

CHAPTER 1 Crop Production

- 1.1 Importance of vegetable crops R.P. Jaques and W.R. Jarvis
- 1.2 Field and garden vegetable crops
- 1.3 Protected vegetable crops
- 1.4 Insects as pollinators of vegetable crops P.G. Kevan

Tables

- 1.1 Farm value of potato and other vegetable crops in Canada
- 1.2 Commercially significant vegetable crops in Canada
- 1.3 Common and scientific names of vegetable crops
- 1.4 Pollination requirements of vegetable crops grown in Canada

1.1 Importance of vegetable crops [*More up-to-date information on the value of vegetable production in Canada is available on the Statistics Canada website*]

Vegetable crops are an important component of Canada's agricultural industry, as well as being a staple in many home gardens. In 1992 the farm cash receipts for vegetable crops, including potato, produced commercially in Canada totalled about \$1104 million (Table 1.1). About 36% of that was reported in Ontario, 21% in Quebec, 16% in British Columbia, and 7% in Prince Edward Island.

Climate, principally temperature, is the major factor limiting the production of vegetables in Canada. Ontario, Quebec, British Columbia, New Brunswick, Nova Scotia and Prince Edward Island produce the majority of commercial vegetables. Warm-season crops, such as bean, cucurbits, eggplant, onion, pepper, sweet corn and tomato, are produced mainly in the southern portions of Ontario, Quebec and British Columbia. The shorter frost-free period and lower mean temperatures in other areas of Canada generally favor cool-season vegetables, such as asparagus, carrot, celery, cole crops, lettuce, parsnip, pea, potato and rhubarb. Vegetables also are grown in greenhouses across Canada; most of this production is in Ontario, British Columbia, and Quebec.

Most of Canada's vegetable production is marketed domestically as fresh produce, with a smaller proportion sold as processed products. In most provinces, commercial and market garden vegetable farms are located relatively close to principal population centers or near major transportation corridors. Exports in 1992 totalled \$285 million.

Minimizing losses in storage is an important consideration for those involved in processing and marketing vegetable crops in Canada. Root crops, in particular, are often stored for many months, awaiting processing or direct sale. Because stored vegetables are usually sold in competition with fresh produce imported from warmer climates, the stored Canadian product must be of high quality. Therefore, diseases and pests of stored vegetables are a major concern to producers, processors, wholesalers and retailers.

Table 1.1. Farm value of potato and other vegetable crops in Canada

Province	Potato		Other vegetables		All vegetables	
	Value \$ million	% of total	Value \$ million	% of total	Value \$ million	% of total
Nfld.	1.3	0.4	3.1	0.4	4.4	0.4
P.E.I.	72.9	20.2	6.7	0.9	79.5	7.2
N.S.	7.4	2.0	12.7	1.7	20.2	1.8
N.B.	47.1	13.0	7.8	1.0	54.8	5.0
Que.	59.3	16.4	170.4	22.9	229.7	20.8
Ont.	41.4	11.4	351.3	47.3	392.7	35.6
Man.	53.4	14.8	17.5	2.4	71.0	6.4
Sask.	11.8	3.3	0.0	0.0	11.8	1.1
Alta.	36.5	10.1	32.4	4.4	68.9	6.2
B.C.	30.4	8.4	141.0	19.0	171.4	15.5
Canada	361.5		742.9		1104.4	

Source: Statistics Canada, Catalogue 21-603 (24 November 1993); reported as farm cash receipts, 1992. *[More up-to-date information is available on the Statistics Canada website]*

1.2 Field and garden vegetable crops

In Canada, most of the commercially significant vegetable crops are produced in the field, and statistics on production areas and values are reported regularly (see Table 1.2). There also is a significant commercial production of protected crops, i.e. those grown in greenhouses or under other conditions of modified environment. A wide variety of vegetables also are grown in home gardens from coast to coast and in some areas of the Yukon and Northwest territories. The common and scientific names of the major and minor vegetable crops grown in Canada are listed in Table 1.3.

Asparagus is an early season crop that is grown mainly in Ontario, Quebec and British Columbia under a wide range of soil and climatic conditions. New shoots are produced annually from a perennial root and harvested as they emerge, starting in early spring. If not cut for food, they eventually become the fern of the asparagus plant. The harvest usually extends three to seven weeks. Afterwards, shoots are grown to maturity to restore carbohydrates for the next year. In Ontario, about 70% of the crop is sold fresh in retail stores or at roadside stands, whereas most of the British Columbia crop is processed into canned or frozen products. There is a limited market for asparagus fern in the commercial floriculture industry.

