# Brussels Sprouts

**VEGETABLE CROPS PRODUCTION GUIDE FOR NOVA SCOTIA**

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## 1.0 INTRODUCTION

Brussels sprouts (*Brassica oleracea* var *Gemmifera*) are part of a large group of plants known as Cole crops. Cole crops are a group in the *Brassicaceae* or mustard family (previously *Cruciferae* or crucifers).

Cole crops originated from the word caulis, meaning stem or stalk of a plant. Cole crops are biennials, but are generally grown as annuals. Brussels sprouts, named after the city in Belgium, did not occur until the beginning of the 19$^{th}$ century.

There are two types of Brussels sprouts that are commonly grown; tall ones (0.6-1.2 m) preferred in areas with a long growing season and short ones (less than 0.6m).

The brassica family is quite cold resistant, making them well adapted to cool season production, with most requiring a cold period for flowering. Brussels sprouts will flower (bolt) when temperatures reach 7$^0$C for one to two months. This crop will grow at temperatures between 7$^0$C and 24$^0$C, but the optimum growing temperature is between 15.5$^0$C and 18$^0$C. Germination temperature for transplants should be in the range of 10$^0$C-30$^0$C; however the optimal temperature is 27$^0$C.

Brussels sprouts require soils that can provide continuous water throughout the season. Well drained, sandy loam soils are suited to early varieties, whereas loamy and clay loam soils are suited to late ones because they are somewhat tolerant of poor drainage. Well drained soils can be rotated closely since clubroot is easier to control.

Brussels sprouts are well suited to the climate of Nova Scotia, and are grown for fresh and processing markets. Large Brussels sprout producers usually mechanize the production system, but smaller growers usually hand pick the sprouts, making it a very labour intensive crop.

## 2.0 CROP ESTABLISHMENT

### 2.1 SEED TREATMENT

Seed companies today, are pelletizing Brussels sprout seeds. Pelleted coatings broaden the temperature range in which the seeds will germinate. Pelleted seed is a mix of powders placed around the seed to form a ball. This makes the seed more uniform in size, weight and shape, allowing for easier handling at planting time.

### 2.2 SEEDING/PLANTING

Brussels sprouts could be direct seeded, but chances for a successful crop are severely diminished. For this reason, Nova Scotia producers tend to produce transplants in a greenhouse for both the early and late markets. About four to six weeks are required to produce transplants, so start in April or May. Plants may be grown in plastic plug trays/plant cells, or in peat blocks (e.g. Jiffy pots). Normally 300 grams of seed will produce enough plants for one hectare. Old or large plants of Brussels sprouts and those grown at low temperatures (10$^0$C to 15 $^0$C) are likely to bolt (premature flower formation) if exposed to a period of cool weather after field setting. Place transplants outside when they are about 15 cm high with 5-6 true leaves. Slight hardening is beneficial, but severe hardening may stunt growth. Hardening is the process whereby, 2 weeks before planting, transplants are gradually acclimatized to the outdoor environment.

For late markets, transplants may be raised in plastic plug trays/plant cells inside a greenhouse, or on a greenhouse seedbed. For greenhouse cell production, follow the instructions given above, but start plants in June. If growing in seedbeds, space rows 25 to 30 cm apart and seed 20 seeds per 25 cm of row with a scatter shoe seeder. Start seed between May and June for

transplanting out in June and July. For best results, place transplants 30-45 cm apart, in rows that are 75 -90 cm apart.

With Brussels sprouts grown for a once over harvesting and especially where smaller sprouts are required for freezing, uniformity of the sprouts up the stem can be improved by growing the plants at a closer spacing, e.g. 60 x 60 cm.

## 3.0 CROP MANAGEMENT

Depending on weather, Brussels sprouts are harvested from late September to November. For optimal taste and quality, it is best to harvest after the first frost. With the use of refrigerated storage, this crop can be sold on the fresh market from September until December.

### 3.1 IRRIGATION

The availability of water can be critical to successful production. Steady, even growth of this crop is necessary for high quality and yields. Fertilizer could be applied through an irrigation system. Brussels sprouts require a regular water supply of 25 – 35 mm per week during the growing season. Shortage of water is detrimental for sprout formation. Sprinkler, big gun, and trickle irrigation methods could be used with this crop.

### 3.2 SOIL FERTILITY

Recommendations for supplemental organic matter, fertilizer, lime or manure should be based on a soil test and a Nutrient management plan. In Nova Scotia, soil tests are performed by the provincial agriculture labs in Truro. To find out more about how to take a soil test, where to send the sample and fees for the tests, visit http://www.gov.ns.ca/agri/qe/labserv/index.shtml#analytical or phone (902) 893-7444. Nutrient management plan balances the crop requirements and nutrient availability, with the aim to optimize crop yield and minimize ground water contamination, while improving soil productivity.

#### *Manure*

Brussels sprouts do well when manure is applied, however it is best not to use manure from animals that have been fed turnips or rutabagas. Excessive use of manure may contribute to tip burn, internal browning and other problems.

#### *Lime*

Lime should be applied to maintain the soil pH in the range of 6.5 to 7.0, unless club root control is required (pH of 7.2). If soil pH is below 6.2, apply lime six weeks before planting.

#### *Nitrogen*

130 – 180 kg/ha of actual nitrogen is required for Brussels sprouts production. If manure is applied then there is a need for a reduction in the amount of total nitrogen applied to the field. Broadcast apply 80 – 100 kg/ha of nitrogen before planting and work in. Apply the remainder in two side dress applications. The first side dress application should be 7-10 days after planting and the second 4 -6 weeks later. If the season is very moist, a third side dress application may be used three weeks after the second application. Adequate nitrogen produces a dark green colour in Brussels sprouts leaves. Nitrogen deficient plant leaves are light green, eventually turning yellow and may be shed.

