occasional heat spells in summer can push daytime temperatures into the 90s°F (35°C). Nighttime summer temperatures are generally in the mid-50s°F (12°C) and drop into the low 40s°F (6°C) by late September. The first killing frost can be as early as mid-September. Temperatures steadily decline in the fall months with October daytime highs in the low 60s°F (17°C) and November in the upper 40s°F (9°C). Fall nighttime temperatures are often in the mid-30s°F (2°C) with frequent forays into the mid-20s°F (-4°C). Winter temperatures are regularly in the low 20s°F (5°C). The lowest temperatures of the winter, usually arriving in late December or early January, can get down to 8° to 14°F (-13° to -9°C) and sometimes colder. However this only occurs in an unusually cold year. These low temperatures can potentially cause damage to biennials that are being overwintered in the field.

Climate of the Rogue River Valley of Oregon

The Rogue River Valley is an ideal area for growing many warm- and hot-season, dry-seeded crops as well as some hot-season, wet-seeded crops. In general this region enjoys hot, dry summers with cool nights throughout the growing season and winters that are fairly mild. However it is possible for this area to get winter cold snaps that can damage overwintering crops. Many warm-season crops produce good quality seed in this region as spring weather is more moderate than in many true hot-season climates. Another factor here is the substantial range in the elevation that occurs across the valley, creating numerous microclimates that can see significant variation in both temperature and precipitation throughout the year. This variability can be challenging for predicting the performance of vegetable seed crops. Growers must become familiar with their local microclimate and how it affects each crop's performance.

Daytime temperatures in spring usually range from 60° to 75°F (16° to 24°C) with substantial drops in nighttime temperatures, that can fall into the low 30s°F (1°C). Some areas experience occasional frosts as late as early June. Growers in all locations can expect frost events until mid-May in most years. Unlike many other regions of the Northwest, June can see warm daytime highs that reach into the mid-80s°F (30°C) when skies are clear. These late spring and early summer high temperatures are why it is difficult to produce cool-season vegetable seed in this area, as high temperatures during flowering and the early stages of seed setting can retard the development of high-quality seed in these crops. Any attempt to grow cool-season, dry-seeded crops will require planting dates that are early enough to ensure that the crop is flowering and setting seed during cooler periods in May or early June. The summer weather from July through September is quite warm, with temperatures regularly reaching the mid-90s°F (24°C) and heat waves that can crest to over 100°F (39°C). This can be challenging for production of many of the warm-season and even some of the hot-season, dry-seeded crops, particularly if heat arrives during flowering and early seed formation, as seed quality can suffer when temperatures are above the low 90s°F (33°C) during this critical growth period.

One moderating influence of this climate is that even during the hottest summer weather, the nighttime temperatures will often drop into the mid-50s°F (13°C), making the duration of the hot daytime temperatures shorter and potentially less damaging to the reproductive cycle than they would be in a climate with high daytime temperatures followed by warm nights. However, these cool summer nighttime temperatures can be problematic for some of the wet-seeded crops that like warmer nights that don't drop below the mid-70s°F (24°C). The hot-season, wet-seeded crops can be successfully grown here, but with the cooler nights reduced seed yield, seed size, or germination percentage can be expected compared to seed of the same crops grown in regions with warmer nights.

Fall daytime temperatures during October and November are consistently in the 50° to 60°F (10° to 16°C) range, usually dropping into the low 40s°F (22°C) at night. These conditions are excellent for the maturation and harvest of many warm- and hot-season, dry-seeded crops. Daytime temperatures then drop off to the upper 20s°F (-2°C) to mid-30s°F (-2° to 2°C) through the coldest weeks of late December and January. Some pleasant sunny and warm spells can occur during winter, bringing daytime highs that occasionally jump up into the low to mid-60s°F (18°C). These temperatures enable some biennial crops to continue to grow somewhat throughout the winter when they are overwintered in the field. Extreme cold snaps from the north and northeast that can cause temperatures to drop into the 5° to 10°F range (-15° to -12°C) are possible during December and January. These temperatures can easily damage and kill many common overwintering vegetables, including most of the biennial seed crops. However, not all winters get this cold in the Rogue River region, with some winters experiencing lows of only 15° to 22°F (-9° to -6°C) at their coldest. This fact, coupled with the varied microclimates in the region, means that it may be possible to overwinter biennial crops in many, if not most, winters, especially if the crop is protected by row cover or by hilling it with soil. A small amount of snow is possible in most years, which can insulate crops if they are well covered by it, but the snow rarely stays on the ground for more than a day or two when it does come. Annual rain is fairly moderate in the Rogue River Valley, ranging anywhere from 20 to 40 inches (50 to 100 cm) depending on location, with most precipitation occurring from mid-October through April.

