Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Canada

CANADIAN NURSERY CROP PROFILE

Field Production

March 2003

Table of Contents

INTRODUCTION 1

ADVANTAGES AND DISADVANTAGES OF FIELD NURSERY PRODUCTION 2

ADVANTAGES OF FIELD PRODUCTION 2
DISADVANTAGES OF FIELD PRODUCTION 2

SOILS 4

COARSE FRAGMENTS 4
SOIL TEXTURE 4
ORGANIC MATTER 4
DRAINAGE 4
SOIL ACIDITY 5
DEPTH TO HARDPAN OR BEDROCK 5
SOIL MANAGEMENT PRACTICES 5
SOIL PREPARATION FOR PLANTING 6

FERTILIZATION 6

IRRIGATION 6

DRAINAGE 6

WEED CONTROL 6

FIELD PREPARATION FOR WEED CONTROL 7
USE OF HERBICIDES 7
Post-emergent herbicides 7
Pre-emergent herbicides 8

LAND IN NURSERY PRODUCTION 8

FARM GATE RECEIPTS 10

CULTURAL PRACTICES 11

EXPORT AND IMPORT OF NURSERY PRODUCTS 16

EXPORTS OF NURSERY PRODUCTS 16
IMPORTS OF NURSERY PRODUCTS 19

MARKETING AND DISTRIBUTION 19

CHANNELS OF DISTRIBUTION 19

NURSERY PRODUCTION ISSUES 21

PEST MANAGEMENT CHALLENGES 24

SEED PROPAGATION 24

ASEXUAL PROPAGATION 25
FIELD PRODUCTION 25
MINIMIZING WORKER EXPOSURE TO PESTICIDES 25

INTEGRATED PEST MANAGEMENT 26

PEST ASSESSMENT 26
Identification *26*
Monitoring *26*
Thresholds *27*
PEST MANAGEMENT 27
Sanitation *27*
Cultural practices *27*
Quarantine measures/ certified or treated seeds *28*
Chemical control *28*
Biological Control and Biopesticides *29*
Physical or Mechanical Control *29*

NON-PEST (ABIOTIC) PROBLEMS 29

DIEBACK 30
FALL NEEDLE DROP OF CONIFERS 30
NEEDLE BROWNING ON CONIFERS 30
SALT DAMAGE 31
SCORCH 31

PLANT PATHOGENS/DISEASES 31

RUST FUNGI 32
BACTERIAL BLIGHT/CANKER (PSEUDOMONAS SYRINGAE PV. SYRINGAE) 33
FIRE BLIGHT 34
ROOT ROTS 34
DOWNY MILDEW (PERONOSPORA SPP.) 36
POWDERY MILDEWS 36
BOTRYTIS BLIGHT (GREY MOULD) AND STORAGE MOULDS 37
VASCULAR WILTS 38
DAMPING OFF 38
CROWN GALL (AGROBACTERIUM TUMEFACIENS) 38
ANTHRACNOSE DISEASES 39

INSECTS AND MITES 39

WHITE GRUBS: JAPANESE BEETLE, EUROPEAN CHAFFER, JUNE BEETLE 41
ROOT WEEVILS 42
MITES: SPRUCE SPIDER MITE, MCDANIEL MITE, TWO-SPOTTED SPIDER MITE, BLISTER MITE, RUST MITE 43
ROSE MIDGE, DAYLILY MIDGE 44
APHIDS AND ADELGIDS 45
BARK BEETLES AND WOOD BORERS 46

CATERPILLARS: BRUCE SPANWORM, WINTER MOTH, CRANBERRY GIRDLER, CUTWORMS, EUROPEAN PINE SHOOT MOTH, TENT CATERPILLARS, SKELETONIZERS, SPRUCE BUDWORM, TUSSOCK MOTH 46
LEAFMINERS AND NEEDLE MINERS 48
LEATHER JACKETS 48
THRIPS 49
LYGUS BUGS 49
SAWFLIES 50
SCALE INSECTS 50
FUNGUS GNATS 50

WEEDS 51

PREVENTION 52
CULTURAL WEED CONTROL 53
QUARANTINE MEASURES 53
PHYSICAL WEED CONTROL 53
CHEMICAL CONTROL 54

OTHER ANIMAL PESTS/ VERTEBRATE PESTS (IE.RODENTS, BIRDS, SLUGS, ETC.) 55

SLUGS AND SNAILS 55
FIELD MICE (VOLES) 55
HOUSE MICE AND NORWAY RATS 56
DEER 56
RABBITS (COTTONTAILS) AND HARES 56

INDUSTRY CONTACTS 58

REFERENCES USED IN THE DOCUMENTS 60

INTERNET REFERENCES 60
LIST OF DOCUMENT NOT AVAILABLE ON THE NET 60

APPENDICES 62

APPENDIX 1: PROVINCIAL ENTOMOLOGY PRIORITIES 62
APPENDIX 2 – PROVINCIAL PATHOLOGY PRIORITIES 65
APPENDIX 3: PROVINCIAL WEED SCIENCE PRIORITIES 67

ADDENDUM: BC WHOLESALE NURSERIES PESTICIDE USE SURVEY – ATTACHED SEPARATELY

Introduction

Traditionally nursery stock was all grown in the field and then dug with root balls, potted or dug bare root. Although container production of nursery crops in Canada has grown steadily since first introduced in the early 1950's, in most provinces, field production still makes up the majority of the land in production. Field nursery production is in many ways similar to other types of field agriculture. Like other field agriculture, soil must be properly managed including sub-soiling, ploughing, crop rotating, and green manuring.

Figure 1: Example of Field Grown Caliper Trees

Unlike most field grown agricultural crops, field nursery crops can remain in the field from 2 to 10 years prior to harvesting. Due to the long growing cycle of some nursery crops such as larger caliper trees, both market planning and planning design for field production is an important factor.

Types of plants typically sold from field production by Canadian nurseries include:

- Caliper trees either hand or machine dug (Figure 1)
- Conifers
- Hedging (hedging cedars and yews make up a significant portion of field production)
- Shrubs
- Bareroot deciduous trees
- Bareroot shrubs

Advantages and Disadvantages of Field Nursery Production

Advantages of Field Production

Field production has some distinct advantages over container production. These include:

- Plants grown in the field do not need as intensive management as container crops
- Plants can be grown to larger sizes in the field and field grown trees are the source of larger trees used in the landscape.
- If market conditions are not favourable for sale, plants can be left in the field, whereas in container production they become root bound

Disadvantages of Field Production

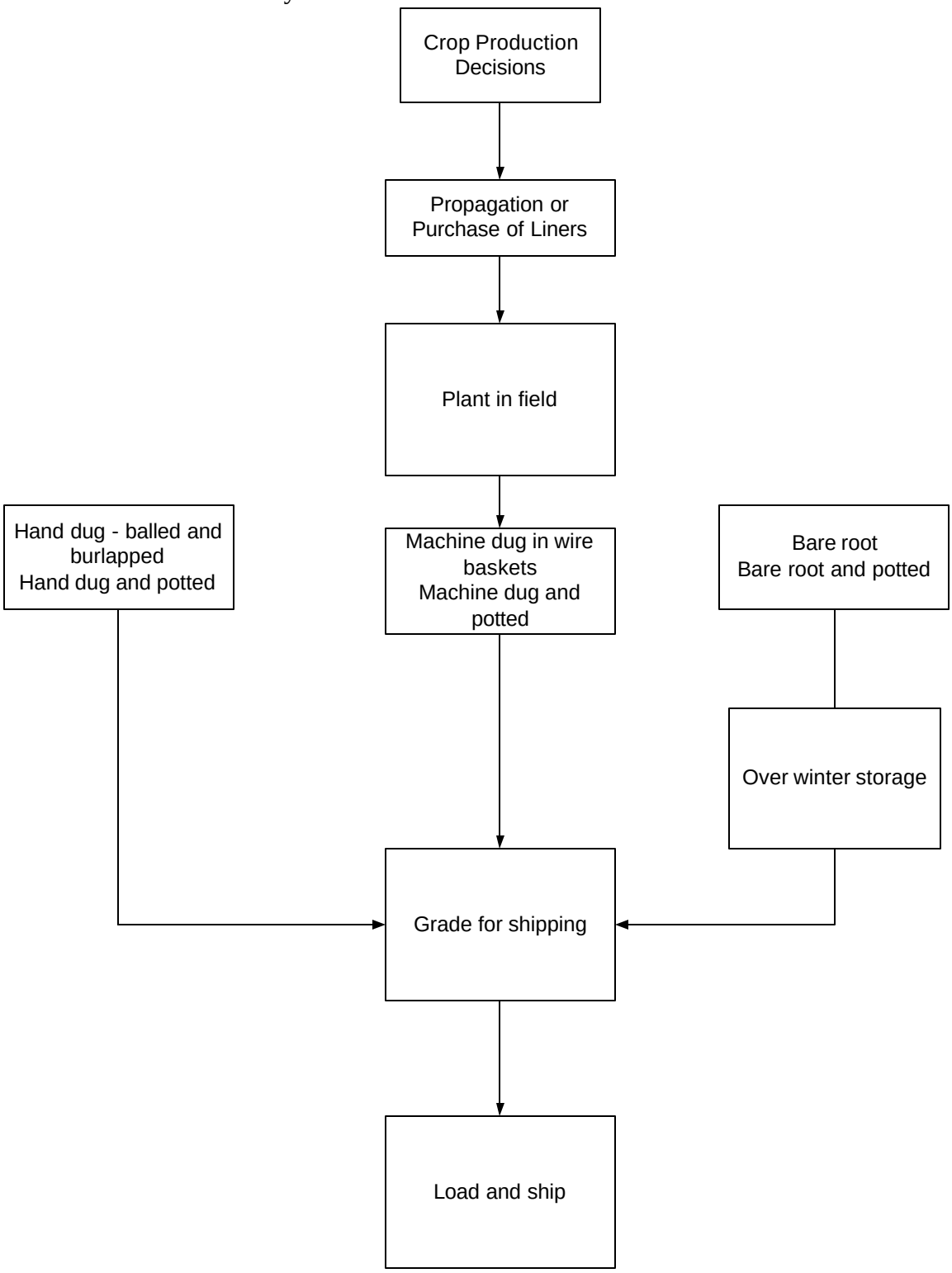
The major disadvantages to field production include:

- Harvest time limited to when the plants are dormant
- Field harvested plants (except for bareroot) are much heavier than similar sized container plants.

Figure 2: Caliper Trees Hand Dug Balled and Burlapped (B&B)

Figure 3

Flow chart of Field Nursery Production



Soils

Important criteria for field nursery production with respect to soils include:

- Percentage of coarse fragments
- Soil texture
- Drainage
- Soil acidity
- Depth to hardpan or bedrock
- Water holding capacity

Coarse fragments

If the percentage of coarse fragments is too high it is impossible to either hand or machine dig the plants.

Soil texture

Soil texture is critical to the production of field nursery stock. The best textured soils for balled and burlap operations and machine digging with baskets, are soils ranging from silty clay loams to clay loams. It is important that the root balls hold together once they are dug. Thus there must be a significant fraction of silt and clay in the soil. For bareroot operations, sandy loams are the best textured soils. When bareroot trees are harvested it is important that the soil can separate from the roots, which is much easier in sandy soils.

Soil texture also impacts the use of fertilizers, as finer textured soils (silts and loams) retain nutrients (have a better cation exchange capacity), than coarser textured soils such as sands.

Organic matter

Most nurseries incorporate organic matter to improve or maintain soil tilth and improve cation exchange and water holding capacity. Organic matter is added by the use of cover crops (green manure) or by the addition of animal manures.

Drainage

Well drained soils are essential for field nursery production. Roots need to be well aerated to allow for oxygen up-take. I if they are subject to wet conditions for too long, root rots will become established. In many areas, subsurface drainage is installed prior to planting to ensure adequate drainage,

Soil acidity

Most field crops grow best with soil pH between 6 and 7, although conifers and broadleaved evergreens prefer a soil pH of between 5.5 and 6. Soil acidity is managed by nurseries by the addition of lime to increase pH and sulphur compounds to reduce pH.

Depth to hardpan or bedrock

If the depth to hardpan or bedrock is not adequate it is impossible to harvest the crop. Larger sized caliper trees can have root balls that are up to 1 metre deep to capture the roots. Therefore, there must be adequate soil depth to allow for proper growth and harvesting. The minimum layer of workable topsoil is normally 60 cm, with a total depth of soil of at least 0.8 to 1 m for optimal production.

Soil Management Practices

The proper management of soil is critical to the production success of field nursery operations.

Soil management practices in Canadian nurseries include:

- Cultivation
- Subsoiling
- Mulching
- Cover croping
- Soil amendments

The objectives of soil management practices are to improve crop quality by improving drainage, weed control and the nutrient holding capacity of the soil. Minimizing the loft of soil due to the quantity of soil removed through harvesting and erosion are also important aims.

Most Canadian field nursery operations carry out the following practices:

- Plant cover crops between rows for erosion protection and to add organic matter to the soil
- After harvest incorporate manure, straw or other organic compounds such as compost to enhance fertility and soil structure
- Use the largest feasible pot size when planting to reduce the amount of native soil removed
- Dedicate one year minimum of rest between nursery crop cycles
- Minimize cultivation as it compacts the soil

Soil Preparation for Planting

Perennial weeds must be eliminated prior to planting. This is commonly done by spraying Roundup prior to ploughing. Once weeds are eliminated, fields are typically ploughed and disked. Either a mouldboard plough or a chisel plough will be used for this operation. If drainage is a problem or if there is a compacted layer, sub-soiling will also take place.

Fertilization

Nursery producers carry out soil tests to determine the appropriate fertilizers to use. Typical farm grade fertilizers are applied, although some nurseries are now using coated fertilizers to lengthen the time that nitrogen is released. Since the plants are typically in rows with significant spaces between the plant and the rows, fertilizer is usually banded or applied around the base of the trees. This reduces weed growth in areas between the plants and reduces leaching of nutrients from areas where the roots have not extended.

Irrigation

Many field production nurseries do not irrigate their crops, but depend on rainfall to provide adequate water for crop growth. In drier areas such as the Prairie Provinces some nurseries have installed drip irrigation systems to ensure they can provide adequate water during summer droughts. Field production nurseries may also have moveable aluminium irrigation systems or large irrigation guns.

Drainage

Well-drained fields are essential for the production and harvesting of nursery crops. Excessive water in fields can reduce plant growth, and in extreme cases, can kill plants outright. In-field drainage speeds the percolation of water through soil, so that water does not collect around plants or remains in low spots. Wet soils due to insufficient drainage make it very difficult to harvest and remove the plants from the field since trucks and other equipment cannot drive on wet soils. Under saturated conditions, wheeled machinery will cause compaction and further reduction in plant growth.

Types of drainage depend on the soil type, slope of land, access to discharge ditches and cost.

Weed Control

The control of weeds in field nursery production is critical as weeds will quickly overtake the growth of the crop and cause it to become un-saleable. Weeds also directly compete with the crop for available nutrients and water. They also can harbour insects and rodents that cause damage to the crop. Heavy weed growth will also impair air movement and lead to a higher incidence of foliar diseases.

Perennial and annual weed control practices in field operations typically combine cultivation techniques and the use of herbicides. Whenever possible, the use of

cultivation is recommended as it is a more environmentally friendly method of weed control. Many caliper tree operations utilize permanent mowed grass strips between tree rows. These strips (swards) lessen the need for weed control outside of the tree rows and reduce the overall cultivation and spraying needs.

Weed control in Canadian nurseries is mainly carried out by:

- physical methods (e.g. cultivation, hand weeding, mulching and cover crops)
- application of chemicals (herbicides)

Cultivation is carried out in all field nursery crop operations and normally by the use of tractor mounted cultivators. Cultivation is critical for weed control during field preparation in advance of planting and during the crop's production cycle.

Field preparation for weed control

Proper preparation of a field prior to planting saves considerable time and money that would otherwise be invested in post-planting weed control. Prior to planting, the fields are normally cleared of existing weeds, either by application of a post-emergent herbicide, or by repeated cultivation. Ideally, the land should then be cover-cropped for at least a year (to suppress annual weeds and exhaust remaining perennial weeds), and the cover crop turned in. This process greatly reduces the number of weed problems likely to occur during the crop cycle, and it adds organic matter to the soil.