#### *Phosphorous*

A soil test will determine the level of phosphorous requirements. Broadcast or band any needed phosphorus before planting and work in. Phosphorous is important for root development and cool, wet soil conditions hinder its uptake. Deficiency symptoms include slow growth and delayed maturity.

***Potassium***
A soil test will determine potassium requirements. Apply potassium in the fall by broadcasting and working into the soil. Excessive potassium may lead to increased tip burn (internal and/or external).

***Sulphur***
Brussels sprout crops have a high need for sulphur, and often on sandy soils, low in organic matter; soil sulphate levels may be low. Early deficiency symptoms appear as interveinal chlorosis on the youngest leaves, and the leaves may become reflexed. Application of gypsum should be considered on these soils.

***Magnesium***
Magnesium deficiency symptoms appear on the older leaves first and include interveinal chlorosis. As the chlorosis intensifies, purple blotches may be seen near the leaf margins. Deficiency is fairly common especially on light acid soils where dolomitic limestone has not been applied. Refer to the table below for fertilizer sources and rates of magnesium.

**Magnesium Application Rates**

| | | | Foliar Applied | | Soil Applied | |
|---|---|---|---|---|---|---|
| **Nutrient** | **Source** | **% Composition** | **Nutrient kg/ 1, 000 L** | **Product kg/1,000L** | **Nutrient kg/ha** | **Product kg/ha** |
| Magnesium (Mg) | sulphate of potash magnesia | 11% Mg | - | - | 30 | 270 |
| | epsom salts | 10.5% Mg | 1.9 | 18 | 30 | 285 |
| | dolomitic limestone | 6-13% Mg | - | - | 120 - 260 | 2 t/ha |

**Micronutrients**

***Boron***
Boron deficiency may result in small buds, hollow stems and lower yields. If the soil test indicates low levels of boron, soil apply or foliar apply some boron. Refer to the micronutrient application table below for a list of fertilizer sources and rates.

***Manganese***
Deficiencies may occur on sandy, over limed soils. Manganese deficiency causes yellowing between veins of young leaves. Leaves gradually turn pale-green with darker green next to the veins, petioles and stems. Foliar sprays of manganese sulphate may be necessary to correct a deficiency. Refer to the micronutrient application table for a list of fertilizer sources and application rates.

***Molybdenum***
Molybdenum deficiency causes whiptail in Brussels sprouts. Whiptail results in a deformed growing point, as well as leaf blades consisting mostly of midribs. If soil tests indicate low levels, foliar application of molybdenum is necessary. Refer to the micronutrient application table below for a list of fertilizer sources and application rates. Excessive molybdenum is toxic to plants and animals – use with care as it will carry over in the soil.

**Micronutrient Application Rates**

| | | | Foliar Applied | | Soil Applied | |
|---|---|---|---|---|---|---|
| **Nutrient** | **Source** | **% Composition** | **Nutrient kg/ 1, 000 L** | **Product kg/1,000L** | **Nutrient kg/ha** | **Product kg/ha** |
| Boron (B) | sodium borate | 12-21% B | 0.1-0.3 | - | 1.0-3.0 | - |
| Manganese (Mn)[3] | manganese chelates | 5-12 % Mn | 0.5 – 1.0 | - | - | - |
| | manganese sulphate | 28 % Mn | 0.5 – 1.0 | 1.8 – 3.6 | - | - |
| Molybdenum (Mo) | sodium molybdate | 39% Mo | 0.1 – 0.25 | 0.25 – 0.6 | - | - |

### 3.3 CROP ROTATION

A general guideline to follow concerning crop rotation is that a crop should never follow itself. Continuous cropping of any crop will result in an increase of disease and insect pressure and possibly a reduction in yields.

A proper rotation will include growing different botanical families on the same piece of land, in sequential seasons. The table below outlines some of the common botanical families vegetables belong to.

| **Botanical Family** | **Vegetable Crops** |
|---|---|
| Asteraceae | Lettuce, Endive, Artichoke, Radicchio |
| Alliaceae | Leeks, Garlic, Onion |
| Chenopodiaceae | Spinach, Swiss Chard, Beets |
| Brassicaceae | Broccoli, Cauliflower, Brussels Sprouts, Cabbage, Kale, Turnip, Kohl Rabi, Radish |
| Cucurbitaceae | Winter Squash, Summer Squash, Watermelons, Muskmelons, Cucumbers, Pumpkins |
| Poaceae | Sweet Corn |
| Fabaceae | Beans, Peas, Peanuts |
| Solanaceae | Tomato, Eggplant, Peppers, Potatoes |
| Apiaceae | Carrots, Parsley, Parsnip, Fennel |

By rotating crops that leave a high amount of residue in the soil, soil fertility can be enhanced naturally. Crop rotation can also improve soil structure by alternating deep-rooted and shallow-rooted plants.

Crop rotation plays a key role in an IPM program by aiding in the suppression of diseases, insects and weeds. Crops within the same plant family tend to be susceptible to the same pests therefore rotation of non susceptible crops for several years allows all plant material to decompose and pest cycles to become broken. Without the presence of susceptible plant material, the number of disease and insect organisms will begin to diminish.