Table 1.2. Commercially significant vegetable crops in Canada

Crop	Area (^{'000})	Production (^{'000 tonnes})	Farm value (\$ million)	Major production by province (%)						
				Ont.	Que.	Ont.	N.S.	B.C.	Alta.	
Asparagus	1.7	3.2	7.6	Ont.	72.8	Que.	18.4			
Bean	7.8	43.4	18.0	Que.	43.2	Ont.	38.7			
Beet	0.9	14.5	4.7	Que.	49.5	Ont.	36.0			
Cabbage	4.8	122.2	27.6	Que.	48.6	Ont.	29.1			
Carrot	7.7	297.0	61.0	Que.	43.6	Ont.	40.7	N.S.	6.4	
Cauliflower	3.0	40.3	21.0	Ont.	52.6	Que.	29.1	B.C.	6.1	
Celery	0.8	38.6	13.5	Que.	51.3	Ont.	40.4	B.C.	5.9	
Cucumber, field	2.8	45.3	14.6	Ont.	57.0	Que.	35.9	B.C.	3.2	
Cucumber, greenhouse	0.1	7.1*	43.3	Ont.	53.6	B.C.	20.2	Alta.	16.8	
Lettuce	2.9	67.4	35.2	Que.	58.2	Ont.	22.9	B.C.	14.2	
Maize (sweet corn)	35.7	314.2	60.6	Ont.	61.8	Que.	28.1	B.C.	6.7	
Mushroom		53.7	147.9	Ont.	54.4	B.C.	30.6			
Onion (dry)	4.5	129.5	34.4	Ont.	50.6	Que.	41.0	Man.	3.8	
Parsnip	0.4	2.1	1.4	Ont.	51.4	Man.	30.1			
Pea	19.5	68.8	23.4	Ont.	48.6	Que.	26.0	B.C.	8.7	
Pepper	2.1	19.8	13.8	Ont.	71.7	Que.	25.2			
Potato	125.6	3530	361.6	P.E.I.	30.6	N.B.	18.7	Man.	15.3	
Radish	0.8	6.1	4.0	Que.	41.6	Ont.	35.9	B.C.	22.5	
Rutabaga	2.6	73.2	18.0	Ont.	43.7	Que.	32.3	N.S.	6.2	
Spinach	0.5	2.4	1.9	Que.	40.2	B.C.	31.6	Ont.	28.2	
Tomato, field	11.4	444.0	83.5	Ont.	96.6	Que.	2.8	B.C.	0.5	
Tomato, greenhouse	0.1	29.8	46.2	Ont.	50.2	Que.	22.2	B.C.	22.0	

*Greenhouse cucumber production in millions of dozens.

Source: Statistics Canada catalogues 22-003, 1992, 1993; 22-202, 1992; data for 1992. [*More up-to-date information is available on the Statistics Canada website*]

Bean (*Phaseolus vulgaris*) is grown for consumption as an edible pod for fresh use or processing (snap, green, yellow and wax bean) or as a dry seed (field bean). Modern cultivars are stringless. Beans for fresh pods are grown in most regions of Canada, with production for processing mainly in Ontario and Quebec. Average annual production of green, yellow and wax beans for the period 1980–1987 was 46,000 tonnes from an area of 8300 hectares, most (93%) of which occurred in Quebec, Ontario, Nova Scotia and British Columbia. Broad bean (*Vicia faba*) is a spring-sown crop in Canada and is popular in home gardens for use as a fresh, frozen or dried product.

Beets consist of four distinct agronomic groups: the garden or table beet, cultivated for its edible root and tops; Swiss chard, grown for its edible leaves and petioles (see below, Swiss chard); sugar beet, used for commercial sugar production; and fodder beet, used for livestock. Table beet production occurs in all provinces, with the greatest concentration in Quebec and Ontario.

Cabbage (see Crucifers)

Carrot is consumed primarily as a fresh vegetable and only relatively small quantities are processed. Approximately 7700 hectares of carrot are grown each year, mainly in the muck soil regions of Ontario and Quebec, and to a lesser extent on inorganic soils in Ontario, Nova Scotia and Alberta. Together, Quebec and Ontario are responsible for 80 to 85% of the total Canadian production. About 70% of this country's carrots are grown on organic soils. Canada imports about 15% more carrots than are exported each year.

Celeriac is grown on a small scale in Canada.

Celery is grown in Canada on about 800 hectares. Quebec has the largest production, followed by Ontario, British Columbia and Manitoba. Despite Ontario being a major producer for both fresh and processing domestic needs, imports exceed the value of home-grown product.

Chicory is grown by specialist producers, mainly around major urban centers, for markets as a salad and culinary vegetable. It is grown in the field for one season, then the de-leafed roots are lifted, cool-stored and forced in darkness for the tight head of smoothly folded, blanched leaves. The roots, particularly of the crinkly leaved cultivars, are dried, roasted and ground as a coffee substitute or additive. They also may be cooked and eaten.

Corn (see Maize)

Crucifers are grown on approximately 15,000 hectares distributed quite evenly across the country. Cabbage and cauliflower are the predominant crops. Broccoli, Brussels sprouts, Chinese cabbage, kale, kohlrabi, radish, rutabaga and summer turnip are less common and production is often concentrated in particular regions. The horticulturally important cruciferous crops belong to thirteen species in three genera within the family Cruciferae. Crops belonging to *Brassica oleracea* L. are collectively known as cole crops. Among these, production of cabbage is greatest, followed by cauliflower, broccoli and Brussels sprouts. Kale and kohlrabi are of minor importance. Kale is grown mostly for animal fodder, and some cultivars are grown as ornamentals. Chinese cabbage, though not produced on a large scale, has increased in importance as a specialty vegetable in recent years. Rutabaga is produced chiefly in Ontario, Quebec and the Atlantic provinces. Radishes are produced mainly in Quebec, Ontario and British Columbia.

Table 1.3. Common and scientific names of vegetable crops

Common name	Scientific name
Alfalfa sprouts	<i>Medicago sativa</i> L.
Anise	<i>Pimpinella anisum</i> L.
Applemint	<i>Mentha suaveolens</i> J.F. Ehrh.
Asparagus	<i>Asparagus officinalis</i> L.
Balm, lemon	<i>Melissa officinalis</i> L.
Basil	<i>Ocimum basilicum</i> L.
Bean, common	<i>Phaseolus vulgaris</i> L.

