Climate and Vegetable Production

The Atlantic region provides a variety of growing conditions. Coastal areas have a long but cool growing season, while sheltered inland valleys have a shorter but much warmer growing season. Areas which have warm summers can still experience very cold winters which cause problems with survival of perennial crops. The temperature at Fredericton, New Brunswick, ranges from an extreme maximum of 39° C to an extreme minimum of -39° C whereas at the coastal location of Yarmouth, Nova Scotia, the extreme maximum is 30° C and the extreme minimum is -20° C, a much narrower temperature range. Such variation in climate requires crop selection and management practices suited to the climate and soil conditions of the location.

The growing season in the Atlantic region is characterized by a cool wet spring, a warm summer with ample rainfall, but with occasional dry periods, and a cool wet autumn. The cool spring with generally high rainfall combined with heavy imperfectly drained soils, common in the region, creates field trafficability problems which delay spring field work and seeding. Delayed seeding means the crop is losing the benefit of any early warm spring days. A late-planted crop risks not reaching maturity or its maximum yield potential before fall frosts threaten. Late seeding also delays harvest to a time when high rainfall can once again cause field trafficability problems.

The growing season for frost sensitive crops is determined by the last spring frost and first fall frost. The frost-free period varies a great deal depending upon latitude, elevation, topography, and proximity to large water bodies. The frost-free period in Atlantic Canada is generally adequate for many vegetable crops; however, heat-loving, long season crops, such as tomatoes are limited to a few locations. Although coastal locations have longer frost-free periods, they do not have the high temperatures required for the rapid growth and maturity of warm season crops. The use of plastic mulches and tunnels can alter the microclimate of the crop to provide sufficient heat for crops such as peppers, melon and eggplant to reach maturity.

Reduction of frost risk and optimization of heat can be obtained by careful site selection, variety selection and management. Consideration of long-term climatic averages and extremes is essential for the successful introduction of new crops, new varieties, new hybrids, and the expansion of production into new areas.

The Climate of Atlantic Canada

Weather and climate dictate what crops can be grown in a region and are mainly responsible for the yearly variation of yields. The difference between weather and climate is that the former is concerned with rain, sun, heat, cold, or winds which happen now, while the climate is the long term average describing what generally happens.
There are four factors which determine the climate of a place;
- position on the globe,
- wind systems,
- the ratio of water to land, and
- topography.

Despite the maritime location of the Atlantic provinces, the climate is a modified continental type. A continental climate is characterized by a wide range of temperature, whereas, a maritime climate is characterized by a reduced temperature range because the ocean supplies heat in winter and provides cooling in summer. Areas near the coast have milder winters and cooler summers, with a longer frost-free period than inland locations. The advantage of a prolonged season however, is offset by the cooler temperatures and fewer heat units available for plant growth.

The wind direction and the relationship of land to water is a major factor determining climatic differences within the region. The southern coasts of New Brunswick, Nova Scotia, and Newfoundland have the highest annual precipitation in Atlantic Canada due to south-easterly storm winds blowing moisture laden air onshore. In contrast, the Northumberland coasts of New Brunswick and Nova Scotia, all of Prince Edward Island, and northern Newfoundland are in a "rain shadow". This means that south-easterly storm winds have already dropped most of their precipitation by the time they reach these areas and precipitation amounts are reduced.

Coast waters differ in the influence they have on the climate of adjoining land. The warm waters of the Gulf of St. Lawrence and especially the Northumberland Strait, do not provide as much cooling in summer as do the cool waters of the Atlantic. In winter, the Gulf waters are frozen and do not provide the warming the Atlantic Ocean does. For this reason, the Gulf waters are less effective in moderating the climate of Prince Edward Island, eastern New Brunswick, northern Nova Scotia, and western Newfoundland. The greatest moderating effect of the Atlantic is seen in southeastern Newfoundland, western Nova Scotia, and southern New Brunswick. The cold Labrador current, curving around Newfoundland’s Avalon peninsula makes this the coolest part of the province in summer and the mildest in winter. This same, although weakened current has a similar but reduced effect on the southeast coast of Nova Scotia.