Crop rotation aids in weed control because the growth habit of each crop differs, which causes a decrease in a weeds ability to compete for space. Tillage practices and timings are different for each crop group resulting in a decrease in a weeds ability to permanently establish.

Due to disease and insect pressures (refer to the pest management section in this guide) it is best not to plant Brussels sprouts more often than once every four years. Brassica crops use a lot of nitrogen so it may be beneficial to plant a legume crop before a Brussels sprouts. Brussels sprouts have an intermediate root depth that will aid in improving soil structure and aeration. This

crop has small seeds which will require a finely manicured seed bed; therefore previous crop residues will not be tolerated. If transplants are used, the roots can tolerate some plant residue, but too much will negatively affect root growth.

## 4.0 PESTS AND PEST MANAGEMENT

Effective management of any pest requires the use of multiple pest control techniques. Integrated Pest management (IPM) is a system that integrates Managerial, Cultural, Physical, Biological and Chemical control techniques to manage pests. A key to IPM is understanding what pests are in your crop, through scouting and adjusting production practices to discourage pests from becoming problems. IPM is a proactive approach to pest management, rather than just a reaction to pests as they occur.

### 4.1 WEEDS

Herbicides are available to use in a Brussels sprout crop. Rates and methods of application can be found on the product label. A number of shallow cultivations are an essential part of a weed control program. Good weed control requires integration of cultural and chemical methods. Brussels sprouts should be planted to land free of perennial weeds, where the annual weed seed population has been reduced by cultural practices such as crop rotation, stale seedbed or hoeing.

Crop rotation is discussed in great detail in the section above, but essentially involves growing different groups of crops on the same piece of land in successive years. Stale seedbed is a technique whereby the planting bed is made early, under dry conditions, water may be applied, and weeds are allowed to germinate and grow. After the first flush of weeds germinates, they are controlled with a total herbicide (glyphosate) or by a flame weeder. For weeds that escape and grow close to the crop, hoeing can be used as a control option. Between row cultivation is an important method of cultivation. This can be done on a regular basis.

Care must be taken to avoid fields where residual herbicides from previous years persist in the soil as crop injury may occur. Refer to the AgraPoint Guide to Pest Management for Brussels sprouts for a listing of herbicides and their application methods.

### 4.2 DISEASES

***Clubroot***

Clubroot (*Plasmodiophora brassicae Wor*.) is a soil borne disease which affects Brussels sprouts. Early infections are difficult to detect as symptoms begin underground. Symptoms include small to large swellings and other malformations of the roots. As a result of these swellings, water and nutrient flow are restricted within the plant, which causes the above ground parts to wilt, turn colour and look stunted. Wilting is most common on warm sunny days; plants may show little wilting early in the morning or late at night. Throughout Nova Scotia, it is a major problem where poor management practices are followed.

The clubroot fungus enters the plant through the many fine hairs on the roots. The extent of the disease is affected by many factors. Moist, cool soils usually produce more diseased plants than dry, warm soil. The disease also thrives best in acid soils; that is when the pH is below 7. Once land becomes infested with this disease, it will remain so for several years.

When clubbed plants rot and break down in the fall, the fungus spores are released into the soil, where they may live for 10-20 years, ready to infect any Cole crop subsequently planted. Since the fungus spores are in the soil, movement of the soil by any means (boots, tools, wheels or wind and water, etc.) also spread the disease.

Control:
There are seven things that can be done to reduce the occurrence of this disease;

1. Isolate (if possible) or avoid the use of infested fields for brassica crops for about seven years. The disease affects only the brassica crops so any other crop may be planted as long as brassica type weeds are not present.
2. Do not apply clubroot infested manure on land to be use to grow brassicas. Cattle fed infected plant material can pass the fungus spores in manure; therefore it is best to put contaminated manure back on the field that contained the infected roots, thus preventing the spread of the disease to other fields. Another possibility would be to place contaminated manure on permanent pasture lands that will not be used for any susceptible crop and where run-off will not carry the disease to clean fields.
3. Rotate crops and fields as a preventative measure before club root occurs. Allow at least three years between growing susceptible crops.
4. Clean and disinfect all equipment used on infested land before using on a non-contaminated field. Washing or steam cleaning will prevent carrying the disease to clean fields. Live steam delivered at 690 kpa pressure for five minutes is the best method to disinfect equipment.
5. Control susceptible weeds whenever possible. Weeds of the mustard family will maintain or increase the level of infestation of clubroot in a field. Examples of susceptible weeds that occur in Nova Scotia are as follows: wild radish, wild mustard, stinkweed, pepper grass, Sheppard's purse, false flax, hare's ear mustard, worm seed mustard and yellow rocket
6. Apply lime to raise the pH of the soil to at least 7.2. Clubroot seems to thrive best in moist, acid soils, therefore wet, poorly drained land should be avoided or drainage improved.
7. Use clubroot free transplants. The only way to ensure clean transplants is to use sterile soil. Clean boxes and equipment with steam. In the early stages of infection, plants may not show any signs of disease, so it is essential to purchase plants from a reliable source or to follow the procedures for producing healthy plants. Make sure you have enough clean plants for the area to be planted. Diseased plants beside healthy ones will result in all plants becoming infected. When growing transplants in the field, it is important to select a well drained area where it is known that clubroot has never occurred. Certain soil fumigants will control the clubroot organism.

* Refer to the AgraPoint Guide to Pest Management for Brussels sprouts for a listing of fungicides and their application methods.