Use of herbicides

There are two major classes of herbicides used for the control of perennial and annual weed species. These are:

- post-emergent, which are applied to actively growing weeds
- pre-emergent, which are applied to weed free soil to kill the weeds as they germinate

These are further subdivided into:

- Selective herbicides, which control weed germination or kill growing weeds without impacting non-target plants.
- Non-selective herbicides, which kill any plant that is contacted by the chemical
- Post-emergent herbicides

Post-emergent herbicides

Post-emergent herbicides are used as described above for preparation of the field prior to planting and also for minor control measures during the life time of the crop. Post-emergent herbicides come in two major groups, these are:

- contact herbicides, which only kill the plant parts they contact
- translocated herbicides, which move throughout the plant and kill all parts

Examples of non-selective, post-emergent herbicides commonly used include:

- Amitrole (Amitrol-T) (translocated)
- Diquat (Reglone)
- Glyphosate-based (translocated) herbicides such as Roundup, Laredo, Wrangler Vision, Victor and Expedite
- Paraquat (Gramoxone)
- Pelargonic and Capric acids (Spectrum A)

Pre-emergent herbicides

Pre-emergent herbicides kill the weeds as they germinate and are usually applied in the early spring before new weeds emerge.

Examples of selective pre-emergent herbicides used are:

- Chlorpropham (Chloro IPC)
- Chlorthal (Dacthal)
- Dichlobenil (Casaron), probably the most widely used pre-emergent herbicide used in field operations in British Columbia
- Fluazifop-p-butyl (Fusilade II)
- Napropamide (Devrinol), commonly used in container crops
- Oxadiazon (Ronstar), registered for use in container crops only (while only registered for use since 1995 in Canada, it has been used for many years in the United States)
- Simazine (Simazine, Simadex and Princep Nine-T)
- Trifluralin

Land in Nursery Production

The 2001 Census of Agriculture reported 4530 nursery farms in Canada. These farms had a total area in production of 22,776 hectares. The breakdown of the number of farms, total area as well as the percentage of land in nursery production, by province is shown in Table 1 & 2.

Table 1

Total Area in Nursery Production[1]

	Farms	Acres	Hectares
Canada	4530	56281	22776
NFLD	28	81	33
Nova Scotia	134	1000	405
New Brunswick	68	407	165
Quebec	627	8913	3607
Ontario	1443	25488	10315
Manitoba	161	2505	1014
SASK	94	801	324
Alberta	586	6642	2688
BC	1377	10396	4207

Table 2

% of Land in Nursery Production by Province[2]

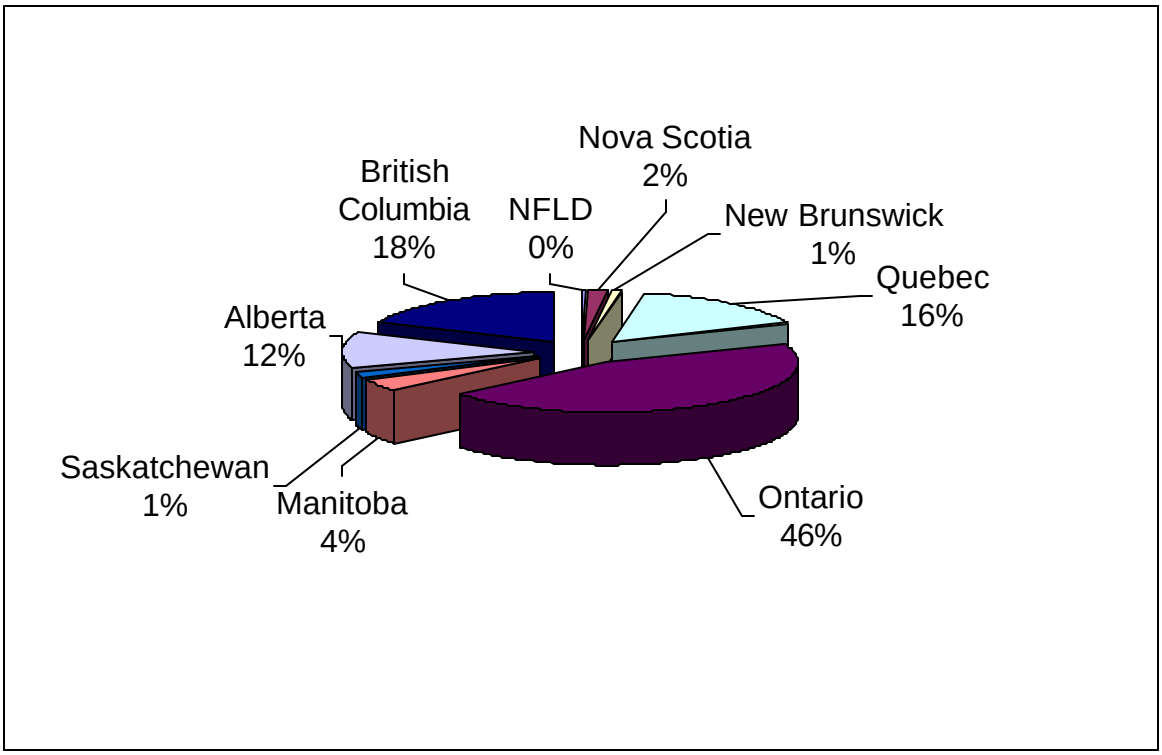
Province	% of land in production
NFLD	0.14%
Nova Scotia	1.78%
New Brunswick	0.72%
Quebec	15.84%
Ontario	45.29%
Manitoba	4.45%
SASK	1.42%
Alberta	11.80%
BC	18.47%

[1] From Statistics Canada Cat # 95F0301XIE

[2] Statistics Canada IBID

Figure 4

Graphic representation of the % of nursery production (by acreage) in Canada



Farms that generate 51% or greater of their Gross Farm Receipts (GFR) are listed in Table 4. These would be considered by the industry as bonified nursery operations as compared to hobby farms or "Tax" Farming. Some of the farms under 51% GFR may also be mixed operations, with other farm products being produced.

Based on the data presented in these tables it can be seen that Ontario has the largest amount of land in nursery production with 45% of the total land in production and the highest farm receipts. This is followed by BC 18%, Quebec 16% and Alberta 12%.

Farm Gate Receipts

The sale of nursery stock in Canada is shown in Table 3. From this table it can be seen that sales of nursery stock in Canada have increased by 76% between 1996 and 2001.

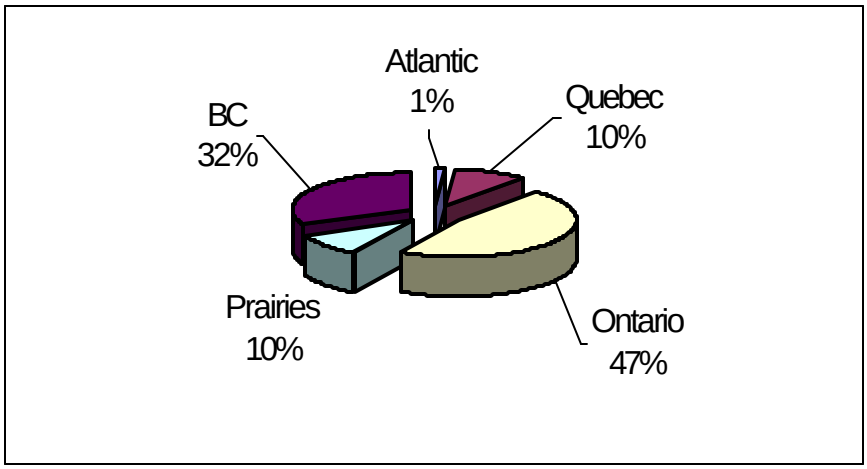
Table 3

Sales of Nursery Stock 1996 and 2001

Year	Atlantic	Quebec	Ontario	Prairies	BC	Canada
1996	6,331,000	33,400,000	125,929,000	23,482,000	90,569,000	279,711,000
2001	5,543,000	50,733,000	229,926,000	49,560,000	155,972,000	491,734,000
% increase	-12%	52%	83%	111%	72%	76%

Figure 5

Regional Nursery Farm Gate Sales as Percentage of Total Canadian Sales



Cultural Practices

Typical cultural practices such as irrigation, soil management, and use of pesticides are provided in Table 5 and Table 6. In Ontario there were 847 nurseries reporting and only 224 reported using irrigation. Since irrigation is a critical component of container nursery production this would indicate that the majority of reporting farms are in field production. On an acreage basis only 22% of reporting farms were using irrigation. This compares to British Columbia where 407 out of 801 nurseries reported using irrigation. On an acreage basis for BC this represented 73% of all reporting farms.

The data presented in Table 7 represents the use of insecticides, herbicides and fungicides. There are some anomalies in the data as Alberta and Saskatchewan report applying pesticides to more acreage than they have in production. This may be due to the application in land owned by the nurseries and being prepared for expansion. The percentage of use based on total land owned is within reason.

Table 4

Farms with greater than 51% of Gross Farm Receipts (GFR's) generated by the sale of nursery products

Region	# of operations	Gross farm receipts (GFR)	# of acres in production	Average GFR per acre	Average GFR per operation	GFRs as % of total	Acres as % of total
Canada	2,568	326,200,849	47,414	6,880	127,025	100.0%	100.0%
Newfoundland and Labrador	6	186,339	28	6,655	31,057	0.1%	0.1%
Prince Edward Island	3	33,391	35	954	11,130	0.0%	0.1%
Nova Scotia	47	3,420,873	635	5,387	72,785	1.0%	1.3%
New Brunswick	23	2,114,442	259	8,164	91,932	0.6%	0.5%
Québec	325	33,509,430	7,482	4,479	103,106	10.3%	15.8%
Ontario	847	163,854,125	22,809	7,184	193,452	50.2%	48.1%
Manitoba	108	10,827,905	2,215	4,888	100,258	3.3%	4.7%
Saskatchewan	46	3,568,273	645	5,532	77,571	1.1%	1.4%
Alberta	362	22,277,226	5,696	3,911	61,539	6.8%	12.0%
British Columbia	801	86,408,845	7,610	11,355	107,876	26.5%	16.1%

Table 5

Canadian Nursery Farms reporting use of irrigation and commercial fertilizers

Geographic identification	Farms reporting	Area in Nursery Production	Average/Farm in Nursery Production	Use of Irrigation Farms Reporting	Use of Irrigation Acres	Use of commercial Fertilizer - Farms Reporting	Use of Commercial Fertilizer - Acres
Canada	2,568	47,414	18.5	930	15,715	1,019	35,619
Newfoundland and Labrador	6	28	4.7	1	x	3	x
Prince Edward Island	3	35	11.7	2	x	2	x
Nova Scotia	47	635	13.5	15	149	22	891
New Brunswick	23	259	11.3	7	71	13	292
Québec	325	7,482	23.0	98	1,328	135	3,913
Ontario	847	22,809	26.9	224	5,074	302	14,356
Manitoba	108	2,215	20.5	29	504	35	1,662
Saskatchewan	46	645	14.0	26	319	18	739
Alberta	362	5,696	15.7	121	2,725	121	7,564
British Columbia	801	7,610	9.5	407	5,541	368	6,173

Table 6

Canadian Nursery Farms Reporting the use of Herbicides, Insecticides and Fungicides

Geographic identification	Farms reporting	Total Area	Area in Nursery Production	Average/Farm in Nursery Production	Use of Herbicides - Farm Reporting	Use of Herbicides - Acres	Use of Insecticides - Farms Reporting	Use of Insecticides - Acres	Use of Fungicides - Farms Reporting	Use of Fungicides - Acres
Canada	2,568	179,754	47,414	18.5	921	29,798	530	18,867	352	10289
Newfoundland and Labrador	6	565	28	4.7	0	0	0	0	1	x
Prince Edward Island	3	92	35	11.7	0	0	0	0	0	0
Nova Scotia	47	4,418	635	13.5	6	159	9	250	9	x
New Brunswick	23	1,756	259	11.3	5	40	3	23	1	x
Québec	325	32,303	7,482	23.0	112	3,238	89	2,117	72	1740
Ontario	847	70,097	22,809	26.9	281	11,796	192	11,290	125	5308
Manitoba	108	8,499	2,215	20.5	45	1,744	14	442	9	147
Saskatchewan	46	4,791	645	14.0	24	1,024	10	277	4	90
Alberta	362	34,891	5,696	15.7	163	7,255	58	1,814	22	801
British Columbia	801	22,342	7,610	9.5	285	4,542	155	2,654	109	2022

Table 7

Use of pesticides by Canadian Nurseries showing % of acreage applied based on area in production

Geographic identification	Farms reporting	Total Area	Area in Nursery Production	Use of Herbicides - Acres	% of Area in Total Nursery Production	Use of Insecticides - Acres	% of Area in Total Nursery Production	Use of Fungicides - Acres	% of Area in Total Nursery Production
Canada	2,568	179,754	47,414	29,798	62.8%	18,867	39.8%	10289	21.7%
Newfoundland and Labrador	6	565	28	0	0.0%	0	0.0%	x	
Prince Edward Island	3	92	35	0	0.0%	0	0.0%	0	0.0%
Nova Scotia	47	4,418	635	159	25.0%	250	39.4%	x	
New Brunswick	23	1,756	259	40	15.4%	23	8.9%	x	
Québec	325	32,303	7,482	3,238	43.3%	2,117	28.3%	1740	23.3%
Ontario	847	70,097	22,809	11,796	51.7%	11,290	49.5%	5308	23.3%
Manitoba	108	8,499	2,215	1,744	78.7%	442	20.0%	147	6.6%
Saskatchewan	46	4,791	645	1,024	158.8%	277	42.9%	90	14.0%
Alberta	362	34,891	5,696	7,255	127.4%	1,814	31.8%	801	14.1%
British Columbia	801	22,342	7,610	4,542	59.7%	2,654	34.9%	2022	26.6%

Export and Import of Nursery Products

Exports of Nursery Products

Although the export data published and presented in Table 8 and Table 9 clearly states that the following numbers are for the export of nursery and tree production, it is clear that for Ontario in particular that other commodities, most likely pot flowers or cut roses, are being captured in this category. The total value of exports from Ontario is greater than the reported total nursery production.

The data does however show a clear trend in the increase of export in Canada from $274 million in 1998 to $417 million in 2002. This is an increase of 52% over a 5 year period. To better clarify the data, a break down by HS product code is provided in Table 11.

Table 8

Exports of Nursery and Tree Production to all Countries (By Province)

	1998	1999	2000	2001	2002
Ontario	176,597,677	192,043,157	221,299,606	251,871,365	258,590,869
BC	32,202,244	44,101,961	58,541,854	69,790,184	71,355,590
Quebec	28,490,938	30,207,055	32,548,544	39,014,112	43,741,566
NB	20,109,198	23,009,520	21,310,883	24,981,520	25,862,023
NS	14,012,322	12,863,316	13,060,098	14,965,261	14,921,146
PEI	881,308	891,742	1,050,230	1,019,107	1,164,132
Man	523,364	793,419	748,890	1,063,855	746,252
Alberta	1,458,513	279,206	497,048	414,816	423,284
Sask	151,784	30,806	87,131	174,286	83,212
NFLD	0	12,988	0	0	0
Yukon	0	3,906	0	0	0
Nunavut	0	0	0	0	0
NWT	0	0	0	0	0
Total	274,429,346	304,239,075	349,146,284	403,296,507	416,890,076

Note: Comparison of the export statistics to production statistics indicate that for the Province of Ontario, other commodities (most likely flowers) are being captured under the export code for Nursery and Tree Production.