Climatic Normals

A long period of weather observations is necessary to establish the normal climatic pattern for a given region. The term "Climate Normals" is used to describe the average data for a 30 year period.
Climatic normals represent the average of widely varied yearly values which occurred over the 30-year period. When evaluating crop performance in any given year, that year's weather should be compared with the long term climatic normals to judge whether the season and crop performance were normal.
Climatic normals provided by Environment Canada for 233 stations throughout Atlantic Canada can be found at http://climate.weather.gc.ca/climate_normals/index_e.html

Frost

Frost normals can vary significantly within short distances due to the effect of sloping terrain or large bodies of water. It is important to have a long period of record when mapping this parameter. The average frost-free period ranges from less than 70 days in central Newfoundland to 170 days in some Maritime coastal areas.

The average is sometimes not adequate for planning, because often it is the extreme event which can be disastrous. For this reason, extremes for the entire period of record should be examined before an important decision is made.

Degree-days (Heat-Units)

Temperature affects plant processes mainly by controlling the rate of growth. The concept of growing degree-days, or heat units, is based on the assumption that plant growth is related directly to the average temperature. There are however, certain minimum or "threshold" temperatures below which plants do not grow. For perennial plant growth, a threshold temperature of 5° C is commonly used, while for tender heat loving plants, such as tomatoes and beans, a base temperature of 10˚ C is more appropriate.

To compute degree-days for a particular day, calculate the average of the maximum and minimum temperature for the day. Then subtract the base temperature from the average temperature.
Example:
Maximum Temperature = 24˚ C
Minimum Temperature = 16˚ C
Average Temperature = 24 + 16 = 40/2 = 20˚ C
Degree-days above 5˚ C = 20 -5 = 15
Degree-days above 10˚ C = 20 -10 = 10
If the daily average temperature is below the base temperature, the degree-day value is zero. Negative values are not used because crop development is not reversed. When using degree-days it is important to know what base temperature and also what temperature scale has been used.

Average Annual Degree-days Above 5º C

The largest heat unit totals in the Maritimes are found in the Annapolis Valley of Nova Scotia, the Grand Lake area of New Brunswick, and the coastal area along the Northumberland Strait. Cold Atlantic waters reduce degree-day totals along the south and eastern shore of Nova Scotia and along the Bay of Fundy. This influence decreases with distance inland.

Degree-day normals are prepared by adding together the degree-days for each day of the month. Degree-day information is used to indicate how much heat is available in an area for crop production. By selecting crops or varieties with a heat requirement matched to the location, a successful harvest is more likely.

Corn heat units are widely used for corn hybrid maturity ratings. They differ from degree-days described above, in that the maximum and minimum temperature are used separately to assess the contribution to corn development. High maximum temperatures are preferred and are given more weight than cooler minima, which reflects the heat loving nature of the crop.

The Farm Level Climate

The climate at the farm level can often be different from the climate of the surrounding area. Local features all interact to produce a climate unique to the location. Knowledge of these factors, when used with the values indicated in the atlas, should provide a better indication of what to expect on the farm in the future. The factors that influence the climate at the farm level are;
- topography,
- slope and aspect,
- large water bodies,
- elevation, and
- wind.

Topography

Topography has a marked effect on the incidence of frost. After sunset the ground cools rapidly and its temperature soon falls below that of air in contact with it. The surface layer of air becomes cooler and heavier. Over sloping ground this cooled surface air tends to drain to lower levels and to collect in depressions or hollows. In a frost hollow, drainage of cold air into the depression results in frost much later in the spring and earlier in the autumn than at surrounding locations. Hillside locations will, on the average, tend to have longer frost-free periods than neighbouring stations on lower ground or in a valley.