***Grey Leaf Spot and Black Leaf Spot***

*Alternaria brassicae* (grey leaf spot) causes small and light brown or grey lesions and *A. brassicola* (black leaf spot) causes larger and darker lesions. These diseases are seed and soil borne. Small black spots (1 to 2 mm in diameter) appear on leaves, later turning into a tan colour with target-like concentric rings. When the spots dry out, the tissue falls from leaves, resulting in a 'shot-hole' appearance. Cool temperatures, rain and high humidity favour the development of this disease. The disease causes small brown sunken lesions and decay of Brussels sprouts buds (several layers deep) under very wet conditions. Alternaria is a secondary fungus; it usually invades the plant after it has been injured by other pests or management practices.

Control:

Use clean, certified seed or a hot water seed treatment if certified seed is not available. Practice long rotations between Cole crops, avoid over head irrigation and make sure to incorporate plant debris. Good air circulation is needed in the field, as well as in storage. Keep storage temperature at $0^0$C and relative humidity at 92 % to 95%. Refer to the AgraPoint Guide to Pest Management for Brussels sprouts for a listing of fungicides and their application methods.

***Downey Mildew***
This disease is caused by the fungus *Peronospora parasitica*. Once infected, the plant shows white, fuzzy masses in patches on the underside of leaves, stems and heads. The tops of leaves turn purple, than later turn yellow or brown. In Brussels sprouts, fungi sporulate and then rots occur. Infection is favoured by wet, cool weather, especially during prolonged periods of leaf wetness, such as during dew or fog. This fungus over winters in seed and plant material, and can survive for one to two years.

Control:
Good air and water drainage is critical in controlling this disease, along with avoiding water on the crop in the afternoon and evenings. Crop rotation with non brassica plants and incorporating plant debris will also aid in controlling this disease. Refer to the AgraPoint Guide to Pest Management for Brussels sprouts for a listing of fungicides and their application methods.

***Rhizoctonia***
The soil borne fungi *Rhizoctonia* and *Pythium* cause two diseases of Brussels sprouts including Damping –off and Wirestem.

Pre-emergence damping off occurs when seeds are attacked and decay, as well as when plants germinate, but fail to emerge. Post-emergence damping off occurs when the stem of 2 to 5cm tall plants are attacked. A water soaked area completely encircles the stem near the soil line and the seedling wilts and topples over.

Wirestem results from an extension of the damping off process, but new infections may occur on plants 10-15 cm tall. The stem above and below the soil line darkens, and the outer cortex tissue decays and sloughs off in sharply defined area encircling the stem. The stem is thin and wiry at the lesion but remains erect. The plant may survive, but will perform poorly.

Control:
For damping off and wirestem in seedbeds, only sterilized soil or soil that has not previously had brassicas for several years should be used. Seeds should be hot water treated and also treated with a suitable fungicide. Plant density should permit adequate light and air penetration. Factors such as deep planting, reduced seed vigour and excessively cold, hot, moist or saline soils that delay seed emergence should be avoided. Deficiencies of calcium, potassium and nitrogen or excessive nitrogen may promote disease. A field rotation with non-brassica crops should be practiced for at least three years. Avoid mounding of soil onto lower leaves when cultivating. Refer to the AgraPoint Guide to Pest Management for Brussels sprouts for a listing of fungicides and their application methods.

***Blackleg***
Blackleg is caused by the fungus *Phoma lingam*. This disease can be seed borne. Early signs of blackleg appear as small spots on leaves of young plants. On stems the spots are more linear and often surrounded by purplish borders. Stem lesions at the soil line usually extend to the root system causing dark cankers. The fibrous root system may be destroyed although new roots sent out above the lesion may keep the plant alive. Many plants wilt abruptly and die.

Control:
Use clean, certified seed, or seed which has been hot water treated. This organism is capable of surviving in the soil for three years without another Cole crop present. Practice a 4 year crop rotation, destroy brassica weeds and thoroughly incorporate plant debris. Good air and water drainage is critical in controlling this disease, along with avoiding water on the crop in the afternoon and evenings. Refer to the AgraPoint Guide to Pest Management for Brussels sprouts for a listing of fungicides and their application methods.

***Black Rot***
Black rot is caused by the bacterium *Xanthomonas campestris* and can live in the soil for one year without another Cole crop present. Humid, rainy conditions favour the disease, which is usually spread by splashing rain or irrigation water. Infection may also spread through the veins into the main stem and leaves of the head, making the product unmarketable. Black rot lesions first appear at margins of leaves. The tissue turns yellow and the lesion progresses toward the center of the leaf, usually in a v-shaped area with the base of the v toward the midrib. The veins become dark and discolouration frequently extends to the main stem and proceeds upward and downward.

Control:
Refer to the Black leg control measures, as they are useful in control of black rot as well.

**4.3 INSECTS**

***Cabbage Maggot***
The cabbage maggot or cabbage fly (*Delia redicum*) adults fly close to the ground near brassica plants and lay elliptical white eggs on the stems of crops or in nearby crevices in the soil. The adult is a two-winged, ash grey fly, with black stripes on the mid section. It is half the size of a housefly, but has longer legs. Eggs hatch in three to seven days. Larvae are white, legless maggots that enter the roots and feed by rasping the plant tissue with a pair of hook like mouthparts and tunnelling into the roots. Feeding damage by the cabbage maggot causes roots to be misshapen and allows the entry of decay organisms and other species of maggots, resulting in stunted or killed young plants. Maggots mature in three to four weeks and pupate. The pupae are 6 mm long, oval, hard shelled and dark brown. Pupae over winter in the soil near the roots of the host plant. Adult flies emerge in two to three weeks; the first generation usually emerges in late May to early June. The presence of adult flies can be determined by looking for eggs which are laid at the base of plants. Generally, there are two to three generations a year.