Table 9

Exports of Nursery and Tree Production to the United States (By Province)

	1998	1999	2000	2001	2002
Ontario	176,535,466	191,969,643.00	221,147,577.00	251,270,423.00	258,522,044.00
BC	32,117,943	43,991,606.00	58,395,812.00	69,180,423.00	71,250,166.00
Quebec	28,366,118	30,039,200.00	32,370,153.00	38,853,465.00	43,498,397.00
NB	20,084,500	22,976,602.00	21,307,770.00	24,810,480.00	25,794,368.00
NS	13,750,291	12,736,372.00	12,811,548.00	14,149,469.00	13,667,319.00
PEI	791,603	812,836.00	952,700.00	1,019,107.00	1,055,951.00
Man	523,364	793,419.00	748,890.00	1,063,855.00	746,252.00
Alberta	1,458,513	279,206.00	497,048.00	403,923.00	423,284.00
Sask	151,784	30,806.00	81,344.00	24,202.00	83,212.00
NFLD	-	12,988.00	-	-	-
Yukon	-	3,906.00	-	-	-
Nunavut	-	-	-	-	-
NWT	-	-	-	-	-
SUB-TOTAL	273,779,582.00	303,646,584.00	348,312,842.00	400,775,347.00	415,040,993.00
OTHERS	647,766.00	590,492.00	831,442.00	2,519,159.00	1,847,081.00
TOTAL	274,427,348.00	304,237,076.00	349,144,284.00	403,294,506.00	416,888,074.00

Table 10

Percent of Canadian Exports by Province in 2002

Province	% of Total
Ontario	62.29%
BC	17.17%
Quebec	10.48%
NB	6.21%
NS	3.29%
PEI	0.25%
Man	0.18%
Alberta	0.10%
Sask	0.02%

Graphic representation of Nursery Export Data

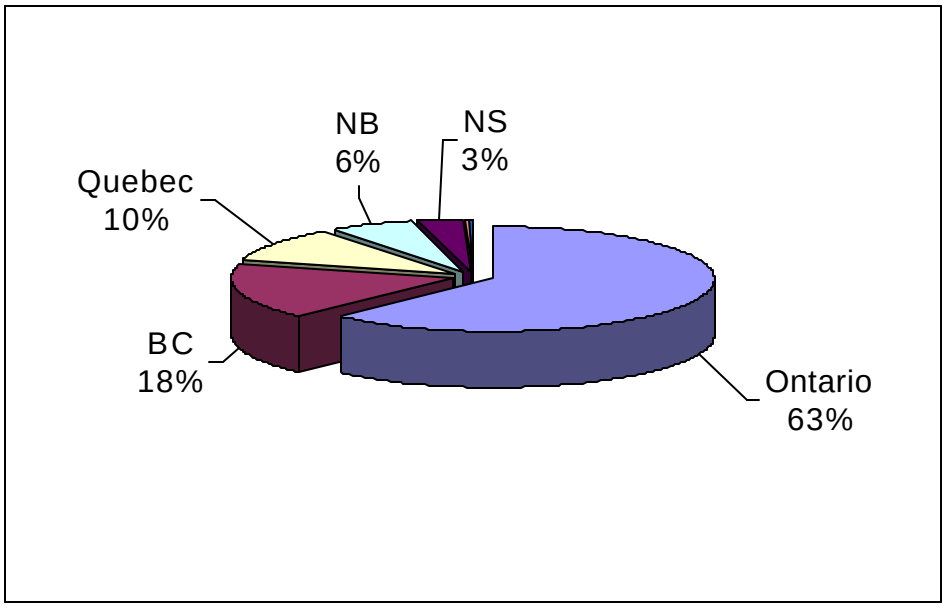


Table 11

Exports to all countries by plant category for 2002

	Bulbs, tubers roots, corms, crowns & Rhizomes (HS 601)	Unrooted cuttings & slips (HS60210)	Edible fruit & nut trees/ shrubs (HS60220)	Rhodo & Azaleas (HS60230)	Roses (HS60240)	Other live Plants including their roots (HS60299)	TOTAL
Ontario	24,154,040	642,445	6,029,095	4,690,287	20,394,812	256,423,142	312,333,821
BC	1,433,669	1,774,029	202,876	283,484	320,741	77,300,176	81,314,975
Quebec	120,142	57,375	3,602,310	42,237	27,633	19,748,800	23,598,497
Nova Scotia			18,874		29,666	4,383,578	4,432,118
Sask			6,336		22,225	42,011	70,572
Alberta			3,931	3,478		469,491	476,900
New Brunswick				151,509		21,613,013	21,764,522
Manitoba						663,275	663,275
PEI						1,154,397	1,154,397
TOTAL	25,707,851	2,473,849	9,863,422	5,170,995	20,795,077	381,797,883	445,809,077

Imports of Nursery Products

Import Commodity Records, Revenue and Excise Canada, now list imports and exports provincially as well as nationally. However, it is still difficult to estimate the imports of nursery stock since the commodity categories include nursery as well as floriculture crops. The majority of imports to Canada come from the United States and the Netherlands. There is also a significant inter provincial trade of plants in Canada. British Columbia in particular exports significant numbers of plants to Ontario, Alberta and other provinces.

It can be seen from Table 12 that imports from all countries have increased by 57% between 1996 and 2001, and imports from the US have increased by 51%. To directly compare export data Table 13 is provided. Total exports of nursery and floriculture products increased by 107 % between 1996 and 2001 and exports to the US also increased by 107%.

Table 12

Imports of Nursery and Floriculture Products 1996 to 2001

From	1996	1997	1998	1999	2000	2001
US	114,891,000	136,662,000	155,908,000	159,289,000	166,830,000	174,123,000
All Countries	215,963,000	245,240,000	286,134,000	295,784,000	312,600,000	341,482,000

Table 13

Exports of Nursery and Floriculture Products 1996 to 2001

To	1996	1997	1998	1999	2000	2001
US	238,804,000	281,115,000	346,125,000	382,604,000	436,070,000	495,639,000
All Countries	243,467,000	286,027,000	353,737,000	391,454,000	442,310,000	505,250,000

Marketing and Distribution

Channels of Distribution

The distribution of nursery products in the domestic and foreign markets can be complex. Stock is often sold several times through a series of brokers and wholesalers before actually arriving at its final destination. Table 14 and Table 15 outline the typical movement of nursery stock between growers, brokers and end consumer. There are no marketing boards or agencies involved in the setting of prices or regulating the supply of products in any province. Wholesale and retail prices are determined strictly by the market and the prevailing supply and demand for nursery products in Canada and also the United States. From Table 15 it can be seen that the most significant growth in sales has been to the retail, landscape and other grower sectors of the industry.

Table 14

Value of Stock Sold to Various End Customers (2001)

Customer	Atlantic	Quebec	Ontario	Prairies	BC	Canada
Retail	1,436,000	9,277,000	19,814,000	16,967,000	15,758,000	63,202,000
Fruit grower	870,000	1,627,000	2,854,000	1,177,000	6,294,000	12,822,000
Landscaper	722,000	5,700,000	61,840,000	19,099,000	15,101,000	102,462,000
Garden Centre	525,000	16,872,000	65,420,000	4,181,000	36,794,000	123,792,000
Mass Merchants	652,000	1,902,000	22,239,000	670,000	8,600,000	34,063,000
Other Growers	197,000	3,537,000	28,319,000	1,884,000	18,386,000	52,323,000
Other	1,141,000	11,868,000	29,440,000	5,582,000	55,039,000	103,070,000
Total	5,543,000	59,733,000	229,926,000	49,560,000	155,972,000	491,734,000

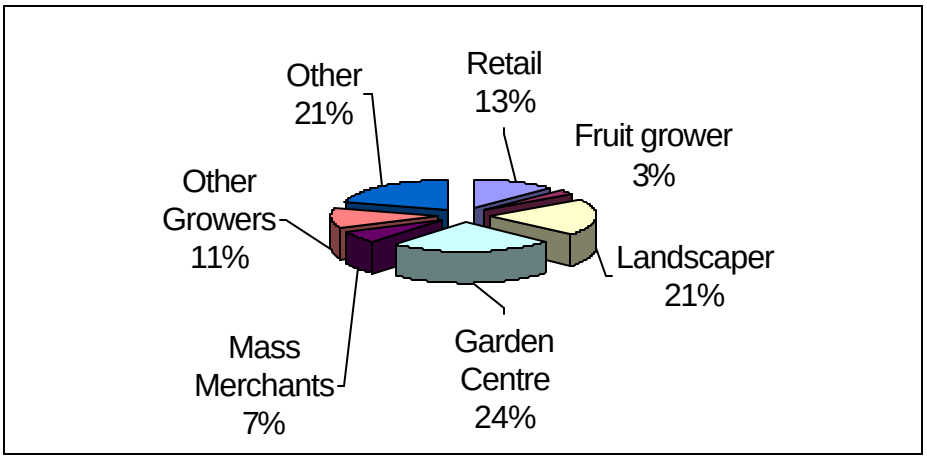
Table 15

Percent Change in Sales by Customer Category 1996 to 2001

Customer	Canada 1996	Canada 2001	% Change
Retail	52,442,000	63,202,000	21%
Fruit grower	10,371,000	12,822,000	24%
Landscaper	51,165,000	102,462,000	100%
Garden Centre	64,452,000	123,792,000	92%
Mass Merchants	29,008,000	34,063,000	17%
Other Growers	20,541,000	52,323,000	155%
Other	51,732,000	103,070,000	99%
Total	279,711,000	491,734,000	76%

Table 16

Nursery Sales by Customer Category 2001



Nursery Production Issues

Plant health is one of the most challenging and important aspects of growing ornamentals. Pest outbreaks are inevitable because nurseries grow such a high density and wide array of plants. Limitations on the quantity and quality of water and extremes in temperatures can increase the stress level of crops, making them more susceptible to pests. Some nurseries grow more than one thousand different species and cultivars of ornamentals. It is inevitable that this incredible diversity of crops will lead to a diverse array of pest problems.

Pests can negatively affect the viability of a nursery. They can destroy plant material or make a crop unmarketable since selling plants infested with a pest can harm a nursery's reputation. The average cost of pest management programs in Canadian nurseries is 1-2% of gross sales although for some crops, the cost of controlling a pest can make it unprofitable to grow. Nurseries have therefore developed programs (e.g. Integrated Pest Management) to manage crop pests.

Although each nursery tailors its own individual pest management program to suit its unique needs, some general pest management principles apply to all nurseries. These principles consist of practicing good sanitation, optimizing crop growth, monitoring crops for health problems, utilizing physical properties and applying biological and chemical controls in a timely and responsible fashion.

Sanitation includes using healthy, pest-free plants, disinfecting cutting and pruning tools, floors, walkways and benches in greenhouses, removing plant residues and diseased plants from production areas, reducing algal build-up, minimizing weed populations in production areas and around ponds and pasteurizing or fumigating the soil. Greenhouses are especially conducive to the use of physical and biological controls. Pests can be physically excluded by screening openings to prevent their entry. Physical properties of the environment, such as temperature and humidity, can also be manipulated to discourage pest build-up. Biological control agents can be released with a minimal risk of dispersal.

Unfortunately, there are limited chemical options available to nursery growers and most of these are old technologies that are not compatible with natural pest control methods. Most growers try to minimize their use of these harmful pesticides due to concerns over possible negative impacts on workers, the crop and the environment. As growers move towards IPM, newer, softer, more compatible pest control products are needed for the nursery industry. Another deterrent is the high cost of some pesticides.

To reduce pesticide use, the industry has adopted an integrated approach to pest management. An integrated pest management strategy has been implemented by 64% of nurseries in BC (*The Nursery and Landscape Industry in British Columbia 2002*). This approach first relies on prevention and timely detection of pests. This is achieved through sanitation of the crop and production areas, avoidance of plants that are very susceptible to pests, regular monitoring of crops for pests and the use of cultural controls. Cultural methods rely on modification of the production procedure to optimize crop vigour and resistance to pests, but not pest development. The integrated approach will also include strategies to protect/promote populations of native beneficial organisms and may include the release of biological controls. Pesticides are used as a last resort when all other control strategies fail and the pest population becomes economically threatening.

In a recent pesticide control survey sent to a number of nurseries across Canada, the majority of respondents indicated they practice some form of IPM and all nurseries use chemical pesticides at some point in their production cycle. In BC nurseries pesticides were used to control 57% of pests and weeds, whereas 37% of control was accomplished by biological and cultural methods (*The Nursery and Landscape Industry in British Columbia 2002*). This is evidence of the industry's interest in and commitment to integrated pest management as growers are relying on alternative controls in addition to pesticides (e.g. mechanical cultivation, hand pulling, and weed discs for weed control). It also suggests that pesticides are still required at times to manage pests and some nurseries are still trying to control pests with chemical pesticides.

Unfortunately, Canadian growers do not have a diverse assortment of pesticides at their disposal. The lack of registered pesticides and restrictive labelling of registered products puts Canadian nurseries at a competitive disadvantage to U.S. nurseries and leads to financial hardship. In 2001, roughly $4 million worth of nursery stock was discarded due to poor health by BC nurseries (*The Nursery and Landscape Industry in British Columbia 2002*). How much of this product could have been rescued if the industry had access to a wider array of pesticides?

Table 17

Commonly Used Pesticide Products in Canadian Nursery Production
(from CNLA national pest management survey)

Active Ingredient	Trade Name	Pesticide Type
Abamectin	Avid 1.0% EC	Miticide
Acephate	Orthene T&O	Insecticide
Agrobacteriumradiobacter	Dygall	Fungicide
Azinophos-methyl	Guthion 50% WP	Insecticide
Bacillus thuringiensis	Dipel 2X DF	Insecticide
Bendiocarb	Trumpet 80W	Insecticide
Bromadiolone	Just One Bite	Rodenticide
Captan	Captan 80 WP	Fungicide
Captan	Captan 50 WP	Fungicide
Carbaryl	Sevin ZLR	Insecticide
Chinomethionat	Morostan 25 WP	Fungicide
Chlorothalonil	Bravo 500	Fungicide
Chlorothalonil	Daconil	Fungicide
Chlropyrifos	Dursban 2E	Insecticide
Copper oxychloride	Fixed Copper	Fungicide
Copper, as elemental	Phyton 27	Fungicide
Diazinon	Diazinon 50WP	Insecticide
Dichlobenil	Casoron G-2	Herbicide
Dichloran	Botran 75W	Fungicide
Dicofol	Kelthane 50WP	Miticide
Dimethoate	Lagon 480	Insecticide
Dimethoate	Cygon 480	Insecticide
Dimethoate	Dimethoate 480	Insecticide
Diphacinone	Ramik Brown	Rodenticide
Dodemorph-acetate	Meltatox 4.0 EC	Fungicide
Endosulfan	Endoculfan 50W	Insecticide
Endosulfan	Thiodan 50 WP	Insecticide
Fenbutatin-oxide	Vendex 50WP	Miticide
Ferbam	Ferbam 76 WDG	Fungicide
Fluazifol P-butyl	Venture L	Herbicide
Folpet	Folpet 50 WP	Fungicide
Glyphosate	Roundup 356	Herbicide
Glyphosate	Touchdown XP	Herbicide
Hot pepper oil	Deer Off	Deer Repellent
Iprodione	Rovral 50 WP	Fungicide
Linuron	Lorox	Herbicide
Malathion	Malathion 500E	Insecticide
Malathion	Malathion 25 W	Insecticide
Mancozeb	Dithane 80% WP	Fungicide
Manozeb	Manzate 200DF	Fungicide
Metiram	Polyram DF	Fungicide
Myclobutanil	Eagle WSP	Fungicide
Myclobutanil	Nova 40W	Fungicide
Napropamide	Devrinol 50-DF	Herbicide
Napropamide	Devrinol 10-G	Herbicide

Active Ingredient	Trade Name	Pesticide Type
Oxadiazon	Ronstar 2G	Herbicide
Oxamyl	Vydate	Insecticide
Oxydemeton-methyl	Metasystox-R 2.4EC	Insecticide
Paraquat	Gramoxone	Herbicide
Petroleum oil	Dorman Oil	Insecticide
Pirimicarb	Pirliss 50DF	Insecticide
Pirimicarb	Pirmor 50 WP	Insecticide
Salts of fatty acids	Safer's Insect Soap 505%	Insecticide
Simazine	Simazine 80W	Herbicide
Simazine	Princep None-T	Herbicide
Soaps	Safer's De-Moss	Herbicide
Steptomycin sulfate	Streptomycin 17	Fungicide
Sulphur	Kumulus DF	Fungicide
Thiophanate-methyl	Senator 70 WSP	Fungicide
Thiram	Thiram 75 WP	Fungicide
Thiram	Skoot	Deer Repellent
Triflualin	Treflan EC	Herbicide
Trifluralin	Bonanza 400	Herbicide
Triforine	Funginex 190 EC	Fungicide
Warfarin	Warfarin	Rodenticide
Zinc phosphide	Rodent Pellets	Rodenticide
Zineb	Zineb	Fungicide

Pest Management Challenges

Seed Propagation

Since field-grown seedlings are usually sold as dormant stock, they can have a higher tolerance for foliar pests during production. This does not necessarily apply to container stock. Specific challenges associated with growing plants from seeds are seed decay and damping off (*Pythium*, *Phytophthora* and *Fusarium*). At times, fungicides will be used to reduce these diseases. However, it is more common for nurseries to rely on production practices that promote uniform and vigorous germination and growth. This includes the use of quality seed that is primed for germination and optimal germination conditions (temperature, moisture and media). Optimal conditions are most achievable in the greenhouse, since the climate and irrigation can be controlled. Another disease of concern is *Botrytis*. *Botrytis* is a problem because seedlings are often grown at a high density. Pesticides are one management option, but cultural practices are also used, such as irrigation management, increased air movement around the crop, timely removal of infected plants and humidity control.