Bean, broad field	<i>Vicia faba</i> L.
Bean, lima	<i>Phaseolus lunatus</i> L.
Bean, scarlet runner	<i>Phaseolus coccineus</i> L.
Bean sprouts (mung bean)	<i>Vigna radiata</i> (L.) Wilczek
Beet, garden	<i>Beta vulgaris</i> L.
Beet, sugar	<i>Beta vulgaris</i> L.
Borage	<i>Borago officinalis</i> L.
Broccoli	<i>Brassica oleracea</i> var. <i>italica</i> Plenck.
Brussels sprouts	<i>Brassica oleracea</i> var. <i>gemmifera</i> DC.
Burnet	<i>Sanguisorba officinalis</i> L.
Cabbage, Chinese (wong-bok)	<i>Brassica pekinensis</i> (Lour.) Rupr.
Cabbage, Chinese (pak-choi)	<i>Brassica chinensis</i> L.
Cabbage, white, red & savoy	<i>Brassica oleracea</i> var. <i>capitata</i> L.
Calabrese	<i>Brassica oleracea</i> var. <i>italica</i> Plenck.
Cantaloupe	<i>Cucumis melo</i> var. <i>cantalupensis</i> Naud.
Caraway	<i>Carum carvi</i> L.
Carrot	<i>Daucus carota</i> subsp. <i>sativus</i> (Hoffm.) Arcang.
Casaba	<i>Cucumis melo</i> var. <i>inodorus</i>
Cauliflower	<i>Brassica oleracea</i> var. <i>botrytis</i> L.
Celeriac	<i>Apium graveolens</i> var. <i>rapaceum</i> (Mill.) Gaud.
Celery	<i>Apium graveolens</i> var. <i>dulce</i> (Mill.) Pers.
Chard, Swiss	<i>Beta vulgaris</i> subsp. <i>cicla</i> (L.) Moq.
Chicory	<i>Cichorium intybus</i> L.
Chive	<i>Allium schoenoprasum</i> L.
Citron	<i>Citrullus lanatus</i> (Thunb.) Matsum. & Nakai
Collard	<i>Brassica oleracea</i> var. <i>acephala</i> DC.
Coriander	<i>Coriandrum sativum</i> L.
Corn (see Maize)	
Corn-salad	<i>Valerianella locusta</i> (L.) Betcke
Cucumber, Armenian	<i>Cucumis melo</i> L.
Cucumber, lemon	<i>Cucumis sativus</i> L.
Cucumber, long English	<i>Cucumis sativus</i> L.
Cucumber, pickling	<i>Cucumis sativus</i> L.
Cucumber, slicing	<i>Cucumis sativus</i> L.
Cucumber, snake	<i>Cucumis melo</i> var. <i>flexuosus</i> Naud.
Dill	<i>Anethum graveolens</i> L.
Eggplant	<i>Solanum melongena</i> var. <i>esculentum</i> Nees
Endive	<i>Cichorium endivia</i> L.
Fennel	<i>Foeniculum vulgare</i> Mill.
Fenugreek	<i>Trigonella foenum-graecum</i> L.
Fern, ostrich	<i>Matteuccia struthiopteris</i> (L.) Todaro
Fiddlehead	<i>Matteuccia struthiopteris</i> (L.) Todaro
Garlic	<i>Allium sativum</i> L.
Gherkin	<i>Cucumis sativus</i> L.
Gherkin, West Indian	<i>Cucumis anguria</i> L.

Ginseng	<i>Panax quinquefolius</i> L.
Gourd, ornamental	<i>Cucurbita maxima</i> Duch.
Gourd, ornamental	<i>Cucurbita pepo</i> L.
Hop	<i>Humulus lupulus</i> L.
Horsemint	<i>Mentha longifolia</i> (L.) Huds.
Horseradish	<i>Armoracia rusticana</i> Gaertn., Mey. & Scherb.
Jerusalem artichoke	<i>Helianthus tuberosus</i> L.
Kale	<i>Brassica oleracea</i> var. <i>acephala</i> DC.
Kohlrabi	<i>Brassica oleracea</i> var. <i>gongylodes</i> L.
Lavender	<i>Lavandula angustifolia</i> Mill.
Leek	<i>Allium porrum</i> L.
Lettuce	<i>Lactuca sativa</i> L.
Maize (sweet corn)	<i>Zea mays</i> L.
Marrow, vegetable	<i>Cucurbita pepo</i> L.
Melon, honeydew	<i>Cucumis melo</i> L.
Melon, serpent	<i>Cucumis melo</i> var. <i>flexuosus</i> Naud.
Mint	<i>Mentha</i> spp.
Mushroom, button	<i>Agaricus bisporus</i> (Lange) Imbach
Mushroom, oyster	<i>Pleurotus</i> spp.
Mushroom, shiitake	<i>Lentinus edodes</i> (Berk.) Pegler
Muskmelon	<i>Cucumis melo</i> var. <i>reticulatus</i> Naud.
Mustard, brown	<i>Brassica juncea</i> (L.) Czern. & Coss.
Mustard, white	<i>Sinapis alba</i> L.
Mustard, yellow	<i>Sinapis alba</i> L.
Mustard greens (rappini)	<i>Brassica juncea</i> (L.) Czern. & Coss
Onion, bunching	<i>Allium fistulosum</i> L.
Onion, common or cooking	<i>Allium cepa</i> L.
Onion, Egyptian	<i>Allium cepa</i> L.
Onion, multiplier	<i>Allium cepa</i> L.
Onion, Spanish	<i>Allium cepa</i> L.
Onion, Welsh	<i>Allium fistulosum</i> L.
Ostrich fern (see fiddlehead)	
Parsley	<i>Petroselinum crispum</i> (Mill.) Nym: A.W. Hill
Parsnip	<i>Pastinaca sativa</i> L.
Pea	<i>Pisum sativum</i> L.
Pennyroyal	<i>Mentha pulegium</i> L.
Pepper	<i>Capsicum annuum</i> L.
Peppermint	<i>Mentha x piperita</i> L.
Potato	<i>Solanum tuberosum</i> L.
Pumpkin	<i>Cucurbita maxima</i> Duch.
Pumpkin	<i>Cucurbita mixta</i> Pangalo