Control:
Biological control options include maintaining high numbers of the following natural predators which are commonly found in the field: ground beetle, rove beetle, spiders, harvestmen or daddy longlegs and ants.

Cultural controls include covering young plants with floating row cover to prevent the flies from depositing eggs after transplanting.

If using pesticide controls, scout plants frequently and treat when damage is first observed. Refer to the AgraPoint Guide to Pest Management for Brussels sprouts for a listing of insecticides and their application methods.

***Caterpillar Pests:***
The imported cabbage worm (*Pieris rapae*), cabbage looper (*Trichopulsia ni*), diamondback moth (*Plutella xylostella*) and Purple-backed cabbageworm (*Evergestis pallidata*) are all pests of Brussels sprouts. High levels of feeding damage will cause severe defoliation, resulting in stunted plants. Brussels sprouts can also become unmarketable if the sprouts are stained with frass (insect excrement) or if frass is visible.

The adult of the Imported Cabbageworm is a white butterfly, easily seen going from plant to plant laying eggs during the summer. The eggs hatch into velvety-green larvae with one thin yellow stripe down the centre of its back. The cabbageworm larvae do not loop when they walk. They are generally the most prevalent of the caterpillars found on Cole crops.

The cabbage looper gets its name from the way it forms a loop as it walks. It is a smooth green larva with two white stripes along the back and two along the sides. The cabbage looper is capable of causing the most damage to Cole crops. Cabbage loopers do not over winter in this region. Adult moths migrate into the region during the summer. Cabbage looper tends to be more problematic during the late summer.

The Diamondback Moth is much smaller than the previous insects. Three to six generations of 1.1 cm yellow-green larvae may develop each year. The larvae squirm actively when disturbed and produce many small holes on the host plant. This pest can bore into the buds of Brussels sprouts. Diamondback moths do not survive the winter in this region. Adult moths migrate in throughout the growing season. There is therefore often an overlap in generations, and all stages may be present at one time.

The Purple-backed cabbageworm is not as commonly seen as the others but will cause serious damage in high numbers. The larvae are purple on the back and pale yellow along the sides. There are one to two generations per year.

Control:
Biological control options include maintaining high numbers of the following natural predators which are commonly found in the field: ground beetles, spiders, damsel bugs, minute pirate bugs, assassin bugs, big eyed bugs, and lacewing larvae will all attack the caterpillars. There are also some commercially available parasitic wasps that sting and parasitize eggs and larvae of caterpillars; these include *Trichogramma* spp., *Copidosoma* spp., *Apanteles* spp., *Diadegma* spp., and *Hyposoter* spp.

Cultural controls include pheromone emitters to disrupt mating, evening overhead sprinkler irrigation, and placement of floating row covers over young crops to exclude egg-laying females.

If using pesticide controls, scout plants frequently and treat when damage is first noticed. Refer to the AgraPoint Guide to Pest Management for Brussels sprouts for a listing of insecticides and their application methods.

***Cutworms:***
Cutworms (*Agrotis ipsilon*) are greyish, fleshy caterpillars up to 5 cm long, which curl up when disturbed. Plants may be chewed off above or below ground level and may be damaged higher up by climbing cutworms. Most of the cutworm damage is to newly set plants in the field, but they are often found attacking seedlings in plant bed and greenhouses. Late infestation of variegated cutworm occasionally occurs.

Control:
Prepare the soil two weeks before planting to cultivate in cover crops and destroy weeds. Check plants frequently and treat when damage is first observed. Refer to the AgraPoint Guide to Pest Management for Brussels sprouts for a listing of insecticides and their application methods.

***Aphids***
The cabbage aphid, *Brevicoryne brassicae*, is a major pest of Cole crops worldwide. Aphids are small, soft bodied, slow moving insects. A colony consists of winged and wingless adults and various sizes of nymphs. Aphids may be black, yellow or pink, but mostly are various shades of green. They are often found in large colonies on the under surface of leaves; however, aphids will feed on heads, flower stalks as well as leaves, resulting in unmarketable produce. Aphids feed by piercing plants and sucking out plant sap, resulting in distorted plant parts and a slowing of plant growth. The plants may be covered by a sticky substance, called honey dew, which is excreted by the aphids.

Control:
Biological control options include maintaining high numbers of the following natural predators which are commonly found in the field: syrphid flies, lacewings and predaceous midge produce larvae which will feed on aphids and the adults and larvae of minute pirate bugs, big eyed bugs, lady beetles, soldier beetles and parasitic wasps like *Diaeretiella rapae* will also consume aphids.

Cultural controls include using high pressure sprinkler irrigation to knock the insects off of plants, as well as using living mulch such as clover interplanted with the crop.

If using pesticide controls check plants frequently and treat when damage is first observed. Refer to the AgraPoint Guide to Pest Management for Brussels sprouts for a listing of insecticides and their application methods.

***Thrips***
Thrips (*Thrips tabaci*) are slender, yellow-brown insects about 1 mm long. They feed by puncturing the leaves and sucking up the exuding sap. This causes the appearance of dark warts or blisters on the leaves. They over winter on refuse, weeds, and legume forage crops. Populations increase quickly when the air temperature is over 21 $^{0}$C.

Control:
Destroy refuse and control weeds. Heavy migrations of thrips can occur following the cutting of forage, particularly alfalfa or clover.