Other pest issues that must be addressed are rodents and birds. Baits and traps are used for rodents, while netting is an effective method of bird management used by forest seedling nurseries.

Herbicides are not often used on seedbeds. There are no crop tolerant, pre-emergent herbicides registered for nursery seedbeds. The high density of plants in a seedbed and the use of mulches on the bed can greatly reduce weed growth if high germination rates are achieved. The tolerance for weed growth is relatively high since the plants are harvested bareroot. Therefore, the risk of transferring weeds with the harvested plants is

low. Weeds between the beds will be managed by cultivation. The situation is much different for seedlings grown in containers.

Asexual Propagation

Cuttings are rooted generally under controlled conditions in a greenhouse, which provides an opportunity to manage pests by manipulation of the cultural conditions. The factors most frequently manipulated are the temperature (both soil and air), mist frequency, and the aeration porosity of the media. Sanitation of the facilities, growing media and cuttings are also very important considerations. The cuttings should be collected from healthy and pest-free plants. Dipping them in a disinfectant can reduce the level of surface contaminants, such as weed seeds and fungal spores.

Common pest problems encountered when rooting cuttings in a propagation facility are decay diseases and fungus gnats. Both pests establish best under moist conditions, and therefore they can be controlled by water management. Biological controls, including predatory nematodes and a midge, *Hypoaspsis*, can also provide effective control. Weed growth is usually not a large problem during propagation, with the exception of liverwort and mosses. The establishment of liverwort in a crop during propagation is a very serious problem that will continue to thrive when transplanted out of the propagation facility. Liverwort and moss growth are also favoured by moist conditions.

Field Production

IPM in field production relies heavily on physical techniques (e.g. directly pruning out boring pests, monitoring levels of native beneficials, etc.). Pesticides tend to be used more often in field production than in greenhouse systems, since the grower cannot control the climate and soil conditions. In addition, the release of beneficial organisms is much less effective because they tend to disperse out of the production area in search for food.

Minimizing Worker Exposure to Pesticides

Even with current increases in the use of mechanization, the production of nursery crops is still labour intensive. Workers handle crops during most production activities, and thereby may be exposed to pesticide residues. Most activities only require workers to be in a production block for one day or up a few days. Therefore, a nursery can ensure that workers do not enter a treated area until the re-entry interval has lapsed by scheduling tasks accordingly. However, this is more difficult with activities that occur on a frequent basis, such as shipping and crop monitoring.

Additional steps that are used to limit worker exposure include placing signs around sprayed areas, instructing workers to wear gloves when working in a treated crop, and spraying on Friday evenings or on weekends. The latter method is effective because field nurseries do not usually bring in workers on weekends, and container nurseries bring in few, if any workers on weekends.

Integrated Pest Management

Integrated Pest Management (IPM) is a decision-making process that uses a combination of techniques to suppress pests effectively, economically and in an environmentally sound manner. The elements of IPM include:

- Planning and managing cropping systems to prevent organisms from becoming pests,
- Identifying potential pest organisms and knowing their life cycle,
- Monitoring populations of pests and beneficial organisms, pest damage and environmental conditions,
- Using injury thresholds in making treatment decisions,
- Reducing pest populations to acceptable levels using strategies that may include a combination of biological, cultural, mechanical, behavioural and, when necessary, chemical controls, and
- Evaluating the effects and efficacy of pest management practices.

In practical terms this means having a plan that lists all possible plant host/pest problems and appropriate control methods which effectively reduce the pest population without reducing the populations of beneficial organisms. An IPM program takes into account all factors that influence plant health and vigour as well as those that affect the health and reproductive capacity of pests. Typically, an IPM program will attempt to optimize growing conditions for the crop while making the conditions less favourable for pest development. Key aspects of nursery IPM programs are: sanitation, optimizing crop growth, monitoring crops for pests, knowledge of pest life cycles and timely use of biological and chemical controls.

Pest Assessment

Identification

It is essential to identify pest problems correctly to plan effective pest management programs. First, it is important to identify whether or not there is a pest problem. Then once a pest has been identified, the grower can look up information on its biology, including life cycle, behaviour, preferred habitat and typical host plants. Knowledge of the life cycle of the insect pest is an important tool due to:

- Concentration of monitoring efforts when and where pests are most likely to occur,
- Using treatments at the most susceptible time in the pest life cycle,
- Conserving and protecting the natural enemies of the pest, and
- Planning preventative measures and improving plant management practices.

This is particularly important when specific, non-residual pesticides, such as soap or horticulture oils are used. Growing Degree Day and Plant Phenology models can help pinpoint this stage down to a week or so. But to narrow the ideal application time to a few days, regular monitoring must be carried out.

Monitoring

Monitoring is the regular inspection of plants (including roots and soil), to detect the presence of pests or adverse environmental conditions. Crop monitoring is essential for pest management and is used to,

- Detect problems while pest numbers are still low,
- Assess the size and spread of a pest population and extent of damage,

- Find out if natural enemies of pests are present and in what numbers,
- Look for conditions that contribute to the pest problem,
- Find out what effect past treatments or natural enemies have had on the pest population, and
- Assist in directing the treatment program (e.g. chemical pesticides)

Most monitoring programs involve walking the nursery fields and randomly sampling individual plants within a defined area. These inspections are done at regular intervals and written records of the observations and pest / beneficial organism counts are made. This involves dedicating a knowledgeable employee for some hours on a regular basis to collect information on pest populations and development stage. The number of plant samples and the location of these plants should be decided in advance to avoid the temptation to always sample the row ends. Insect traps can also be used for some pests, but have to be maintained on a regular basis.

While monitoring, noting the stage of development of permanent plants (budding out, flowering) around the nursery can be valuable, as temperature will affect both plant and insect development. An early or a late spring could then be determined with these plant phenology indicators and early or late emergence of an insect could be anticipated. Monitoring staff should also be aware that the environment will differ inside poly-houses used for overwintering container stock as depending on sunlight levels, insect development is usually well ahead of those same crops in the field.

Thresholds

The insect threshold number that will render the plant unsaleable will have to be assessed by each individual nursery and their respective client groups. Several years of meticulous record keeping will be necessary to predict with confidence when or where not to control. There is very little published information that lists threshold levels for pests in nursery plantings.

Pest Management

Sanitation

The key to successful and economical pest management is preventing pest problems by growing healthy plants. Nursery and landscape sanitation includes the removal or exclusion of factors that allow pests to gain access to crops. Good crop hygiene focuses on starting clean and preventing the introduction of pests. Prevention is often easier and less expensive than managing an established pest population. Keys to an effective prevention program include,

- Starting with healthy and pest-free plants,
- Sanitation of production areas between crops,
- Implementation of sanitation programs during crop production,
- Proper media and plant residue handling/disposal,
- Screening of greenhouse vents,
- Effective algae and weed control, and
- Optimizing crop growth.

Cultural practices

Cultural control activities are actually modified plant care practices. Some activities may include removing infested plant materials or pests (including weeds) from production areas and landscapes

and having them destroyed. Growers will practice supplemental irrigation where natural precipitation events are inadequate and will avoid irrigation late in the day as extended leaf wetness periods into the night create ideal conditions for disease. Also irrigating less often, but with larger volumes, encourages deeper rooted plants that are more tolerant of hot, dry conditions. Steam pasteurizing is sometimes practiced on propagation media before reusing. Plant varieties that are tolerant of diseases and insects are grown. Selecting only healthy plants for cuttings and budwood avoids introducing problems into the production system.

Quarantine measures/ certified or treated seeds

This practice involves the process of receiving new nursery material, holding it in a quarantine area and monitoring for any pests or diseases for a week or two before introducing it into your production area.

Chemical control

All nurseries use ground-based equipment to apply pesticides (although a handful of nurseries may use aerial applications on large production fields). Hand-operated or backpack sprayers are commonly used for spot treatments and areas difficult to reach with tractors. For other spray situations a type of motorized sprayer is commonly used. Motorized sprayers include boom-sprayers, sprayers with handguns and airblast sprayers.

The most common motorized sprayer is a boom sprayer, which has a pump that provides enough liquid pressure to spray the target from nozzles located on the boom. High-pressure sprays (700 – 2,000 kPa) are typically required for insecticides and fungicides. The same sprayers can be used at lower pressures for herbicides. Boom sprayers are solely used on field-grown stock.

Tractor mounted sprayers with handguns are commonly used to spray insecticides and fungicides in nurseries, where large areas are to be sprayed that cannot be efficiently done with a backpack sprayer. Tractor mounted sprayers used by nurseries commonly have a capacity of 100 litres. Handguns are used with dilute sprays where the plants are sprayed for thorough coverage.

The backpack sprayer is the most common type of spraying equipment used on small operations. It is best suited for spot spraying and spraying in confined areas due to its small size and low spray capacity (~13 litres). The backpack sprayer can be used for high-volume or dilute spraying both in field and greenhouse conditions. A smooth, uniform walking speed along with spray wand motion is required to achieve uniform coverage. Nozzles must be selected for the operating pressure of the sprayer and spraying conditions. Backpack sprayers have a positive shut-off spray control valve to eliminate pesticide drips from the wand and nozzle.

Airblast sprayers have become more common on larger farms for spraying insecticides and fungicides. They are solely used on field-grown specimen trees. The sprayer uses a combination

of air and liquid to deliver the pesticide. The pesticide is pumped through nozzles into a blast of air from a high-speed fan. Airblast sprayers may use lower water volumes than boom sprayers. However, drift can be more of a problem due to the fine droplets required for thorough coverage when spraying at low volumes. The components of airblast and high pressure boom sprayers are very similar except for the added fan and air manifold on the air-blast sprayer.

A few nurseries are using new low-volume applicators to apply nonselective herbicides. This equipment atomizes the herbicide into very fine particles that provide very uniform coverage. The atomizer is shielded to prevent drift and spray contact with the crop and is attached to an arm that pivots around the crop plants. The sprayer is well designed to spray around and between plants within the row. Both tractor-mounted and handheld models are used.

Some diseases, insects, and weeds are significant pests on a broad range of hosts; these are discussed in detailed sections below:

Biological Control and Biopesticides

There are many natural predators and parasites that keep pest populations in check. Ladybird beetles (larvae and adults) and lacewings (larvae) are predators. They feed on soft-bodied insects like aphids, mites and scale nymphs. Icheumonid wasps are parasites. The adult females lay their eggs inside soft-bodied insects like aphids. The wasp eggs hatch and feed on the contents of their aphid host, eventually killing the host. Many broad-spectrum insecticides used to reduce pest populations also reduce populations of natural predators. When monitoring for pest populations, look for natural predators and parasites as they are also an important source of pest control and may function in place of an applied pesticide.

Many biological control organisms are commercially available in Canada. Most biological control products are available for the control of insects and mites and are most successful in closed systems (i.e. greenhouses). Some predatory insects and mites can be effective in the field, especially where a continuous supply of pollen and nectar are available to them (energy for reproduction). Recent studies with entomopathogenic nematodes have shown excellent control of root weevils in container production and about a 50% reduction of root weevil populations in the field.

Physical or Mechanical Control

Physical and mechanical control involves such practices as such as mechanical cultivation of field soils which expose and injure weeds and can reduce pest populations by exposing soil insects to natural predators. Also application of sticky bands on the trunks of landscape trees to exclude crawling insects and prevent egg-laying, using yellow sticky tape in propagation greenhouses to offer supplementary control of flying insects, such as fungus gnats. As well as the practice of receiving new nursery material, holding it in quarantine area and monitor for any pests or diseases for a week or two before introducing it into your production area.

Non-pest (Abiotic) Problems

Abiotic diseases principally affect foliage and/or root system function. These diseases cause many plant problems; often predisposing affected plants to be attacked by secondary pest organisms. Gradual dieback and mortality may result.

Weather, soil conditions and human environmental disturbances have a major impact on these conditions. Water quantity and quality is probably one of the most critical issues aspects of crop production and seems to be on the decline as urban sprawl encroaches on cropping lands.

Control measures depend on eliminating or avoiding damaging factors (e.g. salt injury), obtaining resistant plants and improving growing conditions.

Root scorch from high salt levels is a common abiotic condition. It comes from salty irrigation water or from salt applied to remove ice and snow. A late-spring leaf scorch of *Acer* and *Fagus* may come from sudden exposure to full sunlight after a cloudy, wet period.

The ability of a plant to accommodate environmental change varies with the type of plant, its age and condition, and the nature and intensity of the changes. Oak, maple, ash and spruce have difficulty adjusting to new conditions such as soil compaction, drought, excessive water, change in soil level or root damage during construction and often exhibit leaf scorch or needlecast as a symptom of this stress.

Dieback

Nursery and landscape ornamentals often exhibit dieback of leaves and small branches. Symptoms may appear on individual branches or entire plants. Dieback may appear suddenly or develop so gradually that the true impact does not show for several years.

Some of the environmental and cultural causes of dieback include girdling from wires, strings and ropes left on after transplanting. Root problems, soil conditions, poor soil aeration, changes in soil grade, sun scald and low temperatures may also be at fault.

Light to moderate infestations of insects and diseases can also cause dieback symptoms. Some examples include scale insects, wood boring insects, root feeding weevils, white grub larvae, cankers, rusts, fire blight and vascular wilts.

Fall Needle Drop of Conifers

As shorter, cooler autumn days approach, older needles towards the inside of many conifers begin to turn yellow or brown. In some cases, these needles start to drop. This is usually a natural process. The degree of discoloration and leaf drop may relate to stress during the growing season. Low vigour caused by drought, transplanting, poor drainage, soil compaction, insects and disease can cause increased levels of needle drop. The following are some examples of this:

- Pines lose their oldest needles (closest to the trunk). White pines (*Pinus strobus*) often look quite yellow.
- Small branchlets towards the inside of white cedar (*Thuja occidentalis*) turn brown and fall off.
- Fir (*Abies*) and spruce (*Picea*) may lose needles on 1-3 year-old wood.

Needle Browning on Conifers

Winter damage may cause conifer needles to turn brown and drop in the spring. Many factors can lead to this condition, especially dry, windy weather while the soil is frozen. Roots

cannot absorb enough water from the frozen soil to compensate for the foliar desiccation from winter winds.

Good growing conditions during the previous growing season help plants resist winter damage. Roots in the upper soil surface are sensitive to drying and high temperatures. If these roots die during the growing season, poor conditions in the autumn may prevent sufficient regrowth to recover winter moisture losses.

Salt Damage

Road salt affects woody plants as both runoff and airborne drift. When plant tissues are wet and temperatures are above freezing, sodium and chloride salts (the most common ingredients in road salt) enter plant tissues and accumulate. Salt accumulation in the soil can greatly restrict the ability of the root system to uptake water. Repeated road salt injury weakens plants, making them susceptible to damage from many insects and diseases.

Drifting salt spray causes more plant damage than runoff. It can affect plants located 50+ metres away from a road. Symptoms appear more quickly in warm weather and are usually more severe on the side facing the road.