Pumpkin	<i>Cucurbita moschata</i> Duch.
Pumpkin	<i>Cucurbita pepo</i> L.
Radish	<i>Raphanus sativus</i> L.
Rappini (see Mustard greens)	
Rhubarb	<i>Rheum rhabarbarum</i> L.
Rutabaga (swede)	<i>Brassica napus</i> var. <i>napobrassica</i> (L.) Reichb.
Sage, garden	<i>Salvia officinalis</i> L.
Savory, summer	<i>Satureja hortensis</i> L.
Shallot	<i>Allium cepa</i> L.
Spearmint, common	<i>Mentha spicata</i> L.
Spearmint, Scotch	<i>Mentha x gentilis</i> L.
Spinach	<i>Spinacia oleracea</i> L.
Squash, acorn	<i>Cucurbita pepo</i> L.
Squash, butternut	<i>Cucurbita moschata</i> Duch.
Squash, crookneck	<i>Cucurbita moschata</i> Duch.
Squash, summer	<i>Cucurbita pepo</i> L.
Squash, winter (most)	<i>Cucurbita maxima</i> Duch.
Squash, zucchini	<i>Cucurbita pepo</i> L.
Sugar beet	<i>Beta vulgaris</i> L.
Tarragon	<i>Artemisia dracuncululus</i> L.
Thyme, garden	<i>Thymus vulgaris</i> L.
Tomato	<i>Lycopersicon esculentum</i> L.
Turnip, summer	<i>Brassica rapa</i> L.
Turnip (see rutabaga)	
Watermelon	<i>Citrullus lanatus</i> (Thunb.) Matsum. & Nakai
Zucchini	<i>Cucurbita pepo</i> L.

Cucurbits are grown chiefly in Ontario and Quebec, where the gross farm value of field cucumbers alone is \$12 million. In Canada, annual production of field cucumbers is about 45,000 tonnes worth \$14 million. Cucurbit crops include seven species in three genera and contain most of the horticulturally important vine crops, such as pumpkins, summer squash, zucchini, vegetable marrow, acorn, butternut and other winter squashes, ornamental gourds and squashes, gherkins, pickling, slicing, lemon, long English, Armenian and snake cucumbers, musk- and honeydew melons, casabas, watermelon and citrons. In addition, *Benincasa hispida* Cogn., *B. cerifera* Savi and *Cucurbita ficifolia* Bouche are sometimes used as disease- and nematode-resistant rootstocks (see also Protected vegetable crops, 1.3).

Eggplant production in Canada is mainly in southern Ontario. The plants are started indoors and grown in heated frames before being transplanted to the field (see also Protected vegetable crops, 1.3).

Endive, which is botanically related to chicory, is grown commercially mainly in Ontario, Quebec and British Columbia. The leaves are tied in a bunch and blanched in darkness toward

the end of the first growing season. Like chicory, the roots can be lifted for winter forcing.

Fiddleheads are derived from the ostrich fern, which occurs across Canada. Fiddleheads, harvested from wild ostrich-fern stands, are the young, vegetative fronds picked in the spring. Originally, they were a traditional part of the diet of the Maliseet Indians of New Brunswick. Fiddleheads are sold in fresh or frozen form throughout Canada and the United States. Their availability, currently estimated at between 250,000 and 500,000 kg annually, has never been sufficient to satisfy market demand.

Herbs and spices include nearly 50 plant species and cultivars grown primarily in home gardens and by specialist producers throughout Canada. Mustard (*Brassica* and *Sinapis* spp.) is grown on a large scale, but most herb and spice production occurs on small farms near large urban centers. Fresh and dried herbs are field-grown during the summer months and greenhouse-grown in the winter. The leaves, stems, flowers and flower buds, roots, fruits and seeds of these plants are used fresh, dried, frozen, or in oil as flavorings and condiments in salads or for cooking.

Hop is a perennial herb that sends up new vines each year. Traditional cultivars require well-constructed, wire trellises up to six meters high. The cones mature in the fall and are removed from the vines, kiln dried and baled. They are used to flavor and condition beer. Although hop is native to various parts of Canada and has been cultivated in Ontario, Quebec and Manitoba, it is now grown commercially only in coastal British Columbia. Production in that province has declined from about 800 hectares in the mid 1940s to 325 hectares in 1989; meanwhile, the monetary value of the crop has increased. Domestic production is sold in Canada, Britain and the United States.

Horseradish is a hardy, perennial cruciferous crop that is grown in home gardens in all regions except the far north in Canada. The tuberous root is used to make a relish condiment and increasingly in Manitoba to supply a peroxidase market.

Jerusalem artichoke, or sunchoke, is a native North American perennial that grows wild in parts of Canada. It has been variously used as a food plant and for fodder. It is closely related to the sunflower and shares its diseases and pests. The swollen, tuber-like rhizomes of the plant can be eaten raw or lightly cooked and were used as a starch vegetable by aboriginal peoples. In recent years, the Jerusalem artichoke has attracted interest as a source of fuel-grade ethanol. The fortunes of the crop have thus been closely linked to world prices for the more traditional fossil fuels. This plant can become a persistent weed if it escapes cultivation.