Night winds influence temperature differences between hillsides and valleys on clear nights. The best conditions for cold air drainage are found when there is no general air movement. Even a light wind will serve to mix the relatively warm air above with the thin layer of surface air which has cooled through contact with the ground. Moderate winds will prevent differences in temperature between hillsides and valleys.

Slope and Aspect

Slope plays a major role in farm level climate. Valley bottoms experience colder nighttime temperatures and usually warmer daytime maxima than either midslopes or hilltops. The total heat units over an entire growing season are usually highest on midslopes, less on hilltops, and lowest in valley bottoms. This order is much more pronounced when heat units are accumulated between frost dates. Cold air running down the slopes and pooling in valley bottoms causes later spring and earlier fall frost dates. Hilltops usually have a shorter frost-free period than midslopes because of greater exposure to radiative loss to the atmosphere at night. Exposed hilltops have slightly cooler maximum temperatures than midslopes. In winter, midslopes accumulate more snow than hilltops, particularly on the lee side of the prevailing winds. The influence of aspect can change these relationships.

Aspect, or orientation to the direction of the sun, has two roles in crop production. In winter, south facing slopes produce warmer conditions that may result in harmful freezing and thawing cycles. Snow melt accounts for less depth and denser snow packs on south slopes. This results in a decrease in the protective value of the snow which may be important to overwintering perennial crops. In contrast, the growing season conditions are more favourable on south slopes. Warm south and west facing slopes provide more heat units and higher soil temperatures early in the season. Spring soil moisture conditions are generally wet, depending upon soil type. In this instance, south slopes have higher evaporative losses and field trafficability is earlier as a result. Droughty soils may be accentuated on south slopes.

Influence of Large Water Bodies

Large water bodies modify the local climate by warming in winter (if unfrozen) and cooling in summer. This effect is most pronounced near the coast but may extend inland several kilometers depending on elevation, topography, and prevailing winds.

Water bodies may also extend the frost-free period. Near the ocean at night, land breeze circulations draw cool air away from the land areas. Inland, large lakes and rivers heat the air which drains at night to the valley floor. Lakes and rivers also yield large amounts of moisture to the air. When this moist air cools, fog forms. All of these processes delay frost and extend the frost-free season.

Elevation

Elevation has the most influence on precipitation totals and heat unit accumulation. Generally, higher elevations have lower heat unit accumulation. Precipitation on the other hand, increases with elevation due to orographic lifting. When warm moist air masses are forced upwards by rising land, the air mass cools and the moisture is precipitated out as rain or snow. The proportion of precipitation that falls as snow also increases with higher elevation.

Wind

Exposure to high winds is usually detrimental to crop production, and many studies indicate better yields in protected or sheltered areas. Two suggested reasons for this are; desiccation of plants from high evapotranspiration losses, and physical damage to plants directly from the wind. The establishment of some barrier to the wind on the prevailing wind side may be required to improve the situation. If additional winter snow cover is desirable, wind breaks will increase this cover. In Atlantic Canada, summer winds are usually from the south and southwest while winter winds are from the west and northwest.

Water

The crop water balance is of great importance to agriculture. Top agricultural productivity depends not only on optimum temperatures but also on optimum water supply. Too much or too little water can be disastrous. Modifying the natural water regime in some way or other is a common management practice. Soil characteristics are important in the crop water balance and can be improved by increasing organic matter, for instance. Over the short term however, soil characteristics remain constant, whereas climatic factors such as rainfall and evaporation vary widely during the season, and from year to year.

Water Excess

The two major problems caused by excess water are i) poor field trafficability, and ii) poor or harmful growing conditions.

Wet soils are slower warming up in the spring because the sun's energy is used to evaporate water instead of warming the soil. If there is trash or mulch on the field, it will keep me soils cooler and wetter. Plowed land dries quicker because it has more surface area for evaporation and the upturned clods create wind turbulence which helps speed drying. Subsurface drainage has similar beneficial effects.

Excess water due either to rain or over-irrigation will cause delayed growth and maturity, and may encourage the development of disease problems, leaching of nitrogen and possible environmental concerns.