Salt damage on conifers is characterized by,

- Needle browning, beginning at the tip,
- Needle browning and twig dieback on the side facing the road, while little or none on the opposite side,
- No needle browning or dieback on branches near the ground under continuous snow cover,
- Needle and twig dieback severity decreases as you get further from the road, and
- Browning appears in late February or early March and becomes more obvious through spring and summer,

Salt damage on deciduous trees is characterized by,

- Slow bud development on terminal parts of branches facing the road,
- Leaves fail to emerge on terminal parts of branches facing the road,
- New growth on branches facing the road develop lower, dormant buds that causes a tufted or witches broom appearance,
- Flower buds on the road side do not open, yet normal flowering occurs on plants further away from the road, and
- Injury becomes evident as buds begin to break

Scorch

Scorch happens when plants have difficulty taking up water, usually during hot, dry weather. It appears as sudden leaf death or browning on leaf margins or between leaf veins, often in July and August. The veins frequently remain green.

Plants experiencing root injury due to construction, soil compaction, chemicals, drought or extreme heat can show symptoms of scorch.

Plant Pathogens/Diseases

The most economically significant disease of nursery ornamentals is root rot, as it usually kills young plants. Powdery mildew and bacterial blight are more common, but cause less significant damage. Other diseases of nursery ornamentals include *Botrytis*, downy mildew, damping off, rusts, and crown gall. Nematodes are common although not normally damaging, but soil fumigation to destroy these microscopic roundworms is rarely practiced.

Table 18

Pathology (Disease) Priorities

National Priority Ranking	Target Pest	Crop	Comments
1	Daylily rust	Outdoor and GH ornamentals	Daylily rust was first found in Canada and the U.S. in 2001. It is a devastating disease on many varieties of daylilies grown in Canada.
1	Rusts	Outdoor and GH ornamentals	Gymnosporangium rusts on *Juniperus* and Rosaceous plants. White pine blister rust. Hollyhock rust.
2	Fireblight	Outdoor ornamentals (apple and pear)	NO products are registered on ornamentals (non-bearing and ornamental apple, crabapple, pear) for fireblight. Non-food use.
3	Root rot disease complex	Outdoor and GH ornamentals	Pythium, Phytophthora and Fusarium. Only one product registered but on conifer seedlings only.
4	Downy mildew	Outdoor ornamentals	NO registered fungicides for downy mildew on outdoor ornamentals in Canada.
5	Powdery mildew	Outdoor ornamentals	Need reduced-risk products to be used in rotation to manage resistance.
5	Leaf blights	Outdoor ornamentals	Need reduced-risk products to be used in rotation to manage resistance.
5	Fusarium	Container-grown conifers primarily	Only one product registered. Need more reduced risk products to be used in rotation to manage resistance.
5	Black root rot		Low priority issue
5	Botrytis		Low priority issue
5	Wilt Diseases	(*Verticillium*) Field-grown stock Aschochyta wilt of Clematis	NO registered fungicides
5	Armillaria		Low priority issue
5	Crown Gall		ONE registered bacteriocide (Dygall)

Rust Fungi

Rusts frequently distort the shape of infected plant parts. They are a highly specialized group of fungi, with complex life cycles and several spore stages. Some can continually infect a single host plant from year to year, while others must complete their life cycle on different hosts each year. Rust fungi appear as white, yellow, orange, red or brown raised pustules on leaves, buds, fruits and stems. The pustules often have a powdery appearance and are easily visible to the naked eye. Identification of rust fungi usually requires laboratory examination.

Melampsora medusae and *M. occidentalis* are the 2 most commonly occurring foliage rusts in forest nurseries. They attack Douglas-fir, western larch, tamarack, ponderosa pine and lodgepole pine. Both rusts have yellow-orange spore-producing pustules on the needles in late spring through to August. These rusts require the alternate host *Populus* and occur predominantly in bareroot nurseries located in forested areas. On ornamental plants, common rusts include rose rust (*Phragmidium* spp.) on rose, alder rust (*Melampsoridium betulinum*) on *Alnus, Betula* and *Larix*, and rhododendron rust (*Chrysomyxa* spp.) on *Rhododendron* and *Picea*. In Eastern Canada, *Gymnosporangium* rusts (e.g. cedar-apple rust) are very problematic on *Juniperus* and the alternate

Rosaceous hosts (*Malus, Crataegus, Chaenomales, Amelanchier* etc.). This disease causes significant losses to the nursery industry each year.

Daylily rust, *Puccinia hemerocallidis*, is native to Asia but has recently emerged as a pest of daylilies in North America. This rust has a short incubation period, will spread quickly through a nursery and is very destructive, rapidly killing foliage of daylilies. The USDA is concerned that this disease will be a serious pest of daylilies and may threaten alternate hosts such as *Patrinia* spp. and the putative alternative host *Hosta* spp. Currently, there is little information on the biology of *Puccinia hemerocallidis* in North America. Different varieties of daylily have different susceptibilities to the rust. The spores can be spread by wind or by human movement of plants. This rust requires two distinct host plants for the completion of sexual life cycle but can also cycle repeatedly on daylily alone.

Fungicidal treatment of plant materials is considered a viable option for control although there are currently no fungicides registered for use on daylily rust in Canada. Careful removal of infected foliage followed by fungicide application may be an option although the nursery may opt to safely destroy all infected plants rather than try to regrow a symptom less canopy. It is likely that certain extremely susceptible varieties will need to be eliminated from the inventory in order to protect less susceptible varieties from high inoculum pressure and subsequent disease development.

Bacterial Blight/Canker (Pseudomonas syringae pv. syringae)

This bacterial disease attacks at least 40 species of woody deciduous nursery plants. It is a major problem causing die back on container nursery stock during peak shipping periods. Many deciduous, woody shrubs have been found to be susceptible to this bacterium including ornamental maples, lilacs, flowering cherries and oriental pears.

Symptoms first appear as container stock is uncovered in the spring, revealing blackened new shoots and tip dieback on *Acer, Cotoneaster, Euonymus, Forsythia, Magnolia, Philadelphus, Populus, Prunus, Pyrus, Rosa, Rubus, Syringa, Viburnum* and *Vaccinium*.

Other symptoms include blossom blast on pear and leaf spots and vein blackening on *Acer, Cornus, Magnolia, Tilia, Populus* and other hosts. *Malus* is less susceptible. Blossom blight, blackening of buds, leaf shot-hole and stem or trunk cankers with gum exudation are common on *Prunus*. *Pyrus* and stone fruits may also develop fruit spots.

Damage from bacterial blight is often worse following a late spring frost or cold period. Bacteria spread in water can enter young buds, wounds, and leaf pores. Once the weather turns hot and dry, the bacteria cease to cause new infections, although the disease remains "latent" in old cankers. The bacteria pass the summer and over winters inside twigs and buds. Leaf abscission scars can also be infected in the fall on some hosts, although symptoms may not be apparent until spring.

Chemical controls are often needed on young nursery and landscape stock, but more rarely on older established trees and shrubs. *Pseudomonas* blight can often be controlled on mature trees and shrubs with timely pruning and good plant management. Leaf spotting and some shoot dieback in the spring do not usually cause long-term damage to mature plants, and rarely requires chemical control. Mature trees may require treatment if shoot damage has been severe the previous year, to prevent recurring blossom blast, if larger branches are dying back, or if the trees are growing under other stressful conditions that increase their susceptibility.

Cultural controls consist of planting resistant varieties, protecting frost-sensitive plants from cold temperatures and ice formation, minimizing pruning wounds and disinfecting pruning tools, and maintaining plants in good health.

Some growers have reduced disease incidence by using multiple procedures such as, installing drip irrigation systems and delaying the removal of poly cover over high value, susceptible stock. Appling fertilizer after July may result in overly succulent growth in the fall, which is more susceptible to cold damage and blight. Plants should be spaced for good air circulation, and dead twigs and fallen leaves should be removed and destroyed.

Weeds around susceptible nursery stock should be controlled, as they serve as alternate hosts for the causal bacteria. The technique of cauterization (burning *Pseudomonas* cankers with a propane burner) has been shown to provide successful control of bacterial blight in stone fruit orchards in New Zealand: this technique could prove useful for larger landscape trees.

Fire Blight

Fire blight is caused by the bacterium *Erwinia amylovora*. It occurs on members of the Rosaceae family including *Amelanchier, Aronia, Chaenomeles, Cotoneaster, Crataegus, Malus, Photinia, Prunus, Pyracantha, Pyrus, Sorbus* and *Spiraea*. *Erwinia* prefers warm, humid/wet weather. New infections occur in the late spring during periods of rain or high humidity when temperatures are greater that 18°C. The bacteria overwinter in infected wood. New infections occur through blossoms, shoot tips, young leaves and wounds. Rain, wind and insects can spread this disease from plant to plant. Fire blight infections can be severe if conditions are cool and wet when the host trees are blooming.

The bacterium causes foliar and blossom blight, twig dieback and branch cankers. The succulent tips of blighted shoots often droop, forming a "shepherd's crook" and turn brown to black. Dry leaves remain on the plant and appear scorched. Cream yellow or tan coloured ooze may be present at the edge of cankers and on young infected shoots. Bleeding perennial cankers may appear on limbs, trunks or roots as the infection spreads. Entire trees can sometimes be killed and rootstocks can also be infected. In rootstocks, the bacterium causes a crown necrosis that resembles Phytophthora crown rot.

Management of fire blight involves cutting out and disposing of infected foliage and branches as soon as symptoms are noticed in late spring and through the summer. Cultural controls involve good plant management and providing good air circulation, drainage, avoiding overhead irrigation particularly early in the morning, using moderate amounts of nitrogen to prevent over succulent growth and removal of nearby infection sources (e.g. neglected apple or pear trees). Bactericidal sprays (e.g. copper sprays or streptomycin) at flowering may be helpful.

Root Rots

Armillaria root rot *(Armillaria ostoyae)* occurs on over 700 species of conifers and cedars, hardwood trees, shrubs and berries. This fungus is native to BC soils, and most often infects plants on newly cleared land. *Armillaria ostoyae* is the species found in infected conifers in BC, but other species may also attack berries, hardwood and fruit trees. In landscape plants, the disease is commonly found on conifers, *Malus, Quercus, Rubus,* and *Thuja*.

The first symptoms o root rot are plant decline and dieback, with leaves turning yellow and wilting. Only one side of the plant may be affected. Cutting away the bark at or just below ground level reveals a white mat of fungal mycelium. Black, shoestring-like strands of fungal mycelium (rhizomorphs) may be visible in the mat or scattered around the base of the plants. Rhizomorphs look like roots when found in the soil. In the fall, a cluster of honey-coloured mushrooms may appear at the base of infected trees. Sometimes only 1 or 2 mature trees will die out in a hedgerow, while in other cases a larger planting may be affected.

Pythium root rot in Douglas-fir seedlings.
Photo courtesy of
Pacific Forestry Centre,
Natural Resources Canada.

The fungus spreads from plant to plant by means of the rhizomorph strands, which can grow for several metres through the soil. In the fall, the mushrooms produce air-borne spores that also spread the disease. *Armillaria* can survive for many years on dead roots and old cane stubs. It is usually a disease of mature trees that are suffering from environmental stress. Healthy, vigorous trees can often out-grow the infection until other factors, such as flooding or soil compaction, inhibit root growth.

Cultural controls include watering deeply when needed, while avoiding surface watering around the crown and main trunk. Infected trees should be removed, and the soil in the root zone re-planted with a resistant species. For mature shade trees with early decline symptoms, it may help to remove any grass or ground cover and expose the soil in a 1 meter radius around the base of the tree, keeping the soil warm and dry and providing a less favourable environment for fungal growth. In field nurseries, planting in trenches lined with plastic sheeting may help if the infection is coming from an adjacent stand. There is no effective chemical control for root rot conditions. Soil fumigation may suppress the disease temporarily, but will not eradicate it

There are many species of *Pythium* and *Phytophthora* that attack a wide range of plants. Woody plants are more commonly attacked by *Phythophtora* species, and herbaceous plants by *Pythium*, but there are many exceptions. *Pythium* species are often present in dead roots and crowns of woody plants as secondary invaders, following *Phytophthora* root rot, other diseases, or environmental damage.

Commonly affected plants include *Azalea, Calluna, Cedrus, Chamaecyparis, Cornus, Cotoneaster, Erica, Ilex, Gaultheria, Juniperus, Larix, Malus, Pieris, Pinus mugo mughus, Pseudotsuga, Rhododendron, Taxus,* and *Thuja occidentalis*.
Root, crown, and occasionally foliar, branch, or stem infections can be caused by these fungal organisms. Plants with root rot typically exhibit drought or nutrient deficiency symptoms including leaf drop, wilting, and general decline. Infected leaves and shoots are often black and soft. Infection often spreads from the roots up into the crown or base of the stem or trunk. Cutting into the infected area reveals a dark brown to black rot with a distinct margin between rotted and healthy tissue.

Phytophthora and *Pythium* spread via infected planting stock or through movement of sporangia in contaminated soil, water, and wind-blown rain. Sporangia germinate to produce zoospores that infect roots and other plant tissues. Thick-walled oospores of *Phytophthora* and *Pythium* will survive in soil for many years. Infection is favoured by wet conditions in poorly drained soils and either in or under container-grown plants (e.g. *Cotoneaster, Rhododendron* etc.). In the landscape, root rot is common on slopes subject to drought in the summer and excessive moisture in the winter. Drought-stressed plants are more susceptible to root rot infection when moisture is restored.

In the nursery, only disease-free stock plants should be used for propagation, and strict sanitation should be practiced during propagation, media preparation and potting. Good drainage within and underneath containers is of primary importance. Susceptible genera should not be planted in soil contaminated with *Phytophthora*. In landscaping, plants should be pruned and spaced to allow for good air circulation. Weeds and grasses around the plants should be controlled in order to maintain a warm, dry area around the roots. Fallen leaves and dead twigs should be destroyed.

Downy Mildew (Peronospora spp.)

There are several species of *Peronospora* that can cause downy mildew on a wide variety of plants. Commonly affected ornamental plants include *Buddleia*, foxglove, *Phlox*, *Prunus, Rosa, Rubus*, and snapdragon. Most downy mildew fungi are specific to a single host plant, but some can infect plants in several genera.

Symptoms are variable and can include a downy, felt-like or powdery white to yellow residue on the underside of leaves; leaf and growing tip distortion; stunting and yellowing of plants; yellowing of leaves and early leaf drop; and/or purple spotting of leaves along the veins or mid-vein blotches. The symptoms can resemble nutrient deficiencies or soil/root problems caused by other factors.

Peronospora fungi infect plants via sporangia that enter through leaves and stem buds, but can then grow systemically, progressing down to the stems, crowns and even the roots. Infected mother plants that do not show serious symptoms can thus transmit the infection to cuttings, which die off after transplanting or continue to grow poorly. Optimum conditions for sporangial infection are cool temperature (about 16°C) and several hours of leaf wetness. Many downy mildew fungi also produce oospores that can carry over in soil and plant debris for several years and provide a continuing source of infection each year.

When temperatures are cool in the evening, overhead watering should be avoided. Drip irrigation or morning watering will allow the leaves to dry off quickly. When propagating, the mother plants and seeds should be disease-free. Perennial plants should be separated from new production plants, as the perennials may harbour and spread the fungus. Plant debris, including fallen leaves, should be removed. Good sanitation is important in preventing disease spread.

Powdery Mildews

There is a powdery mildew fungus that attacks almost every plant species, with the exception of conifers, which are generally resistant. With few exceptions, most powdery mildew fungi are very host specific. Under favourable conditions, these diseases can cause significant damage. Commonly affected ornamental plants include *Acer, Azalea,*

Betula, Ceanothus, Clematis, Cornus, Corylus, Gaultheria, Hydrangea, Kalmia, Lonicera, Malus, Nandina, Quercus, Rhododendron, Ribes, Rosa, Syringa, Vaccinium and *Viburnum*.

A powdery, chalky white or light-coloured growth appears on infected leaves, initially resembling spray residue. The spores may be seen on both the upper and lower leaf surfaces, with some variation by species. Symptoms may first appear as only mild, diffuse yellow spotting on the upper side of the leaves. The underside of these spots will show white, powdery sporulation. In more severe cases, dwarfing, leaf and growing tip distortion, overall yellowing and severe browning of the foliage may occur. On some species, such as *Malus*, shoot growth may be stunted.