Idaho

History of Seed Production in Idaho

Vegetable seed has been grown commercially in Idaho for more than 90 years. In the early years

Carrot seed crops are successful in the Treasure Valley. Shown here are carrot umbles in early seed set. *Photo credit: Organic Seed Alliance* of growing seed in the Idaho valleys of the Snake River Plain there were many attempts to grow different seed crops. While some crops like onions, carrots, peas, beans, and sweet corn would eventually take a prominent place in the local agricultural economy, there were others like cabbage, squash, cucumbers, and pumpkins that were more ideally suited to other areas of the West and would not become commercially established in Idaho.

Climate of the Treasure Valley and the Magic Valley of the Snake River Plain

The Treasure Valley is part of the Snake River Plain of southern Idaho and along with the Magic Valley to its east, is an ideal area for growing hot-season and many warm-season, dry-seeded crops as well as several of the hot season, wet-seeded crops. The cool spring weather coupled with relatively hot, dry summers and comparatively mild winters make this region a world-class seed production area for snap bean, carrot, onion, and sweet corn seed production. On average, spring temperatures range from the high 60s°F (20° to 25°C) to the mid-to-high 70s°F (25°C). The summers can start in earnest in mid June with temperatures nearing 80°F (27°C) and then getting well into the low 90s°F (33°C) by late July and August, with possible spikes reaching into the low 100s°F (38°C) during heat waves. Nighttime temperatures in summer are often in the mid 60s°F (19°C). Fall daytime temperatures in September and early October average in the low 70s°F (20°C) and weather often remains dry until late September, which is ideal for maturation and harvest of dry-seeded crops. Nighttime temperatures during this period are often into the mid 40s°F (7°C) and the first fall frost usually occurs in the Treasure Valley by early to mid-October and in the Magic Valley it is often two to three weeks earlier. Magic Valley weather is also frequently 5° to 7°F (3° to 4°C) cooler than the Treasure Valley throughout the growing season.

Fall rains come in October to this region and most yearly precipitation occurs between October and May. Winter weather usually begins in late November with possible snowfall coupled with temperatures that regularly go down to the mid-20s°F (-4°C). Winter low temperatures usually occur in late December and early January, and are often 15° to 22°F (-9° to -6°C) for a few days. These temperatures will usually not hurt the carrot or onion crops that are in the field overwintering if these crops are at a proper size for optimum frost tolerance and properly hilled with soil to help protect them. Winter temperatures will occasionally drop into the single digits and can dip below 0°F (-18°C), which can put overwintered seed crops at risk in some years. It is possible to get snow during the winter, although it rarely stays on the ground for more than a few days. If it does occur before a cold snap, and it covers the crop, the snow can help insulate and protect an overwintering crop in the field.

Climate of Northern Idaho

North Idaho is the northern region of the Idaho Panhandle, north of the Idaho Palouse, and nestled between the Selkirk, Cabinet, and Bitterroot Mountains. This rolling countryside has a diverse agriculture and weather system that is influenced by Pacific weather patterns that result in relatively mild weather. This region is well suited to a number of both cool- and warm-season, dry-seeded crops. As summers seem to be getting hotter in the past decade there are also growers who are experimenting with a number of hot-season wet- and dry-seeded crops.