If using pesticide controls, check plants frequently and treat when damage is first observed. Refer to the AgraPoint Guide to Pest Management for a listing of insecticides and their application methods.

***Flea beetles***
Flea beetles (*Phyllotreta* spp.) are small shiny black beetles, about 2 mm in length. They are very active early in the growing season, especially during periods of dry sunny weather. Flea beetles can seriously damage seedlings and transplants, and to a lesser extent larger plants, by chewing small pinholes through the leaves. There is one generation per year. The larvae live in the soil and feed on roots.

Control:
Biological control options for flea beetle include using a braconid wasp that will parasitize and kill adult flea beetles, and using nematodes that attack the larvae.

There are several cultural controls which can be used to combat flea beetles. Trap crops such as Chinese type cabbages, radishes or collards can be used, living mulches or polycultures are other possibilities. Covering young seedlings with floating row cover to prevent the insects from attacking the plants is another option. Using white or yellow sticky traps every 4.5 – 9 m and making sure to destroy plant debris are also good cultural control practices.

If using pesticide controls, scout plants frequently and treat when the threshold has been reached. One flea beetle per plant (up to the sixth leaf stage) is the threshold number. After the 6 leaf stage, feeding will not interfere with plant growth. Refer to the AgraPoint Guide to Pest Management for Brussels sprouts for a listing of insecticides and their application methods.

***Tarnished Plant Bug***
Adult tarnished plant bugs are light brown to reddish brown in colour and about 5-6 mm in length. They occur throughout the season and are very active and quick moving. Bacterial and fungal rots may invade these damaged tissues.

Control:
Keep plantings and adjacent areas weed free. Avoid planting next to legumes. Check plants frequently and treat when damage is first observed. Refer to the AgraPoint Guide to Pest Management for Brussels sprouts for a listing of insecticides and their application methods.

***Slugs***
Slugs exist in various sizes up to 10 cm. They eat holes in the leaves and leave a trail of mucus, which makes plants unsightly. The control of slug populations has been a continuing problem in the Cole crop industry. They are especially troublesome in Brussels sprouts.

Control:
Slugs prefer areas which are cool, moist and high in organic matter. Sod crops, weedy fence lines and hedgerows fulfill these conditions. Since slugs can over winter fairly easily, cultural practices aimed at controlling them should begin at least one year before the susceptible crop is put in. If possible, sod crops should not be followed by Cole crops. A cultivated strip around the crop has been shown to reduce the number of slugs migrating from weedy field borders. If urea (4 kg/ha) is sprayed on this cultivated strip, slug movement may be further impeded. The salt irritates the slugs as they move over it. Repeated applications are necessary as rainfall washes it into the soil. Slugs are usually more numerous in heavy, moist soils; sandy soils usually have fewer slug problems.

### 4.4 PHYSIOLOGICAL DISORDERS
Brussels sprouts show various non-parasitic disorders which cause tissues to die off. In some cases, these deviations have been shown to depend mainly on heritable characters; whereas in other cases external factors had a least marked effect.

***Tip Burn of Brussels Sprouts***
This problem can cause severe economic losses. Internal leaves turn brown, especially on the edges or tips. Inside sprouts, the centre tissues often breakdown. It is a physiological disorder which is associated with an inadequate supply of calcium to the young, actively growing inner leaves. High humidity, low soil moisture, high potassium, high nitrogen, or low soil calcium all influence calcium availability.

***Internal Browning***
In Brussels sprouts, the symptoms are a yellowing of the distal ends of the leaves within the sprout, generally on a line through the centre region of the sprout and midway between its growing point and exterior surface. From a practical aspect, internal browning is especially troublesome because it cannot usually be detected from external examination of the sprouts, yet quite a small number of affected sprouts may taint a large sample; especially when they are blanched for quick-freezing.

Factors which have contributed to internal browning have done so by bringing about a temporary localized calcium deficiency in the sprouts. Rapid growth, low soil moisture and high relative humidity, which inhibit transpiration, are commonly implicated. The actual soil calcium levels have very little influence unless they are extremely low.

Ensuring the soil moisture is close to field capacity can reduce the risk of internal browning. Excessive nitrogen fertilizer should be avoided. Foliar sprays of calcium nitrate may prevent the onset of internal browning if applied before the onset of adverse growing conditions.

## 5.0 HARVESTING AND HANDLING

The highest quality sprouts are produced during sunny days and evenings of light frosts prior to harvesting. Sprouts harvested after a frost, tend to be sweeter in taste. Sprouts should be

harvested when 2-3 cm in diameter, round, firm and tight. The outer leaves of sprouts should be tightly clasping and not yellow in colour. Harvesting should begin before the lower leaves of the plant turn yellow.

Sprouts may crack, turn soft, yellow and/or rot if left on the stem too long. Sprouts with small, loose leaves at the base are considered to be of medium quality, while those with many loose leaves and an open top are of poor quality. A yellowish green colour is not desirable.

Two methods of harvesting Brussels sprouts include a once over harvest where the whole stalk/stem is harvested and all sprouts are stripped or multiple harvests where individual sprouts are picked when they reach market size.

Whole stem harvesting provides a once over harvest of mostly uniform, mature sprouts. Plants are topped (the growing point is pinched off) when the lower sprouts are 25 mm in diameter, which is about three to four weeks before harvest. Topping stops stalk elongation and promotes the development of individual sprouts. After topping, a full stem of uniform sized sprouts will develop in 4 weeks. Harvesting of sprouts can then be accomplished using a machine or 'sprout combine', or by cutting the entire stem.