Lettuce is grown widely for its leaves in Quebec, Ontario and British Columbia. Crisphead or iceberg lettuce is most popular for field growing, and butterhead and leaf lettuce are widely used for greenhouse production. In Ontario, 65% of fresh-market head lettuce is produced on organic soils in York and Simcoe counties, but head lettuce also is grown in Lambton, Niagara and other counties in southern Ontario and to a lesser extent in eastern Ontario. The main production area in British Columbia is the Fraser River delta (see also Protected vegetable crops, 1.3).

Maize, as sweet corn, is grown commercially on about 36,000 hectares, and in home gardens across Canada for fresh consumption. Commercial production of processing corn is very

important, particularly in the counties of Ontario that border Lake Erie. Fresh-market sweet corn, although lower in yield per hectare and tonnes produced, gives a greater price per unit-weight than corn for processing. For example, in 1990, the Ontario fresh-market crop had a farm-gate value of \$31.6 million, compared to \$13.5 million for the processing crop. Sweet-corn types have only been known since the early 1800s, probably arising from a mutation of a dent corn cultivated by the aboriginal peoples around the Great Lakes. Sweet corn differs from dent corn in the possession of the recessive *su-gene*, which prevents the conversion of sugar to starch within the kernel. In Ontario, sweet corn has not changed substantially for many years, the major cultivar being Jubilee. The supersweet cultivars, distinguished by the “shrunken” or *sh2-gene*, have received positive market acceptance. However, many of the new lines are poor field performers, and efforts are being made to improve their emergence characteristics through seed treatments, plant breeding, changes in planting date and other cultural practices. Although sweet corn is affected by the same diseases and pests as field corn, the relative importance of different problems varies greatly.

Mint is grown either as a fresh or dried herb or for its oil, which is steam distilled from the foliage. There are about 25 species of mint worldwide. Production in Canada consists of small plantings of peppermint, common spearmint, Scotch spearmint, applemint, pennyroyal and several minor species. Field-scale planting of mint for oil production is centered primarily in southern Alberta.

Onion and other *Allium* crops Approximately 4500 hectares of common dry bulb onion are grown in Canada, with about 90% of the production in Ontario and Quebec. Most dry bulb onions are grown on organic muck soils at Bradford, Leamington, Thedford and Grand Bend in Ontario and Saint-Jean-sur-Richelieu, Quebec, and on inorganic soils in Manitoba and southwest British Columbia. Canada imports two to four times as many dry bulb onions as are exported each year. Other *Allium* crops, such as Spanish and bunching onions, leek, garlic and shallots, are grown on approximately 800 hectares. Chive also is a popular home garden plant that often is potted and grown indoors.

Parsley, as leaf parsley, is an excellent source of vitamins A and C. It is commonly used as a garnish by the food service industry. Cultivars with curled leaves are most popular for this purpose and, in Canada, they are grown in market gardens wherever leafy salad vegetables are produced. Leaf parsley also can be dried and flaked for use as a seasoning. Root parsley is grown less commonly. The taproot is used as a food flavoring and seasoning.

Parsnip is a minor crop in most provinces. Most of Canada's production is centered in Ontario, Quebec and the Atlantic provinces.

Pea is grown in home gardens as a fresh vegetable and commercially for seed and for dry edible and processing uses. In 1992 vegetable pea production was 69,000 tonnes, with 75% in Ontario and Quebec, and with a farm value of \$23.4 million. Southern Alberta and interior British Columbia are the best seed-producing areas. Large-scale production of dry edible pea occurs across the Prairie provinces. Processing pea is grown mainly in southwestern Ontario. The green, wrinkle seeded garden pea, harvested immature for canning and freezing, differs slightly from the yellow, smooth-seeded field pea that is harvested fully mature, but both are affected by the

same diseases and pests.

Pepper is grown in the field on a small scale in Canada, mainly in southwestern Ontario and Quebec. Losses from pest damage have reached 50% or more within individual fields. Because of the high standard of pest-free product required by processors, annual losses from product rejection would reach 75% if control measures were not applied. Sweet pepper is an increasingly important greenhouse crop in British Columbia, Alberta and Ontario (see also Protected vegetable crops, 1.3). Various hot peppers are grown locally for specialty markets.

Potato is the most important vegetable crop in Canada. Production is regionally concentrated but distributed across southern Canada, the major producing provinces being Prince Edward Island, New Brunswick, Manitoba, Quebec, Ontario, Alberta and British Columbia, in that order. Home-garden production occurs in every province and territory. More than 125,000 hectares of potato were grown across the country in 1992, with an average yield of 28.5 tonnes per hectare. In Canada, this crop is subject to over 50 infectious and physiologic diseases and pests, many of which are frequent causes of major losses in both quality and quantity. To avoid the build-up of fungal, bacterial and viral diseases in vegetatively propagated stocks, Canada has rigid seed potato certification regulations. In many provinces, potato cultivars are routinely tissue cultured to provide disease-free seedlings and then are grown for up to seven generations (classed as Nuclear, Pre-Elite, Elite 1, Elite II, Elite III, Elite IV, Foundation, and Certified) prior to being sold for seed increase, table stock production or home-garden use. Each generation is inspected for diseases by Agriculture Canada inspectors on farms that have been approved for growing potato seed. The provinces of Alberta, Prince Edward Island, and New Brunswick have laws that compel all commercial potato growers to plant Certified or higher classes of seed. The certification system provides for monitoring of disease levels in the seed potato crop. There is a zero tolerance for diseases such as bacterial ring rot (see Introduced diseases and pests, 3.11). For some tuber-borne diseases, such as fusarium wilt and blackleg, and for some viruses, there are maximum permissible levels of infection at each certification class. For example, the level of blackleg in an Elite III crop must not exceed certain established guidelines; otherwise the potatoes may be downgraded to a lower class. If disease levels exceed the official level, then certification is denied. Potato losses are considerable every year in Canada; without this rigid system of seed certification, losses from tuber-borne diseases would make growing the crop uneconomical.