High humidity favours spore production, and low humidity favours spore maturation and release. Warm days and cool nights are ideal for disease development. In coastal BC, powdery mildew can occur as early as January on some plants.

The spores spread mainly by wind and carry over on leaf debris and perennial foliage from year to year. When a powdery mildew spore lands on a susceptible leaf, it enters the leaf cells via a germ tube and then grows inside the leaf, producing the abundant chalky sporulation that is visible 5 to 10 days later. Spores can infect susceptible leaves whenever they are in contact, so protectant fungicidal sprays are often necessary to protect new spring growth before infection occurs.

Infected plant parts should be pruned and burned or buried, if practical. Fallen leaves should be raked and burned or buried. Good spacing will allow for air circulation and reduced humidity. On severely affected plants, fungicidal sprays may be necessary. Several resistant cultivars and hybrids are available for different genera.

Botrytis Blight (Grey Mould) and Storage Moulds

Botrytis cinerea is a widespread fungus that occurs wherever there is high humidity and decaying plant material. The disease first becomes established on dying or dead tissue and then spreads to healthy plant parts. Infections first appear as water-soaked areas on soft or senescent foliage, flower parts or young stems. These areas turn tan to brown or greyish-white as they dry out. Fuzzy grey spore masses develop on infected tissues under cool, moist conditions. Spores are airborne and can infect healthy plant tissue. This disease is often problematic in overwintering polyhouses where stagnant moist air and day/night temperature fluctuations result in condensation on the plant. *Botrytis* can carry over on old plant debris and as sclerotia in the soil. Sclerotia can survive for several years.

The disease is primarily a problem in container stock; however lush, dense seedling beds and closely planted landscape plants may also be affected. Because conifer seedling stock may be stored for a period of several years, *Botrytis* and other storage moulds are of major importance. Symptoms initially develop on the lower needles of bundled seedlings. Damage can quite often develop without conspicuous surface mould. The disease progresses up the shoots and stems, and the needles become watery and decayed. Affected needles normally fall off. Branches may have water-soaked lesions from which the bark easily strips, exposing the dead, yellowed cambium.

Commonly affected woody plants include *Alnus, Azalea, Camellia, Cedrus, Cornus, Crataegus,* cypress*, Hibiscus, Hydrangea, Ilex, Juniperus, Prunus, Pseudotsuga, Pyrus,*

Rhododendron, Rosa, Syringa, and *Viburnum.* The most commonly affected flowering perennials are *Aster, Chrysanthemum, Convallaria majalis, Dahlia, Dianthus, Paeonia,* statice, *Tulipa,* and many herbs.

Infected plants or plant parts should be quickly removed from production areas to prevent the spread of *Botrytis* spores. Plants should be well-spaced to encourage air movement, and weeds should be controlled. If practical, plants should be watered only in the morning, and left to dry off quickly, and humidity in greenhouses should be reduced. When fungicidal sprays are used, products should be alternated to prevent the development of resistant strains.

Vascular Wilts

Vascular wilts are caused by fungi or bacteria entering a plant's vascular system through the roots. These infections can reduce water supplied to the leaves, causing wilt. Often the first symptoms seen are nutrient deficiencies, yellowing, wilting and dieback of young twigs and branches, often on one side of the plant or tree. In early stages of wilt, leaves may recover

temporarily during cool, moist periods. Eventually, the wilt becomes established and the leaves and twigs die, leading to branch mortality and the eventual death of the entire plant. Serious vascular wilt diseases include "Dutch Elm Disease" (*Ceratocystis ulmi*) and *Verticillium* wilt of *Acer, Tilia* and *Catalpa* (*Verticillium dahliae*). *V. albo-atrum* is less common but can persist in soil for 1-2 years and is often found on alfalfa. These fungi attack may deciduous trees, herbaceous perennials (e.g. *Ascochyta* wilt of Clematis), berries, weeds and vegetables but do not infect conifers, cedars or grasses.

Verticillium wilt is not a problem in container production unless infested soil, compost or wood chips have been used for potting or mulching. To avoid wilt diseases, use resistant plant varieties and grow susceptible crops in disease-free media. One can sometimes maintain Verticillium wilt-infected plants by improving vigour through pruning, fertilizing and watering. Since these disease organisms live deep inside the plant, surface application of fungicides will not be effective.

Damping Off

The pre-emergence form of this disease rots either ungerminated seeds or germinants before they emerge. The post-emergence form rots seedlings slightly above and below the soil surface, causing them to topple over. Many fungi are involved, including *Cylindrocarpon, Fusarium, Rhizoctonia, Pythium, Phytophthora,* and more.

Seeds should be sown at their optimum temperature, and irrigated in the morning so the soil is not soaked overnight. In some cases, a fungicidal treatment may be warranted.

Crown Gall (Agrobacterium tumefaciens)

This soil-borne bacterium affects over 600 plant species in more than 90 families. Common hosts include *Aster*, blueberry, *Chrysanthemum*, *Cydonia*, *Euonymus*, *Juglans, Juniperus*, *Malus*, *Tagetes*, *Prunus*, *Pyrus*, *Rubus, Rosa*, *Salix* and *Vitis*.

Galls may develop on the crown, roots, or in some cases on the aerial shoots and branches of infected plants. Galls are usually soft, spongy and white at first, but later

turn hard and brown. They range in size from a few millimetres to several centimetres in diameter. Infected plants often show symptoms of nutrient deficiency, such as discolouration of leaves, followed by a general decline and stunting.

In some cases, galls may have physiological causes. Roses often produce a graft canker gall due to an incomplete graft. Rhododendrons produce galls on branches, roots, or at the base of the plant, caused by genetic disorders and/or environmental factors. Apples are also susceptible to galls due to physiological or environmental causes. Fungi such as *Exobasidium* or Taphrinia fungi on azalea, *Cotoneaster* and *Prunus* or insects such as midges, wasps and gall mites on various ornamental species may cause other galls.

The bacteria can survive for at least 2 years in soil. They spread on diseased nursery stock, in irrigation or ground water, and on cultivation and pruning equipment. The bacteria infect roots and crowns, often entering through wounds caused by pruning tools, insects, freezing or pathogenic nematodes. Rain splash can move bacteria from soil to stems and leaves where they can infect plants through wounds or stomata.

Crown gall can be managed with several cultural practices. Purchased stock should be examined for the presence of galls, and plants with gall symptoms should not be planted. Mechanical injury to roots and bark in the crown area should be avoided, as this creates entry sites for bacteria. If only a few plants are affected, they should be removed and destroyed to prevent the infection from spreading. If only a few branches are affected, the galls can be pruned off. Pruning tools should be sterilized with bleach or other disinfectants between cuts. Crop rotation and soil solarization may be effective, but little information is available regarding the effectiveness of these techniques.

A biological control, Dygall, is available as a pre-plant treatment. This treatment is not effective on plants with galls, and may have reduced effectiveness on plants to be sown in infested areas. Dygall is not effective on all biovars of crown gall.

Anthracnose diseases

Various leaf anthracnose diseases on trees and shrubs reduce the market value of woody nursery stock each year. Probably the most challenging anthracnose disease can be found on Euonymus (*Colletotrichum gloeosporioieles*). The fungus attacks newly-emerged shoots and leaves, causing leaf spot and cankers which may lead to dieback and significant crop losses. Euonymus anthracnose is most active as container plants are maintained under polyhouse structures until inclement, early spring weather.

Insects and Mites

Table 19

Entomology priorities

National Priority Ranking	Target Pest	Crop	Comments

1	White grubs (June beetles, EU chafer)	Outdoor ornamentals, nursery crops and Christmas trees (soil applied use pattern) NOT Containers	No products currently registered to control white grubs on ornamentals. White grubs of June beetle and European chafer causing new (expanding host range) economic damage to field-grown woody ornamentals and Christmas trees (*Abies*, *Picea, Cornus, Syringa* etc.). Estimated crop losses up to 40% at some farms with sandy soils. Injectible systems would be favourable for large, landscape trees (supports IPM).
2	Root weevils adults & larvae	Outdoor ornamentals, container and field	
3	Spruce spider mite, Two-spotted spider mite, European red mite, Broad mite	Outdoor ornamentals and nursery crops	Only one miticide (Vendex) is currently manufactured and registered for use on ornamentals. Need other products to manage resistance. Need miticides (decrease toxicity to insect beneficials) to replace other general insecticides.
4	Rose midge Daylily midge	Outdoor ornamentals, container	
5	Aphids	Outdoor ornamentals and nursery crops	Roses, Caragana, Crabapples, Perennial Vines and many other ornamentals have economic losses each year due to leafhoppers and aphids.
5	Leafhoppers	Outdoor ornamentals and nursery crops	Roses, Caragana, Crabapples, Perennial Vines and many other ornamentals have economic losses each year due to leafhoppers and aphids.
National Priority Ranking	**Target Pest**	**Crop**	**Comments**
5	Pine shoot beetle, Elm bark beetle, Shot hole borer, Leafminers, Leaf beetles, Bronze birch borer, Aphids, Leafhoppers, Scale insects	Outdoor ornamentals and nursery crops (foliar/ bark applied use pattern)	No products currently registered for pine shoot beetle or shot hole borer. Pine shoot beetle is a quarantined pest; infestations prevent shipping and harmonized pest control options. Only old OP and OC's registered for elm bark beetle. Injectible systems for insecticides would be favourable for large, landscape trees (supports IPM).
5	Leather jackets	Greenhouse and outdoor, container ornamentals	

5	Thrips	Outdoor ornamentals, container and field	
5	Lepidopteran pests		
5	Lygus bug		
5	Sawfly		
5	Scale		
5	Mealybug		
5	Slugs		

White Grubs: Japanese Beetle, European Chaffer, June Beetle

Pests below the soil line can seriously damage plants before making themselves known. It can be difficult to determine the extent of the pest problem of the effectiveness of treatment. Monitoring programs should include examination of crowns and roots below the soil, especially where symptoms of stress are evident.

Japanese beetles (*Popillia japonica*) are a quarantined pest by the Canadian Food Inspection Agency (CFIA). This means that its movement (i.e. Japanese beetles and infested plants or soil) is being regulated to help prevent further spread into unifested areas. While not a major cause of crop damage in Canada, it is important to control infestations and prevent new ones. Established populations exist in counties of southern Ontario.

Japanese beetle adults are about 13 mm in length and easily identified by their bright, metallic green head and thorax, metallic brown to copper wings tinged with green edges and six tufts of white hairs along either side of the abdomen. The larvae are "C"-shaped, milky-white grubs about 25mm in length. There is only one generation per year with adults emerging from the soil in late June to mid-July, feeding actively and laying eggs through the summer. The larvae feed into the fall, overwinter and start feeding again in the spring. Pupation takes place in May and early June.

Adults do not damage turf but will damage the foliage of over 300 species of nursery and fruit plants including members of the rose family as well as maple, *Acer*; birch, *Betula*; mountain ash, *Sorbus*; linden, *Tilia*; and fruit trees such as apples, *Malus*; cherries, peaches, plums, *Prunus*; grapes, *Vitis* and blueberries, *Vaccinium*. Larval feeding on the fibrous roots of grasses makes this stage a destructive pest for turf. Injured turf initially wilts and yellows during August and September. As the damage progresses, dead patches of turf can be observed. Often confused with drought stress, these affected areas can be lifted and pulled back to reveal the grubs beneath. Grubs will also feed on the roots of ornamentals and vegetables.

Control strategies should be planned to discourage and prevent adult beetles from laying eggs in nursery fields. Since eggs are usually laid in grassy areas, clean cultivation may discourage egg laying. Clean cultivating soils may also help reduce populations by bringing eggs and grubs to the surface, exposing them to sun, wind and predators. It has also been noted that while adults may prefer to feed on clover and alfalfa, grubs do not thrive well or rarely feed on white, red, or alsike clover, buckwheat, alfalfa, oats, barley,

common rye and orchard grass. These may be possible ground covers to discourage grub populations. Many weeds are hosts to adult Japanese beetles and grassy or weedy areas surrounding fields may act as potential breeding grounds for the pest. Maintaining good weed control will help eliminate potential food sources. There are currently no chemical treatments registered for use against Japanese beetles in nursery settings.

In addition to Japanese beetle larvae, the larvae of European chafers (*Rhizotrogus majalis*) and June beetles (*Phyllophaga* sp.) make up the group of insects called "white grubs". White grubs submit into a distinctive "C" shape when uncovered in the soil. Traditionally, pests of turf, white grub larvae have been expanding their host range. In the last few years, white grub larvae have been found feeding on the roots and crowns of woody nursery stock in the field. In some cases, white grubs have been responsible for losses up to 30% of newly-planted woody nursery stock in the field. There have also been cases of white grubs feeding on vegetable crops and cash crops.

The European Chafer completes a life cycle in one year. Eggs hatch around mid-July, and the grubs molt twice over 8 weeks. The mature grubs are well adapted to cool moist conditions and feed all fall. During the winter they dig down during periods of freezing conditions, but otherwise remain within 5 cm of the surface. They feed in the spring until April when they become pupae. Adults emerge in late May; fly to nearby deciduous trees to mate and feed, and subsequently females deposit up to 50 eggs each. The grubs are the damaging stage. They feed on all types of grass and, if numerous and food is scarce, may move into vegetable plantings to feed on corn, potatoes and other crops. European chafer grubs prefer to feed on fibrous roots, and can damage ornamental and nursery plants by reducing their fibrous root system.

Most of the damage is done by the third (final) instar grubs in the fall and early spring, but damage can be masked by the abundant moisture at these times. Drier weather can quickly result in the appearance of brown, dying patches. Considerable damage to turf can occur in the fall and winter from animals, especially skunks, and birds digging up the grass to feed on the larger grubs. The adult beetles feed at dusk on the leaves of deciduous trees but, even when numerous, seldom cause significant damage.

There are no reliable commercial or natural biological agents for this pest. Healthy, vigorous, well-irrigated turf can withstand low levels of grub feeding. Insecticides are most effective when applied in August and September against the smaller grubs. However controls can also be applied successfully to non-frozen turf in the fall and early spring. Before applying sprays, remove excessive thatch and irrigate if the soil is dry to bring the grubs to the surface. After applying a pesticide, water the treated area to move it to the root zone.

Root weevil damage to a conifer seedling.
Photo courtesy of

Root Weevils

Root weevils are pests of both ornamental and forest nurseries. The two most problematic root weevils found across Canada, include the black vine weevil (Otiorhynchus sulcatus) and strawberry root weevil (O. ovatus).

Adult weevils feed on leaf margins and cause a characteristic notching pattern. Adults are elusive, feeding at night and hiding during the day. As a result,

populations often go undetected until damage occurs. Larvae can be even more damaging than adult weevils, since they are present in the soil for 9 to 10 months of the year, where they feed on plant roots. The larvae can completely girdle the stems of ornamentals at the soil line. Weevil larvae girdle container-grown forest seedlings in June and July, often just below the point at which foliage begins. They feed throughout the fall and during warm periods in the winter; the woods weevil feeds all winter. Weevil damage can go unnoticed in forest seedlings until they are lifted.

Adult weevils have 1 generation per year, in which they lay between 200 and 400 eggs at plant bases. Depending on the species, either adults or larvae may overwinter. Emergence time varies on the species, ranging from May to June. Newly emerged adults feed for approximately 4 weeks before laying eggs: it is best to target adult weevils rather than eggs or larvae. The genera *Camellia, Erica, Heuchera, Juniperus, Kalmia, Picea, Rhododendron, Pinus, Rubus, Rosa, Sedum, Thuja, Taxus, Vaccinium, Tsuga, Yucca* and *Viburnum* are all susceptible to weevil damage.

Controls for weevils in ornamental crops are most often directed at the adults. As they are wingless, using a board with carved grooves placed grooved side down on the ground can be used to monitor for adult populations. Entomopathogenic nematodes *(Heterorhabditis megidis)* may be applied in spring or autumn to control larvae but are much more effective on container crops than field crops. If insecticides are necessary, sprays should be applied in late June to early July. Spraying at dusk or after dark may increase the efficacy of the application, because adults leave the soil at night to feed on the foliage.