If using a machine, the stalk is passed through a 'sprout combine' that strips off leaves and then detaches the sprouts, releasing them into a container. If harvesting the entire stem by hand, a conveyor system is used to load the stalks directly onto a truck which transports them to the stripping point. The stripping point may be a hand-trimming bench in a pack house, or a machine stripper in a pack house, the field headland, or on a trailer moving up and down the field.

If a grower decides to pick individual sprouts multiple times, sprouts are first picked from the bottom of the plant, by breaking off the leaf below the sprout and snapping off the sprout. Upper sprouts will continue to form and grow as lower ones are harvested. Sprouts are picked into hampers or baskets and removed from the field as soon as possible. Sprouts are cleaned, loose leaves trimmed, sorted by size and damaged sprouts are removed.

Generally, multiple hand harvests have been replaced with mechanical harvesters that only go through the field once and gather all produce at that time. New cultivars have been bred to develop uniformly and are adapted to being harvested mechanically.

Once the Brussels sprouts have been harvested they need to be packed according to industry standards. The Canadian packing guidelines require Brussels sprouts to be packed in one of three ways: 1. 11-14 kg waxed cartons, 2. 14 kg cylindrical wooden drums, 3. 283-453 g plastic cups. For storage purposes, Brussels sprouts should be packed in perforated film lined cartons to prevent moisture loss and to allow gas exchange. Brussels sprouts used for the processing market have their outer loose leaves removed, flash frozen and packed into plastic bags.

**5.1 STORAGE AND CONDITIONING**

After harvesting, it is best to rapidly remove field heat with either, vacuum cooling, hydro cooling, icing or forced-air cooling. Vacuum cooling is most effective when sprouts are pre-moistened to reduce wilting and can be an effective method of cooling even when sprouts are packaged as long as the packaging material is ventilated. Hydro-cooling is also an efficient method to rapidly cool sprouts from $20^0$C to $2^0$C in about 15 minutes. Package or top-icing is especially useful if storage or transport conditions cannot maintain recommended temperature or relative humidity. Forced-air cooling effectively cools sprouts if packaging is properly vented to allow good air contact with the product.

Sprouts can be stored on the stalk of the plant for a period of time. Plants should be pulled by the roots before the ground freezes, a can then be held in a humid cooler at $0^0$C for 4-6 weeks.

More commonly, sprouts are removed from the stem prior to storage. Brussels sprouts held at 0 $^0$C and above 95% relative humidity will keep for 3 to 5 weeks. Exposure to ethylene will accelerate yellowing and cause leaf abscission. Controlled atmospheres of 1 to 2.5% oxygen and 5% to 10% carbon dioxide will increase the storage life of sprouts held at 5 or 10 $^0$C, but have no benefit at 0$^0$C. Carbon dioxide greater than 10% can cause internal browning and pitting of outer leaves and oxygen less than 0.5% can cause reddish-tan discolouration of the heart leaves and bitter flavour.

## 6.0 FOOD SAFETY: A Prerequisite to Quality

(Kendra Heffel, Food Safety & Quality Systems Specialist / Auditor, AgraPoint International)

In order to produce high-quality Brussels sprouts, food safety issues must be addressed; retailers and end consumers demand it. There are several important and simple steps to be taken to ensure the safety of the Brussels sprout crop:

Premises and Production Sites

Ensure that contamination hazards have been addressed such as flooding, past pesticide usage, environmental pollution (soil, air or water) and animal access is restricted as much as possible. A field history should be maintained for each production site, as well as soil test results. Buildings that house product should be clean, have adequate drainage, and have no entry points (i.e. holes, crevices, cracks) for pests. Either a self-managed or third party serviced pest control program may be used, with documentation maintained of pest activity and any chemicals or bait used. Regular inspections must be conducted and documented to prove due diligence and ensure no additional hazards have arose.

Crop Production Materials

If applicable to the crop, ensure, via testing and/or certification letters, that seed is approved and is not contaminated by pathogens. All crop production materials must be purchased and received from approved suppliers. Pesticides must be applied by, or under the supervision of, a licensed operator. Detailed application records must be maintained for all fertilizer, pesticide, manure, compost, mulch and all other soil amendments. Pre-harvest intervals must be met for all pesticide applications, and manure must not be applied less than three months before harvest. A copy of pesticide labels should be maintained on file for cross-reference with application records. All materials should be stored in a controlled-access location, separate from product and packaging materials, and kept covered, clean and dry. Pesticide containers must be triple rinsed after use, and not used for any other purpose.

Water

Agricultural water is defined as water used for irrigation and the application of pesticides and fertilizers. Agricultural water does not have to be tested, however potential hazards must be identified and addressed (i.e. animal access, upstream contamination, runoff and spills, condition of well). Preventive measures such as buffer zones, level ground, fences and ditches, must be implemented to aid in contamination avoidance.

Water that is used for fluming product, cleaning equipment, and in hygiene facilities, if sourced from a private well, must be tested twice annually (at beginning of season and midway) for total coliforms and E.coli. If ice is used, it must be made using potable water, as well as tested annually for total coliforms and E.coli. Producers using municipal water must receive notice if the water source becomes contaminated. If wash water is treated (eg. chlorine), treatment records must be maintained.

Equipment, Cleaning and Maintenance
Calibration procedures and records for equipment such as sprayers, irrigation equipment and spreaders must be maintained. Sprayers should be calibrated at the beginning of each season, midway through, and anytime maintenance is performed (eg. nozzle replacement). All food contact equipment must be easy to clean, made of non-porous materials and inspected for damaged or loose parts. Cleaning solutions and maintenance materials (eg. lubricants, greases) that may come into contact with product or food-contact surfaces must be food-grade, and stored in designated areas.