Rhubarb is grown both for fresh use and for processing in plantings ranging in size from a few hectares in British Columbia, central Canada and the Maritime provinces, to backyard gardens in all parts of the country. It also can be forced in heated sheds using crowns brought in from the field. Rhubarb is popular in home gardens because it provides some of the first produce in the spring. The leaf petiole is used as a cooked desert, in pies and to make wine.

Spinach is grown commercially in Ontario, Quebec and British Columbia for use as an ingredient of fresh salads or as a cooked vegetable. It is also an occasional greenhouse crop, where it can be grown in hydroponic culture.

Swiss chard is a minor crop grown throughout Canada, primarily in home gardens, because it is valued for its leafy petioles, which are cooked. A second year's growth can be forced by

removing the seed stalks as they emerge.

Tomato ranks second to potato in farm value among field vegetable crops grown in Canada. Ontario produces more than 95% of the Canadian crop, and 83% of that is concentrated in Essex and Kent counties in the southwest. Approximately 80% of all field tomatoes are processed, the remainder being used for fresh-market consumption. Traditionally, transplants have been imported from the southern United States, principally Georgia, to establish the crop, but the use of transplants grown in plugs of soil in plastic trays in Canadian greenhouses is increasing substantially. In Ontario, tomato crops are transplanted from May 1 to mid-June and harvested from mid-August to the end of September. Most tomatoes for processing are harvested by machine, and hand picking is now almost exclusively confined to tomatoes for fresh-market sales. The average yield for processing tomatoes in Ontario is approximately 48 tonnes per hectare. Because of the value of the tomato crop and the need to use lighter, sandier soils for mechanical harvesting, crop rotation is limited, resulting in heavier pest pressures (see also Protected vegetable crops, 1.3).

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1.3 Protected vegetable crops

Protected crops grown in Canada include alfalfa and bean sprouts, ginseng, some herbs and spices, mushrooms, and greenhouse cucumber, lettuce, pepper and tomato. The techniques and facilities used to grow these crops are often sophisticated and expensive; however, production costs are offset by high returns per unit area of production and the capability of growing successive crops, in many cases year round.

Traditionally, greenhouse lettuce, endive, chicory, cucumber and tomato were grown in soil groundbeds variously amended with peat, manure, straw, peanut hulls or other organic materials. However, since the 1970s, there has been an increasing use of soilless media in both commercial and home greenhouses. In British Columbia and to some extent in Alberta and the Atlantic provinces, tomato and cucumber are grown in bags of sawdust; rockwool and other synthetic substrates are used throughout the country. Crops of high-quality lettuce are grown by the nutrient film technique (NFT) in a few locations.

Soilless production was introduced largely to enable producers to better regulate crop nutrition and environmental factors, such as root-zone temperature and pH, and to reduce the costs of soil disinfestation for root disease control. In the latter case, however, some diseases, such as corky root rot of tomato and black root rot of cucumber, have been more severe in rockwool than in soil. This often results from breaches in hygiene whereby the soilless substrate, with a greatly reduced antagonistic microflora, becomes contaminated with soil-borne or water-borne pathogens.

Control of diseases in hydroponically grown crops presents special problems. Experience has shown that solid substrates, such as rockwool, perlite and other inert materials, as well as sawdust, require pasteurization, especially if recycled. NFT gullies, reservoirs and tubing have to

be cleansed thoroughly and disinfested by hypochlorite solutions or other sterilants. The contamination of water supplies, particularly with *Pythium* and *Phytophthora* species, bacteria, and the *Oplidium* fungal vectors of viral diseases, is a constant threat. Growers who use water from wells or creeks, or who store water in outdoor or even indoor reservoirs, should consider installing a water treatment system that uses heat, ozone, ultraviolet light, chlorine or ultrafiltration to remove or inactivate pathogens. Plants for hydroponic production should be raised only in an inert substrate, never in soil or peat. In one survey, all of 52 commercial peats examined contained *Fusarium* spp., and 15 contained *Pythium* spp., many of them potential pathogens.

Alfalfa sprouts are produced on a limited commercial scale in Canada. A crop can be raised in four to five days, giving diseases and pests little time to become established. Marketing in a sealed container (punnet) eliminates many potential pests entirely.

Bean sprouts are seedlings of the mung bean or green gram that are eaten raw as a salad vegetable and used in Chinese cooking. Seeds are germinated in shallow water in a high humidity. One gram of seed yields six to eight grams of sprouts. Mung bean also is grown for seed and for its pods, which are eaten fresh.

Ginseng is native to eastern North America. It has been a minor commercial crop in Canada since about 1900, primarily in Ontario and British Columbia. It is produced from stratified seed in shaded plots known as gardens. The root is the portion of the plant that is processed commercially, but the seeds are of value, and in the Orient the leaves also are used. In North America, the root is dried before being sold. It is processed into pickles, powders, or extracts. Nearly all Canadian ginseng is exported to the Orient for processing. In 1988, Canada produced about 160,000 kg of root. Ginseng has a number of serious diseases but little research has been done on diseases and pests of this crop.