Bareroot conifer seedlings should be kept clear of weeds and cull material. Traps, consisting of lumber planks placed flat on the soil, should be monitored frequently for adults during the summer. Infested areas may be sprayed 2 weeks after emergence, and again 3 weeks after the initial spray. The areas surrounding container conifer seedlings should be kept clear of weeds and cull material. To kill larvae in plugs, a drench of nematodes may be applied in September when the larvae are young.

Mites: Spruce Spider Mite, McDaniel Mite, Two-spotted Spider Mite, Blister Mite, Rust Mite

Mites are spider-like arthropods that are almost invisible without magnification. Many species of harmful, harmless, and beneficial mites are present in nursery stock. Typical damage appears as speckling, bleaching, or bronzing of the foliage. Heavily infested foliage may drop prematurely. Some species, such as McDaniel *(Tetranychus mcdanieli)*, spruce spider mite (*Oligonychus ununguis*) and two-spotted spider mites *(T. urticae)* produce webbing on needles or leaves. Mite populations will increase rapidly and can cause significant damage if left unchecked. Identification of mite hot spots early in the season is important.

Spruce spider mite webbing on a conifer seedling.
Photo courtesy of
G.B. Neill, Pacific Forestry Centre,
Natural Resources Canada.

Blister mites *(Eriophyes pyri)* cause discoloured blisters on leaves, and russeting and deformities on fruit. Rust mites *(Aculus schlechtendali, Epitrimerus pyri,* and others) cause the leaf surface to become bronze, brown, or silver. Bladder

gall (Eriophyid) mites are yellow-white in color and slow-moving. They live in colonies in the needle sheaths of conifers, and cause galls to form on *Juniperus* and *Cedrus.* The spruce spider mite *(Oligonychus ununguis)* is currently the most damaging mite pest of conifer seedlings. These mites feed on needles, resulting in dryness, mottled patches, and bleaching. Severely affected foliage turns yellow to rust-brown, and the needles drop off. Fine silk webbing can be found among the needles of infested twigs.

Native predatory mites, such as *Amblyseius* spp. and *Phytoseiulus persimilis*, usually keep pest mites under control in ornamentals. The *Stethorus* lady beetle, or spider mite destroyer, is a relatively good control on mature plants in landscape areas, but it usually appears too late in the season to prevent damage on young nursery plants. Plants should be examined for these beneficials before spraying: if beneficials are present, spraying should be delayed or avoided. As two-spotted spider mites thrive in hot and dry conditions, regular foliage wetting will help suppress this pest. Blister mites must be controlled with a dormant spray, as it is protected within the plant tissue during the growing season. When other mites are first detected, a chemical spray may be applied. If so, applications should be repeated in about 10 days.

Rose Midge, Daylily Midge

The rose midge, *Dasinerua rhodophaga*, is native to North America. The adults resemble small 1-2mm reddish-brown mosquitoes. Females lay eggs inside the sepals of flower buds or leafy tips which hatch into creamy white to reddish coloured larvae then feed on the buds and rose tips. Pupation generally occurs in the soil but may also occur in the damaged rose tips. The adults emerge from pupae in the soil in the spring in synchrony with the production of new plant growth and flower buds. The entire lifecycle can take as little as 2 weeks.

The larval stage is the only damaging life stage of this pest. The damage is very diagnostic as the larvae feed on new leaf growth and tunnel into immature flower buds causing the buds to bend, wither, blacken and die. The damage often resembles foliar burn caused by pesticides. Under severe infestations, rose midges can cause complete failure of a bloom cycle.

The combination of a short life cycle and the fact that only one or two larvae are necessary to damage a tip or bud and continue reinfestation means that control has to be near complete to arrest an infestation. In other jurisdictions successful control measures require repeated soil and foliar insecticide applications. These chemical measures will also affect other insects, including beneficials. However, there are currently no insecticides registered for use in Canada against rose midge. Pruning out infected buds can help for limited infestations and will help to reduce the midge populations. Plastic sheeting placed under infected roses will help to collect larvae as they drop to pupate in the soil.

The daylily midge or hemerocallis gall midge, *Contarinia quinquenotata*, is a pest of daylilies particularly in Europe but has been recently identified in British Columbia. The adult is a small, seldom seen fly that lays its eggs in daylily blooms. The maggots feed on unopened flower buds and cause them to become distorted and unable to open. Infested buds will contain numerous white maggots that are around 3 mm in length. Damage is evident between April and July as the larvae develop inside flower buds causing them to become inflated, distorted and unable to open. This pest has the potential to become a serious problem for daylily producers in Canada.

There are currently no chemical options to control this pest although systemic insecticides can be effective. Removal and destruction of distorted buds can help control this pest. The planting of an early yellow daylily trap crop has been found to reduce the population in Southern England.

Aphids and Adelgids

Aphids and adelgids both feed by piercing and sucking mouthparts. Their feeding can stunt plant growth, or induce the formation of galls and witches broom. They have very complex life cycles that often involve alternate hosts. These small, soft-bodied, sap-sucking insects vary in color from pinkish white to green and black. They may be winged or wingless and range from 1.8 to 3mm in length. They reproduce continuously throughout the season and most species overwinter on plants as eggs. Aphids suck plant sap from the undersides of leaves and needles, and prefer to feed on new growth.

Symptoms of feeding include mottling and distortion of foliage. The ornamentals that are most commonly attacked are *Picea* (by spruce aphid, *Elatobium abietinum*); *Euonymus*, *Hedera*, *Prunus* and *Rosa* (by green peach aphid, Myzus *persicae*); *Prunus* (by black cherry aphid, *Myzus cerasi*), and *Rosa* (by rose aphid, *Macrosiphum rosae*, and potato aphid, *Macrosiphum euphorbiae*).

The giant conifer aphid *(Cinara* spp.), spruce aphid, and Cooley spruce gall aphid *(Adelges cooleyi)* feed on conifers. Giant conifer aphids attack all species of conifer seedlings in nurseries. Great numbers of these large aphids feed in groups on twigs or branches, and may cause foliage chlorosis. The small, dull-green spruce aphid is usually found on older needles, and causes mottling followed by chlorosis and needle drop. The Cooley spruce gall aphid feeds on Sitka, white spruce, Englemann spruce, and Douglas-fir. In the nursery, damage is most severe on Douglas-fir where the aphids are covered in tufts of white cottony wool and feed on new needles. In older spruce trees, the aphids cause large cone-shaped galls. This damage is rarely visible in the nursery.

Cooley spruce gall aphid: feeding damage on Douglas-fir. Photo courtesy of Pacific Forestry Centre, Natural Resources Canada.

A conifer root aphid, *Pachypappa tremulae*, has infested stock at several nurseries in the province. To date, most infestations have occurred on container spruce, but related root aphid species also infest pine, larch and Douglas-fir.

Infestations are usually on the surface of the plug between the roots and the container wall, closer to the top of the plug than the bottom. Most nurseries that have sustained infestations of this aphid have not reported any damage. Studies have shown that they have no measurable effect on seedling performance, and therefore no control strategies are recommended.

Aphids in ornamentals and conifer seedlings can often be managed by physical and biological controls. A strong spray of water will dislodge aphids, thereby damaging their mouthparts. This technique will often control light infestations. Many natural enemies such as aphid midges, lady beetles, lacewings, syrphid larvae and parasitic wasps help reduce aphid populations in both ornamentals and conifer seedlings.

However, populations of natural enemies often become abundant only when the aphid population is high and may not reduce the aphid population below damaging numbers early in the growing season. Plants should be monitored regularly, starting in early spring. If aphid levels become damaging before natural enemies appear, natural enemies may be released, or a pesticide may be necessary.

If possible, growers should delay spraying until June when natural enemies will begin to significantly reduce aphid populations. Preventive dormant oil sprays applied prior to bud break will control overwintering aphid eggs.

Bark Beetles and Wood Borers

Wood borers are beetles that tunnel into the buds, shoots, bark or wood of most shade trees, conifers and some fruit trees. Some species attack healthy trees (e.g. emerald ash borer, *Agrilus planipennis*), but most attack trees and shrubs already weakened from another stress (e.g. healed-in, balled and burlapped trees are under stress and can be attacked). It is important to prevent borer injury, as infested plants may be damaged beyond repair before the pest makes itself known. Signs of damage include dark, discoloured or dead areas and branches. Sap and sawdust-like borings may cling to bark and litter the ground. Borers also provide an entrance for disease-causing fungi. They can weaken trees, making wind damage likely, and may eventually girdle and kill the tree.

To prevent infestation, it is recommended to burn all plant debris, keeping trees growing vigorously and avoiding transplant shock. Remove and burn damaged limbs and plants. It is important to note that many of the borers that plague the nursery industry are quarantined pests, and many of these quarantined pests lack registered chemical control (e.g. pine shoot beetle, emerald ash borer etc.).

Caterpillars: Bruce Spanworm, Winter Moth, Cranberry Girdler, Cutworms, European Pine Shoot Moth, Tent Caterpillars, Skeletonizers, Spruce Budworm, Tussock Moth

Bruce spanworm *(Operophtera bruceata)* and winter moth *(O. brumata)* are almost identical in appearance and habits, and are often discussed together in terms of pest management. These insects attack a wide variety of deciduous ornamentals. Young larvae drift on silken threads, so nursery trees can become infested from neglected backyard trees in the area. From early spring to early June, these caterpillars feed on buds, foliage, flowers and fruit. Defoliation occurs when infestations are severe. Genera known to be susceptible to Bruce spanworm include *Acer*, *Fagus*, *Quercus*, and *Populus*. *Acer, Betula, Malus, Populas, Quercus* and *Vaccinium* are often attacked by winter moth.

Ornamental trees can be protected with sticky bands applied to the trunk and larger limbs. The bands should be applied in late October to trap female moths crawling up the tree to deposit eggs. All bands should be removed and burned in February and March.

The cranberry girdler *(Chrysoteuchia topiaria)* has been found in nurseries throughout the province. Adult girdlers are small, delicate moths with silvery-grey coloring. The larvae girdle seedlings in the root collar area. Damaged seedlings have a ragged appearance, and occur from August to November (depending on the nursery location and season). In bareroot nurseries, Douglas-fir and true firs are the preferred hosts. In containers, both spruce and Douglas-fir have been attacked.

Pheromone traps are available to monitor moth populations. An average of 3 moths per trap indicates that damage from larvae in the fall will be significant. If this threshold is reached, oviposition by the adults should be reduced by applying an insecticide. Cultural controls for the cranberry girdler include removing or reducing grassy areas in and around the nursery, as this pest readily feeds on grass. Grassy sites may harbour source populations; frequent mowing can help to reduce these populations.

Adult cutworm moths are dull-coloured and usually nocturnal. Their larvae are large, soft, dull-coloured caterpillars up to 4 cm long with hairless bodies and shiny heads. Larvae of several cutworm species have been pests in forest nurseries, including the bertha armyworm *(Mamestra configurata)*, the variegated cutworm *(Peridromoa saucia)*, and the black army cutworm *(Actebia fennica)*. All species of seedlings and stock types can be attacked. Populations are likely present at all nurseries in every growing season, but the severity of infestations varies greatly. Damage is usually confined to very young succulent seedlings. Foliage, roots or stems may also be affected.

Crop and non-crop areas should be kept free of weeds to reduce the number of egg-laying female moths. The use of light traps in greenhouses can reduce adult populations. Moths can be excluded from greenhouses and shelterhouses by keeping the doors closed and placing screens over the fan intakes and vents. For small outbreaks, cutworms should be removed from the growing media and destroyed. Tebufenozide (an insect growth regulator) may be applied to help control cutworms.

The larvae of the European pine shoot moth *(Rhyacionia buoliana)* can damage most *Pinus* species by boring into the buds and shoots, and injuring or killing them. They overwinter in the bud and emerge the following June, and the adult flight occurs in June and July. This pest is largely controlled by natural enemies.

Pheromone traps can be used to indicate if moths are present. If any moths are found, treatment is recommended. Pine stock should be examined at the end of September for an excess of resin around the buds. This symptom indicates the presence of European pine shoot larvae. Infested seedlings should be culled and burned.

Forest tent *(Malacosoma disstria)*, Eastern tent *(M. americanum)* and Western tent *(M. californicum)* caterpillars overwinter as hardened egg masses encircling a twig. Eggs hatch in May, and larvae feed in colonies, consuming flowers, buds and foliage. The apple and thorn skeletonizer *(Anthophila pariana)* overwinters as a pupa, emerging in the spring to lay small green eggs under leaves. Larvae feed within rolled-up leaves. There can be up to 4 generations per year.

Genera susceptible to damage by forest tent caterpillars include *Acer, Betula, Crataegus, Fraxinus, Populus, Prunus, Quercus, Rosa, Salix, Tilia* and *Ulmus*. Western tent caterpillars are likely to attack *Arbutus, Betula, Ceanothus, Corylus, Crataegus, Ilex, Malus, Populus, Prunus, Quercus* and *Salix*. Genera susceptible to attack by skeletonizers include *Betula, Malus, Prunus, Pyrus* and *Sorbus*. During the dormant, season, egg masses should be pruned or peeled off the twigs. In the spring, if tents are not numerous, they should be pruned off along with the feeding caterpillars, and destroyed. The biological controls tebufenozide and *Bacillus thuringiensis* var. *kurstaki* are registered for these types of caterpillars.

The spruce budworm can be a serious problem in nurseries located near areas where forest infestations occur. Between May and July, nursery stock can be infested with

larvae that have overwintered in and around the nursery site. Larvae are voracious feeders, and can cause significant damage to small conifer seedlings. *Abies* and Douglas-fir are the preferred hosts. *Picea* can also be damaged if grown in an area where infestations are heavy in surrounding trees. Adult moths lay their eggs on nursery stock during their flight in mid-July. Larvae are difficult to find and control; and may accompany nursery stock to the reforestation sites.

Nursery personnel should monitor the crop carefully in the spring, and control larvae that blow onto the seedlings. Pheromones and light traps can be used to monitor adult populations. Significant infestations of larvae warrant a pesticide application.

Larvae of tussock moths *(Orgyia pseudotsugata)* can be chronic pests on Douglas-fir, true firs, and ornamental spruce. The females cement their white egg masses to the styrofoam containers in reforestation nurseries. When the blocks are re-used in the spring, the larvae emerge to infest container stock. Larvae are brightly coloured in yellow and black hairs, and will attack all species of conifer seedlings.

Larvae are often easily detected by nursery staff and can be removed manually. The hundreds of hairs on these caterpillars can cause a rash on the skin of some people. When infestations become too large for manual control, insecticide sprays can be used.

Leafminers and Needle Miners

These insects are the larvae of various species of wasps, flies, moths and beetles that live and feed within plant foliage. They feed on the soft internal tissue of foliage, but not on the upper or lower epidermal layers. The symptoms of their feeding are white blotches or lineal mines in the foliage.

The larvae and their excrement are often found inside the mined areas. Mined foliage often turns yellow or brown, and may droop and drop prematurely. Most needle and leafminers overwinter as larva. In general, the larvae overwinter in the foliage of evergreens, and in the leaf litter of deciduous plants. The larvae pupate in the early spring, and the adult insect begins to lay eggs on the underside of newly developing foliage. The larvae mine into the foliage upon hatching. Most have only 1 generation per year, although some can have up to 4 generations.

Pests that mine the foliage of conifers are known as needle miners, and those that mine broadleaf ornamentals are called leafminers. All of the economically important needle miners are Lepidopterans. Most miners have quite specific host preferences. Genera known to be susceptible to leafminers and needle miners are *Abies, Alnus, Arbutus, Betula, Crataegus, Cupressus, Ilex, Juniperus, Picea, Pinus, Platanus,* privet, *Pseudotsuga, Thuja, Tsuga* and *Ulmus.* Pests of ornamentals include the aspen blotchminer, the spruce needle miner, and the aspen, birch, boxwood, cypress, holly, lilac and Madrone serpentine leafminers.