Water Deficits

Although severe drought rarely occurs in the Atlantic region, periods of prolonged dry weather have caused yield reductions in a variety of crops. Climatic data can help determine how often water deficits occur. There is considerable variability in water deficits within the Atlantic Region as a result of both climatic and soil variability.

The crop water balance depends on the kind of crop, the stage of development, soil characteristics, and the climate. Most crops will have higher yields when they have a steady adequate supply of water. In some instances it is necessary to irrigate to maintain optimum soil water content. Information on daily rainfall and evaporation, combined with crop and soil characteristics are the basic components of any weather-based irrigation scheduling system. The purpose of such systems is to estimate the soil water content so that the appropriate quantity of water can be applied at the right time to maintain optimum crop growth.

A loam soil will hold about 16 mm of water per 0.1 m of soil depth. The total water content in 0.5 m of loam top soil is about 80 mm however, only about 50% of the total water available can be removed before crop growth is slowed and only about 65 mm of soil water is actually available to the crop. Sandy soil of the same depth may hold in total 45 mm out of which only 40 mm is actually available to the crop. During mid-summer, crop water use can vary from 4 to 8 mm per day. Using a figure of 6 mm per day, in a week the 40 mm of soil water in this example would be gone and crop growth would suffer.

Mulches and plastic reduce water loss from the soil early in the season and can improve germination. Once the crop is well established and the rows are covered by foliage, water loss from the soil surface is only a small part of that used by the crop. Some discussion on the water requirements of specific crop groups can be found in the section "Soil and Water Management".

Microclimate Modification

The climate of the farm level can be modified from the general climate of the region in order to improve production. The two major climatic factors affecting crop growth are temperature and water. After identifying the specific requirements of each crop it is then possible to evaluate what methods are available to optimize conditions for growth. The advantages of enhanced productivity and the higher prices of the early season market must be compared to higher costs of production.

Temperature

In Atlantic Canada the two most important concerns regarding temperature for vegetable production are to increase minimum temperatures to prevent frost damage and to increase maximum temperatures in order to promote faster growth.

Several methods are available to prevent frost damage to crops. Some are expensive; however, when compared to the market value of the crop and its possible loss, they are a good investment. Similarly, the cost of production associated with promoting faster growth by increasing the amount of heat the crop receives must be evaluated in light of higher early season prices and greater flexibility in crop and hybrid selection that can reach maturity.

Frost Modification

Frost free periods in Atlantic Canada vary tremendously due primarily to topography and proximity to large water bodies. Site selection is a passive form of increasing the frost free period on a farm while irrigation and plastic are two active methods.

Site Selection: Where available land permits, the best means of avoiding late spring and early fall frosts is through proper selection of the field. Cold air runs downhill and will accumulate in hollows or depressions. It is, therefore, very important to avoid valley bottoms or areas where cold air can be trapped. On sloped land a border of trees on the downslope side of a field can trap cold air coming from further up the slope. In instances such as this, a pathway must be cleared in the trees to permit cold air to flow away from the production site to lower land If possible; a midslope site is the best for avoiding frosts. A hill top site is better than a valley bottom but will be less desirable than a midslope site, except in coastal areas.

Where possible, land that is immediately adjacent to a large water body will benefit from the heat holding capacity of the water, resulting in a longer frost free season.

Irrigation: Irrigation is successfully used to prevent frost damage to crops. The continual freezing of liquid water results in heat being given off to the plant. Protection as low as -7^{o}C can be attained, depending upon wind conditions. High winds cause evaporative cooling and also interfere with the distribution of the water. Most radiative frosts are not associated with high winds, however. When using irrigation, a system must be selected that will provide a continuous film of liquid water. If a sufficient amount of liquid water is not present, damage will occur that is often worse than having no irrigation protection at all.

The ability of the soil to handle larger volumes of water particularly in the spring must be considered in Atlantic Canada.