Greenhouse vegetables are grown in soil and in soil-free culture. In 1991, approximately 312 hectares were devoted to greenhouse vegetable production in Canada. Ontario leads in greenhouse tomato production, but other provinces, especially British Columbia and Quebec, also grow a considerable amount. Soilless culture helps to avoid soil-borne diseases, but high standards of crop hygiene must be maintained to avoid introducing pathogens and pests to the cropping system. In Canada, the most widely grown greenhouse vegetable crops are tomato, cucumber, pepper and lettuce. The annual value of greenhouse vegetable production in 1992 has been estimated at \$113 million (Statistics Canada, Cat. 22-202, 1992). The most popular types of greenhouse vegetables include red- and pink-fruited tomatoes, long English cucumber, sweet bell pepper and butterhead lettuce. White-spine cucumber, hot pepper and leaf lettuce also are grown, but to a lesser extent.

Herbs and spices for supermarket retail and restaurant use are grown in greenhouses during the winter months.

Mushrooms are fungi that produce a conspicuous fruiting body. In North America, there are more than 3000 species, of which about one-fifth are edible, but only a very few species are grown commercially. Mushroom cultivation in Canada began about 1912, when they were grown experimentally beneath greenhouse benches in eastern Canada. Canadian fresh market production has developed to the point that mushrooms are the second most valuable vegetable crop, with a farm-gate value of \$148 million in 1992. More than 50% of this production occurred in Ontario, and 30% in British Columbia (Statistics Canada, Cat. 22-003, 1993). The commercial button mushroom is the main type cultivated in Canada, accounting for 99% of the total production; other types grown here are the oyster mushroom and the shiitake or black forest mushroom. Canada also imports processed mushrooms.

Vegetable sprouts available in the marketplace in addition to those of alfalfa and bean include onion and radish, but specific disease and pest problems have not been reported.

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1.4 Insects as pollinators of vegetable crops

Insect pollination is important to vegetable crop production in Canada because some crops require cross-pollination by insects in order for any produce to be harvested. The insects involved are mostly honeybees (*Apis mellifera* L.).

Insect pollination is absolutely required for cucurbit crops, such as cucumber, melon, pumpkin and squash. In *Cucumis* and *Cucurbita*, the vines produce unisexual flowers, although the plants are bisexual. Pollen of these plants is typically large, spiny and oily, showing clear adaptations to insect pollination. Even though melon is self-fertile, insects are needed to effect pollination. Cross-pollination seems to be required in *Cucumis* and *Cucurbita* to obtain seeds and, in most cultivars, fruit. An exception is the long English cucumber, which forms a desirable, seedless fruit if not pollinated; if the flowers are pollinated, the fruits become misshapen (bull-necked), seeded and bitter. Honeybees are used for pollination of most cucurbit crops in North America (see Table 1.4). In Holland, the keeping of honeybees is prohibited in some areas during the summer to avoid the production of malformed cucumbers.

Although honeybees are the most manageable pollinators, they are not the best-suited for some vegetable crops. Pollination of squash and pumpkin is carried out effectively by the solitary squash bee *Peponapis pruinosa* (Say). This native bee is well established in southern Ontario and is probably the main pollinator at some locations. Squash bees emerge from underground nests in synchrony with the blooming of squash and pumpkin. The bees are active on the newly opened flowers from just before dawn, when the flowers open for their short, morning-long life. The female squash bees gather pollen to provision their nests. They have all but finished their pollinating activity by the time honeybees begin to forage. Populations of *P. pruinosa* in the vicinity of squash and pumpkin fields are immediately beneficial to productivity.

Some crops in the pea and bean family (Leguminosae) require pollination, but most are self-fertile and self-pollinating (see Table 1.4). However, scarlet runner bean requires pollination, which is accomplished mostly by insects or sometimes by hummingbirds. Bumblebees are especially adept at pollinating scarlet runner bean and are used in Europe in greenhouse production of this crop. The importance of insect pollinators in other species and cultivars of pea and bean is difficult to judge, the available data indicating no effect or some increase in crop yield (see Table 1.4).

Solanaceous vegetables, such as pepper, tomato and eggplant, usually produce fruit well when grown outdoors. Self pollination, which is brought about by wind, agitation and gravity, seems to be effective. However, in greenhouses, pollination usually is incomplete unless assisted. Traditionally, growers ensure the transfer of pollen by touching the flower with an 'electric-bee' vibrating rod. Recently, culturing of the bumblebee *Bombus terrestris* (L.) has taken on importance in Europe for pollination of these solanaceous crops, especially tomato. The successes there have spurred interest in Quebec, Ontario and British Columbia in North American species of bumblebees. Honeybees work effectively for pepper production in

greenhouses.

Some seeds, apart from sprouted beans and alfalfa, also are used as vegetables. One example, sweet corn, requires cross-pollination, which occurs by wind. Newer cultivars of sunflower are self-pollinating, but the older cultivars require cross-pollination by insects. Some native bees, such as *Eumegachile pugnata* (Say), are specialist pollinators of sunflowers and may be useful on Jerusalem artichoke in some areas. Although it is assumed that many umbelliferous flowers require cross-pollination to set seed, the pollination requirements for anise, caraway, celery, coriander, dill, and fennel are incompletely understood or unknown (see Table 1.4). Generally, these plants are visited by a wide variety of insects; it is recognized that insects are necessary to bring about pollination, because the sexual parts of individual florets mature at different times.