Employee Hygiene and Training
Even smaller operations need to ensure their employees receive the proper training and that training is documented. Refresher training in food handling and hygiene practices must be provided at least annually, at the beginning of the production season. Hygiene facilities must be provided for employees and hand-washing signs posted as visual reminders. A visitor policy must also be established that details restricted access areas of buildings.

Sorting, Storing and Traceability
All new and reusable packaging materials must be clean and free of debris and stored separate from product or pesticides. Market ready packaging materials must be food-grade. While sorting, foreign objects must be removed, as well as rotten product and crop debris. Careful attention must be paid, while sorting and storing product, to maintain traceability documentation from the field, row, plot, etc. Product that requires temperature control must be stored in predetermined and monitored environment. Prior to transporting product, vehicles must be inspected for condition and possible hazards to the product. All information about the product leaving the premises must be documented.

Further information is available within select commodity manuals provided by the Canadian Horticultural Council (hgale@hortcouncil.ca) and may be obtained from provincial associations or direct from CHC. Following the guidelines within these manuals will ensure that all possible hazards to the product have been evaluated and assessed. By going one step further, and participating in a third party audit of your On-Farm Food Safety (OFFS) programs, you can provide your customers with the confidence they seek from your operation and products.

## 7.0 BIBLIOGRAPHY


Atlantic Provinces Agricultural Services Coordinating Committee. Cole Crops Vegetable Crops Production Guide for the Atlantic Provinces. Publication No. 1400. April, 1997.

ATTRA Publication. Cole Crops and Other Brassicas: Organic Production. 2006. www.attra.ncat.org/attra-pub/PDF/cole.pdf

ATTRA Publication. Organic Allium Production. 1999. www.attra.org/attra-pub/allium.html

BBC Radio 4. Gardeners' Question Time – Factsheets. August 2001. www.bbc.co.uk/radio4/gqt/fsheets/12_08_01/fsheetsq8.shtml

Canadian Food Inspection Agency. Brussels Sprouts. www.inspection.gc.ca/english/plaveg/fresh/vegleg/bru/brue.shtml

Howard, Ronald, J. Allan Garland and W. Lloyd Seaman. Diseases and Pests of Vegetable Crops in Canada.1994.

Innvista.com. Crop Rotation. www.innvista.com/health/foods/rotation.htm

Johnny's Selected Seeds. 2005 Seed Catalogue. 2005. Page 10.

Manitoba Government. Cabbage, Cauliflower, Brussels Sprouts, Broccoli Production. www.gov.mb.ca/agriculture/crops/vegetablecrops/pdf/bmz00s04p.pdf

Michigan State University Extension Bulletin E-1668: Disorders of Cole Crops. January 1983.

North Carolina State University Cooperative Extension Service: Vegetable Crop Irrigation. August 1997. www.ces.ncsu.edu/depts/hort/hil/hil-33-e.html

North Carolina State University. Brussels Sprout Production. January 2001. www.ces.ncsu.edu/depts/hort/hil/hil-6.html

NDSU Factsheet. Crop Rotations for Increased Productivity. January 1998. www.ag.ndsu.edu/pubs/plantsci/crops/eb48-1.htm

OMAFRA Factsheet: Horticultural Crops-Vegetables. August 2005. www.omafra.gov.on.ca/english/environment/hort/veg.htm

OMAFRA Fact sheet. Fertilizing Cole Crops: broccoli, Brussels sprouts, cabbage, cauliflower, horseradish, kale, kohlrabi. September 2003. www.omafra.gov.on.ca/english/crops/facts/pub363/fertilizing_colecrop.htm

OMAFRA Fact sheet: Fungal Diseases of Cruciferous Crops. April 1985. www.omafra.gov.on.ca/english/crops/facts/85-043.htm

OMAFRA Fact sheet: Bacterial Diseases of Cruciferous Crops. January 1997. www.omafra.gov.on.ca/english/crops/facts/86-046.htm

OMAFRA. Vegetable Production Recommendations 2006-2007. Publication 363.

OMAFRA Factsheet. Caterpillar Pests of Cruciferous Crops. September 1999. www.omafra.gov.on.ca/english/crops/facts/99-035.htm

Oregon State University. Brussels Sprouts. August 2004. http://oregonstate.edu/Dept/NWREC/brussprt.html

Prince Edward Island Farm Extension Services. Brussels Sprouts. May 2004. www.gov.pe.ca/photos/original/af_factbsprouts.pdf

Royal Horticultural Society. RHS Help and Advice: Crop Rotation. www.rhs.org.uk/advice/profiles1200/crop_rotation.asp

Stokes Seeds. 2005 Seed Catalogue. 2005. Page 8.

UC Davis Postharvest Technology Research and Information Centre. Brussels Sprouts: Recommendations for Maintaining Postharvest Quality. August 2006. http://postharvest.ucdavis.edu/Produce/ProduceFacts/Veg/brussels_sp.shtml

University of Georgia. Brussels Sprouts. http://www.uga.edu/vegetable/brusselsprouts.html

USA Gardener. How to Grow Broccoli. http://www.usagardener.com/how_to_grow_vegetables/how_to_grow_broccoli.php

USDA. The Commercial Storage of Fruits, Vegetables, Florist and Nursery Stocks. USDA Agriculture Handbook #66. April 2004. www.ba.ars.usda.gov/hb66/