Plastic: Clear single layered polyethylene does not provide much frost protection at the best of times and under certain atmospheric conditions, can actually be worse than no cover at all. New plastics are being developed that provide better protection; however, more than 3° C protection is unlikely at present.

Heavy accumulations of condensation will improve protection slightly, provided the condensation remains on the film.

The maximum frost protection found in studies in Atlantic Canada revealed 1-2° C protection for clear polyethylene row tunnels under ideal conditions. Double walled tunnels provided 2-4° C protection. Large structures that house sensitive crops should rely on supplemental heating systems to protect from frost.

Heat Modification

The promotion of rapid growth is primarily a result of warm temperatures. Two to three weeks earlier production can often be attained by providing additional heat for many crops and also new crops can be grown, which in our climate would not normally reach maturity.

Heat units can be modified by any means that will regulate the temperature the crop experiences. For most practical purposes there are two methods to increase daytime heating, windbreaks and plastic.

Windbreaks: The amount of heat a plant receives is a complicated process. Solar energy heats the plant directly, and heat from the surrounding air and soil indirectly. If air movement takes place around the crop, this transfer of heat from the adjacent air and soil will be diminished. Any method of reducing the air movement near the crop will result in more heat being available for the plant.

Windbreaks can benefit the crop environment by providing more heat, better humidity and less mechanical damage. Careful attention must be paid to disease and insects when using windbreaks.

The effectiveness of a windbreak to the leeward side is measured in the number of heights of the Windbreak. Therefore, if a windbreak is 5 m tall it will cover a greater horizontal distance than if it were only 2 m tall. However, the density or porosity of a windbreak is also important. The denser the windbreak, the greater the reduction in wind at a distance very close to the break i.e. 1-3 heights from the windbreak, however at a distance of 8-10 heights the wind reduction is very small. When a windbreak is less dense the wind reduction very close to the break is moderately reduced but the wind reduction extends to a much greater distance from the break. Generally, 50% porosity will provide an effective reduction in wind at 10·15 heights to the leeward side. Of course, the windbreak should be oriented perpendicular to the direction of the prevailing winds at the time of year protection is required. During our growing season in Atlantic Canada this is usually from the south and southwest, however local landforms can modify this.

Plastic: All plastic enclosures and mulches provide an increase in heat unit accumulation compared to outside air temperatures.

Clear polyethylene row covers can provide an increase in daytime maximum temperatures of 10-20°C depending upon the amount of direct sunshine. This results in accelerated growth. Precautions should be taken to avoid excessive daytime heating by providing a method of ventilating the enclosure on warm days. Ventilation can be achieved through installing holes and slits in the poly; however this method should not be used when frost risk is high as holes will lessen even more the protection the plastic may afford. Manual lifting of the row runnels is often used to prevent overheating. Temperatures in excess of 50° C have been measured and clear plastic enclosures could prove lethal to the crop if not ventilated during hot days. It is best to maintain the optimum temperature range for the crop under the plastic. Plastic is most advantageous on cool early season days when inside temperatures are favorable for plant growth compared to outside air temperatures. Later in the heat of summer, plastic may not be advantageous.

Plastic should be removed from a crop when the plants come in contact with the cover.

Similar advantages in growth are found in larger structures as well. Ventilation is still required on hot days.

Black plastic mulches can provide modest increases in soil temperature of 1·3° C for depths of 5-20 cm providing strong solar radiation is present and there is good soil contact. At night, however, black plastic slows the convection of soil heat to between the plastic and the soil surface, the crop then can be more susceptible to frosts. Surface temperatures on the black plastic of 65° C have been measured. It is, therefore, important that transplants do not touch the plastic surface and the transplants are well watered at planting.

Clear plastic mulch provides better soil heating than black plastic; however, there is a problem with weed control.

Floating rowcovers provide moderate increases in daytime heating and require less daytime ventilation than row runnels. In addition, floating mulches do no present a physical barrier to the crop growth as the cover actually will permit expansion in size of the crop.

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