Almost all vegetables grown in Canada are propagated from seed, notable exceptions being asparagus, garlic, Jerusalem artichoke, onion, potato, rhubarb and some herbs. Among cruciferous crops, cross-pollination by insects is the rule (see Table 1.4). It is also the generally accepted condition for onion and allied crops, for such umbelliferous crops as carrot, celery, dill, fennel, parsnip and caraway, and for salsify and Jerusalem artichoke. The pollinators involved are varied and include honeybees, other bees, flies, moths and other insects. Beet, chard and spinach require cross-pollination by wind, although insects may visit the flowers of male plants for pollen, which is also the case with corn.

Cross-pollination is important to vegetable breeding, even in plants propagated vegetatively, e.g. asparagus, horseradish, onion, potato and rhubarb. There are special techniques for the management of insect pollinators in vegetable seed-production enclosures. The insects used include honeybees, bumblebees, orchard bees (*Osmia* spp.), leafcutting bees (*Megachile* spp.), flower flies (family Syrphidae), blow flies (family Calliphoridae), and house flies (family Muscidae).

As the technology of vegetable production and improvement advances, pollination needs to be carefully considered. At present, the diversity and quality of insects as pollinators, and the botanical aspects of pollination technology for efficient cropping of vegetables are neglected areas of research in Canada.

Table 1.4. Pollination requirements of vegetable crops grown in Canada.

Crop plant	Pollinating mechanism	Product of pollination	Note	Crop plant	Pollinating mechanism	Product of pollination	Note
Anise	insects	sf, sp		Gherkin	bees	F,sp,sb	
Applemint	?bees	sp		Ginseng	insects	sp,sb	
Asparagus	insects	sp, sb		Gourd,	bees	F,sf,sp,sb	
Balm, lemon	?bees	sp		Hop	wind	F,sp,sb	
Basil	?insects	sp		Horsemint	?bees	sp	
Bean,	mostly selfing	F,sf,sp,sb		Horseradish	insects	sp	
Bean, broad	bees, selfing	sf,sp,sb	#1	Jerusalem	unknown	sb	
Bean, field	bees, selfing	sf,sp,sb	#2	Kale and	insects	sp,sb	
Bean, lima	much selfing	sf,sp,sb		Kohlrabi	insects	sp,sb	
Bean, scarlet	bumblebees	F,sf,sp,sb		Lavender	bees, insects	sp	#4
Borage	bees	sp		Lettuce	selfing, insects	sp,sb	
Broccoli or	insects	sp,sb		Maize, sweet	wind	sf,sp,sb	

Brussels	insects	sp,sb		Marrow,	bees	F,sf,sp,sb	
Burnet	unknown	sp		Melon,	bees	F,sf,sp,sb	
Cabbage,	?insects	sp,sb		Mint	bees	sp	
Cabbage,	insects	sp,sb		Muskmelon	bees	F,sf,sp,sb	
Cabbage,	insects	sp,sb		Mustard,	insects	sf,sp,sb	
Caraway	insects	sf,sp		Onion, all	insects	sp,sb	
Carrot	insects	sp,sb		Parsley	insects	sp	
Casaba	bees	F,sf,sp,sb		Parsnip	insects	sp,sb	
Cauliflower	insects, selfing	sp,sb		Pea	mostly selfing	F,sf,sp,sb	
Celeriac	insects	sp		Pennyroyal	?bees	sp	
Celery	insects	sf,sp,sb		Pepper	selfing,bees	F,sf,sp,sb	
Chard,Swiss	wind	sp,sb		Peppermint	?bees	sb	
Chicory	insects	sp,sb		Potato	bees, hand	sb	
Chive	insects	sp,sb		Pumpkin, all	bees	F,sf,sp,sb	
Citron	bees	F,sf,sp,sb		Radish	insects	sp,sb	
Coriander	insects	sf,sp		Rhubarb	insects, wind	sb	
Corn-salad	?insects	sp		Rutabaga or swede	insects	sp,sb	
Cucumber,	bees	F,sp,sb		Sage	?bees	sp	
Cucumber,	bees	F,sp,sb		Savory	unknown	sp	
Cucumber,	parthenocarp	F		Shallot	n/a	n/a	
Cucumber,	bees	F,sp,sb		Spearmint	?bees	sp	
Cucumber,	bees	F,sp,sb		Spinach	wind	sp,sb	
Cucumber,	bees	F,sp,sb		Squash, all	bees	F,sf,sp,sb	
Dill	insects	sf,sp		Tarragon	n/a	n/a	#5
Eggplant	bees, selfing	F,sp,sb	#1	Thyme	bees	sp	
Endive	selfing	sp		Tomato	bumblebees,	F,sp,sb	
Fennel	insects	sp		Turnip, summer	insects	sp,sb	#6
Fenugreek	unknown	sf,sp		Turnip, winter/table	insects	sp,sb	
Fiddlehead	n/a	n/a		Watermelon	bees	F,sf,sp,sb	
Garlic	none	n/a	#3	Zucchini	see squash		

Symbols: F = fruit used as human food; sb = seed used for breeding; sf = seed used as human food; sp = seed used for planting; n/a = not applicable; ? = suspected.

Notes: 1 = pollination by bees increases seed set; 2 = pollination by bees does not seem to increase seed set; 3 = flowering is rare; if produced, seed is mostly non-viable; 4 = self-pollination results in seed abortion (but greater oil yield); 5 = propagated by cuttings; 6 = self-pollination results in less seed, and seed of poorer quality, than does cross-pollination.

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