Spring weather tends to be cool and have even rainfall, with daytime temperatures that range from the mid-40s°F (7°C) in March to the low 70s°F (23°C) in mid-June. This is ideal weather to grow many cool-season, dry-seeded crops, especially if they flower and produce their initial seed set before the temperatures reach the low 80s°F (28°C) in mid-July. The last killing frost in the spring can arrive anytime between the end of April through the middle of May. Nighttime average temperatures steadily rise from the mid-30s°F (2°C) in early April to the upper 40s°F (9°C) by mid-June. As in much of the Northwest, summer weather doesn't kick in until after July 4th. For summer days in July and August, temperatures routinely reach the mid-80s°F (30°C) with occasional hot spells that exceed 90°F (32°C). However, even during the hottest period of the summer, the nighttime temperatures still tend to drop to the upper 50s°F (14°C). Both cool- and warm-season crops do not have a problem with these cool nights, but they can limit the potential for commercial success with the both the dry-seeded and wet-seeded hot-weather crops.

This does not mean these crops cannot be grown, but the seed yield, seed size, and even the germination rate may be greatly diminished compared to production in warmer regions.

Fall daytime temperatures range from the low 70s°F (22°C) in late September to the low 40s°F (6°C) in November. The first frost can arrive anytime from mid-September to mid October. Nighttime temperatures in fall range from the low 40s° to the high 20s°F (-3° to 6°C) through the end of November. This allows for seed harvest of many of the cold-hardy crops if dry weather prevails during the early fall. By December temperatures from the mid-30s°F (2°C) to the low 20s°F (-5°C) prevail with the coldest weather usually coming at the end of December through early February. Growers can usually expect at least seven to 10 days of temperatures between 10° and 17°F (-12° to -8°C). Historically, arctic cold snaps have occurred during winter months, bringing temperatures below 0°F (-18°C) in many years. The occurrence of these arctic cold snaps has been less and less common over the last decade, but anyone considering growing biennials or overwintering crops of any kind should realize this potential for serious cold damage.

Yearly precipitation averages between 20 and 32 inches (50 to 80 cm) across North Idaho. Rains generally arrive in mid-September and last until the following June. Much of the precipitation during the winter months is in the form of snow. These winter snows can bring significant accumulations of 12 inches (30 cm) or more during the coldest stretches of December and January. If this snow is present during the coldest parts of winter it can act as a layer of insulation for any overwintering seed crops out in the field.

VI. References and Resources

Organic Seed Alliance Publications

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Note: The following Extension publications are available from: https://cru84.cahe.wsu.edu/Default.aspx (search for "seed and crop name") (verified 16 October 2013).

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Kale and Collard Seed Production in the Pacific Northwest. M. L. Jarmin and R. E. Thornton. 1985. Pacific Northwest Cooperative Extension Publication 269.

Lettuce Seed Production in the Pacific Northwest. W. M. Colt, R. G. Beaver, W. R. Simpson, and C. R. Baird. 1985. Pacific Northwest Cooperative Extension Publication 273.

Mustard and Chinese Cabbage Seed Production in the Pacific Northwest. M. L. Jarmin and R. E. Thornton. 1985. Pacific Northwest Cooperative Extension Publication 270.

Radish seed production in the Pacific Northwest. W. M. Colt, R. G. Beaver, W. R. Simpson, and C. R. Baird. 1985. Pacific Northwest Cooperative Extension Publication 274.

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Turnip and Rutabaga Seed Production in the Pacific Northwest. N. S. Mansour, J. R. Baggett, and M. Jarmin. 1985. Pacific Northwest Cooperative Extension Publication 265.

Washington's Small Seeded Vegetable Seed Industry. J. Thomas et al. 1997. Washington State Extension EB1829.

Additional References and Resources

History of Specialty Seed Crop Production in the Pacific Northwest. R.L. Rackham. 2002. Willamette Valley Specialty Seed Crops Association, Corvallis, OR.

Climate Crop Table

	Crop Type	Dry-Seeded	Wet-Seeded
Climate	Cool-Season	Spinach, table beets, Swiss chard, turnips, Asian greens, many mustards, Siberian kale, rutabaga, parsnips, cilantro	
	Warm-Season	Radish, most kales, collards, Swiss chard, sugar beets, some cabbages, lettuce, celery, parsley, peas, fava beans, some common beans	
	Hot-Season	Garden beans, dry beans, lima beans, edamame, carrots, onions, sweet corn	Summer and winter squashes, cucumbers, melons, watermelons, tomatoes, peppers, eggplants

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