Leather Jackets

Leather jackets are the larvae of crane flies. They have largely been seen as pests of nurseries in coastal British Columbia. Adults fly in late summer and resemble large grayish-brown mosquitoes with bodies about 2.5cm long, two wings and long spindly legs. Adults lay eggs in the fall, which quickly hatch. They overwintering larvae girdle

seedlings from March to May. The grayish coloured, legless larvae have tough leather-like skin, no distinctive head and can reach 4cm in length.

Any stock present in the nursery in the spring can be attacked, although most damage has occurred on early sown transplants and bare-root stock. They will feed on almost any species of nursery stock. The damage consists of girdling just below the soil surface. Damaged stock appears off-coloured and dried out. When infesting container plugs, the leatherjackets often remain with the seedling during the lift. Although they do limited damage to the seedlings while growing in the nursery or during cold storage, they may girdle the seedling when outplanted in the spring.

Control on conifer seedlings can be achieved by drenching with entomopathogenic nematodes (*Steinernema feltiae*) in the fall to kill the young larvae after all eggs have hatched. Removal or reduction of grassy areas in and around the nursery that may harbour populations can also help.

Thrips

Thrips are tiny (0.5 to 1 mm) insects that feed on the tender growth of some shrubs and trees. There are many species of thrips, including the Western flower thrips (Frankliniella occidentalis). These insects are weak flyers, but can be dispersed great distances by air currents. They are rasping (rather than sap-sucking) insects and injure both leaf and flower buds. Their feeding results in distorted growth as buds expand, and early flower senescence. Thrips can also transmit several plant viruses.

Liming the soil below benches is a good way to destroy pupae, which drop to the ground as part of their life cycle. The soil can be treated with a solution of hydrated lime. Yellow or blue sticky traps are used to detect the presence of adult thrips. The cards should be placed in the crop when the temperature is less than 18°C, and more cards should be added when the temperature increases and the thrips become active. If predators (mainly Amblyseius spp.) are present in sufficient amounts, a spray may not be necessary.

If damage is noticed on young growth, a high pressure and high volume spray can be applied. Thrips will hide in the deep crevices of expanding leaves and flowers. During periods of high temperature, sprays may be applied every 4 to 5 days to control newly emerging adults.

Lygus Bugs

Lygus bug adults, usually 7mm long and half as wide, are broad, flattened and oval-shaped with a small projecting head. They range in color from yellowish-green to reddish-brown and are covered with small, irregular, yellow, reddish-brown and black splotches. Lygus populations overwinter as adults, become active with warm spring weather.

They can start feeding on seedlings when the true or secondary needles develop after seedling emergence. Feeding by the adults and nymphs initially causes distortion of seedling terminal shoots, which later become multiple-leaders. Damage has been found on 1+0 seedlings of all species, but pine, larch and spruce are preferred, while 2+0 stock is only attacked during the period of leader elongation. Lygus bugs are also referred to as

tarnished plant bugs. Preliminary monitoring programs involve the use of yellow sticky cards to better time insecticide applications.

Sawflies

Adults have two pairs of wings and resemble small, amber coloured bees. The larval stages of sawflies resemble caterpillars (e.g. pine sawfly) or slugs (e.g. pear sawfly, rose slug). Pine sawflies overwinter as eggs on needles and pupate in late spring Pear slug and rose slugs overwinter in the soil as mature larva and pupate in the early spring. Adults lay their eggs on the undersides of host leaves. Sawflies feed in colonies and quickly strip foliage from their host plants generally in early summer (June – July). The larvae skeletonize the upper side of the leaf leading to browning and premature leaf drop.

Scale Insects

Scale insects suck the sap of many shrubs and trees, including evergreen and fruit trees. Oyster shell *(Lepidosaphes ulmi)* and San Jose *(Quadraspidiotus perniciosus)* scales have armoured scales and do not produce honeydew, while scales in the Lecanium family are soft and produce large quantities of honeydew, which attracts the growth of sooty mould.

As even dead scales can affect the appearance of a plant, it is often best to discard heavily infested plants. *Acer, Cornus, Fraxinus, Malus, Populus, Rosa, Salix* and *Syringa* are susceptible to oyster shell scale damage, while Lecanium scales are known to attack *Acer, Betula, Carya, Celtis, Cercis, Crataegus, Fagus, Gleditsia, Juglans, Malus, Morus, Platanus, Populus, Prunus, Pyrus, Quercus, Salix* and *Tilia*. Two other scales which cause significant economic damage in the nursery and landscape are Euonymus scale (*Unaspis euonymi*) and Magnolia scale (*Neolecanium cornuparvum*).

If pesticides are necessary, timing of application is critical for successful control. During most of their life cycle, scales are protected from pesticides by their shell. The only time they are not protected is during the crawler stage, which is when the first-instar nymphs emerge from eggs. Crawlers can be detected with double-sided sticky tape traps wrapped around branches near female scales. The number of crawlers caught should be counted, and traps should be replaced weekly. The plants can be treated either when a sharp increase in crawler levels is observed, or when the peak density of crawlers is caught. Crawler stage timing varies between species, can occur from early spring to June or July.

Fungus Gnats

Fungus gnats *(Bradysia* spp. and *Corynoptera* spp.) are primarily pests of container nursery stock grown in the greenhouse (e.g. cuttings, young liners). Adult flies are often seen running or flying near the soil surface, especially in wet areas. The slender white larvae have shiny black heads and are sometimes found in plugs. Most species feed on decaying organic matter and algae. Although some species may damage seedling roots, they are not normally attracted to healthy plants.

The best form of fungus gnat control is good sanitation. The flies are attracted to areas covered in moss and algae, where they lay their eggs. Good drainage and removal of water puddles from the greenhouse floor is important. After the stock has been lifted, the styrofoam containers should be washed and the greenhouses cleaned out and sanitized. Good cultural practices that produce healthy, vigorous stock and proper irrigation will

enhance the crop's ability to tolerate damage from this pest. There are 2 biological control agents that are currently used for fungus gnat control: *Hypoaspis miles* (a soil-inhabiting predatory mite) and *Steinernema feltiae* (an entomopathogenic nematode).

Weeds

Weed control is critical for the production of high quality trees and shrubs. Weeds compete with crop plants for water, nutrients and light. They also harbour insects, diseases and rodents that can damage nursery crops and increase the need for pesticide applications. Nursery stock that contains hard-to-control perennial weeds such as field horsetail or yellow nutsedge can be unmarketable. Yellow nutsedge is reportedly present in about 5% of all container-grown stock in the southeast United States. Some States have expressed a desire to designate both yellow and purple nutsedge as quarantine pests.

The most common weeds in container nurseries are liverwort, moss, snapweed, oxalis and chickweed. Horsetail is primarily a pest of field nurseries. Groundsel, grasses, and *Epilobium* are problematic in both container and field nurseries. An integrated weed management program should be implemented on the entire nursery site for the most effective results.

Weeds have evolved very effective mechanisms of dispersal and survival. For those reasons, it is easier to prevent or exclude weeds in the first place than to treat them once established. Weeds or weed parts are often brought into a nursery or landscape inadvertently on nursery stock or in soil, irrigation water or growing media. All media and plants brought onto a site should be visually inspected for weeds prior to use. If weeds are present, quarantine (if possible) until the problem is corrected. Hand pulling established weeds is often not sufficient and follow-up treatments will be required. It is also important to keep media clean once it arrives at the site.

Physical control includes mechanical removal and mulches. Cultural weed control modifies the habitat (soil conditions, fertilization, irrigation) to favour the growth of the crop rather than the weed. Various treatments may be used in container production including hand weeding, weed discs and bark mulches. Chemical controls are chosen based on the properties of the weed, the extent of the infestation, the weather conditions, the pesticide's toxicity to human and non-target organisms, residual activity, and effects on the environment. In field plantings, herbicides are only applied directly to the rows: the area between the rows is cultivated or mowed.

There is increasing interest in non-herbicide methods of weed control in the industry, due to:

- Concerns over herbicide phytotoxicity over diverse range of ornamentals grown,
- A lack of effective herbicides registered in Canada,
- Environmental concerns associated with herbicide run-off, and
- Concerns of herbicide residues getting into irrigation ponds.

Adopting an integrated approach to weed management can reduce herbicide use in the nursery and landscape. Growers are encouraged to use prevention, physical, cultural, and chemical controls as part of this integrated program.

Table 20

Weed science priorities

National Priority Ranking	Target Pest	Crop	Comments
1	Broad-spectrum, pre-emergence weed control	Ornamentals, field and container-grown	Looking for more herbicides as part of a rotation to manage resistance. Registered herbicides are very limiting in labelled hosts for container ornamentals.
1	Broad-spectrum, post-emergence weed control	Ornamentals, field and container grown conifers	Looking for more herbicides as part of a rotation to manage resistance. Registered herbicides are very limiting in labelled hosts for container ornamentals.
1	Nutsedge, grasses and some broadleaf weeds (request labelled weeds)	Outdoor ornamentals, field	Labels for existing herbicide products should be expanded to include the many ornamentals found on the U.S. label.
2	Annual bluegrass	Field-grown ornamentals	

Prevention

Limiting the introduction of weeds and weed parts: It is much easier to prevent or exclude weeds than to treat them once established. All plant and media material brought into a nursery should be visually inspected for weeds prior to use and quarantined if infestations are discovered. It is also important to keep media clean once it arrives at the site.

Preventing weeds going to seed: Seed production, particularly for annual weeds is very high and these seeds can lie dormant in the soil for many years. For example, lamb's-quarters and pigweed can produce up to 72,000 and 117,000 seeds per plant, respectively. Their seeds can remain viable for 20-40 years. Perennial weeds are equally insidious, since new plants can arise from small root fragments. It is recommended to spray creeping, perennial weeds with a systemic herbicide to kill their roots before cultivating the field. Using cultivation alone will be inadequate and will only spread the weed.

Some weeds also have highly effective seed dispersal mechanisms. The slightest touch of a mature seedpod of bittercress (*Cardamine oligosperma*) will result in their seeds being shot up to 0.6m away. Dandelion and groundsel seeds are attached to "parachutes" that are spread great distances with the slightest breeze. Therefore, it is even important to control weeds on the perimeter of the site to prevent spread into the growing area. Mowing, cultivation or chemicals can control such weeds.

Cultural Weed Control

Attempts should be made to modify the habitat to make it more favourable for growth of the crop rather than weeds. Weeds have evolved particular adaptations to environmental conditions. Changing soil conditions (e.g. correct drainage, pH or compaction problems) and cultural practices (e.g. fertilization, irrigation and pest control) can provide a more effective and longer lasting solution to a weed problem, since healthy and vigorous plants are better able to compete against weeds. When planting ground covers, it is imperative to use competitive plants and to plant them close together so they will fill the area within a few years. An advantage of cultural methods, relative to herbicides, is they provide a longer-term solution to weed problems.

Quarantine Measures

Closely inspect all plant material introduced to a nursery or landscape for pests. Plants with pest problems should be "quarantined" until the problem is rectified.

Physical Weed Control

Mechanical Removal: Cultivation practices such as rototilling or hoeing are common and effective means of controlling weeds. Entire plants or plant parts may be buried, or weeds may be severely stressed by cultivation. Periodic cultivation should be carried out about 2 weeks after shoot emergence when the shoots have taken up food reserves from the root system, but before significant levels of photosynthates have been translocated down to the root system. For this strategy, cultivation can simply consist of chopping off the tops with a hoe, or using a line trimmer to cut the weed as low as possible.

By repeating this throughout the season, food reserves in the root system are eventually depleted, or the weed is sufficiently stressed to succumb to pests, diseases or environmental stresses. Hand pulling, burning and even steaming of emerged weeds can be effective but must be done when weeds are young and prior to flowering and seeding.

Mulches: Mulches control weeds by creating a relatively dry surface that is inhospitable for weed seed germination and also by smothering small weeds. In addition to weed control, they moderate soil temperature and retain soil moisture. Organic mulches have the additional benefits of providing nutrients and organic matter to the soil. Two organic mulches commonly used in the landscape are bark mulch and leaf compost. Sawdust is not used in the landscape, but is used at times as mulch for field-grown nursery stock.

Weed control in mulched pot (left), and liverwort growing in bare soil (right).
Photo courtesy of BCMAFF.

Organic mulches will tie up some nitrogen as they decompose. Therefore, it is recommended to add

extra nitrogen to the mulch, otherwise plant growth may be reduced. Inorganic mulches are also used. Mulches of decorative stones and lava rock actually create a more difficult weed control situation in the landscape, since they impede physical cultivation.

Mulches are being used to control weed growth in container-grown ornamentals as well. Forest seedling nurseries routinely apply a thin layer of fine gravel to container-grown seedlings for weed control. Similarly, some ornamental nursery growers are using pumice or sawdust mulches. Geotextile weed discs and plastic lids are other options.

Chemical control

Chemical control should only be used if the other methods are shown to be inadequate to control weed problems. This is particularly true in a landscape situation where the public may be directly impacted by the application of pesticides, and where guidelines for pesticide application in public areas requires that people be informed about pesticide use.

In general, if herbicides need to be used, ones would be selected that have low toxicity to humans and non-target organisms, have low residual activity and minimize adverse effects to the environment. Herbicides must be applied accurately, at the right time and at the right stage of weed growth for maximum effect. Liquid applicators include hand sprayers as well as large power sprayers. Chemicals that dissolve readily may be adequately mixed by using hydraulic agitation of a pump bypass. Oil-water emulsions and wettable powders usually require constant vigorous mechanical agitation.

Nonselective, postemergence herbicides kill any plant or plant part that is contacted by the spray, either intentionally or by spray or vapour drift. They are often most effective on young, newly emerged weed seedlings. Some nonselective herbicides are systemic including Amitrol, Roundup and Touchdown. The systemic herbicides are effective against specific perennial and many annual weeds. In contrast, EcoClear, Gramoxone and Reglone are not systemic and only kill annual weeds.

Repeat applications are required to control perennial weeds. Nonselective, postemergence herbicides are used to control weeds on land prior to working the soil and planting nursery stock, or on non-crop land. EcoClear, Gramoxone, Roundup and Touchdown can also be used as a directed spray to control weeds between established nursery stock. Directed sprays are often applied with a shielded sprayer to permit spray coverage of the weeds but not of desirable plant material. For all of these herbicides, spray contact with the foliage or green bark of desirable plants can result in severe crop injury.

Selective, postemergence herbicides are used to kill emerged weeds by over-the-top application to certain ornamental crops. Herbicides in this category include Velpar and Venture. These herbicides must be applied at the correct rates and in the correct manner. Without extreme care, crop damage can occur and poor weed control may result.

Selective, preemergence herbicides are used on weed-free soil or growing medium to destroy specific weed seedlings as they germinate. These products usually will not provide any control of emerged weeds. There are products registered for use in the field and for container-grown stock. Bonanza, Rival and Treflan are registered for incorporation prior to planting specific field grown stock, whereas Kerb is registered for application in established stock. The selective herbicides used on field-grown nursery stock cannot always be safely used on plants grown in containers, because herbicides are

less readily bound in soilless media and due to the close proximity of the roots to the growing media surface in containers.

The products registered for use on specific container stock are Casoron, Devrinol, Gallery, Kerb, Ronstar, Princep None-T, Simazine and Treflan G many of the preemergence herbicides for use with container stock are formulated as a granular product to reduce crop injury when applied. Granular herbicides should be applied with an adjustable spreader that permits accurate calibration and application of the product. If not applied accurately, poor weed control and/or crop injury can occur.

Other animal pests/ Vertebrate pests (ie.Rodents, birds, slugs, etc.)

Slugs and Snails

Slugs and snails are most prevalent in spring but can be active throughout the year if temperature and humidity are suitable. Most will over winter in the egg stage, hatch in spring, mature during the summer, and lay eggs in fall. Because they require moisture for survival, slugs and snails hide during the day in dark, damp, sheltered places such as under boards, pots, weeds, and debris.

Slugs and snails may damage foliage as well as flowers, roots and tubers. They can attack foliage of woody ornamentals, especially those with foliage on the ground, and herbaceous perennials. Damage can be most severe in greenhouses and cold frames that are continually damp. Rasping mouthparts make irregular holes in leaves. Silvery streaks of slime are very characteristic of slugs and snails.

Cultural control can be very effective. Weed control and removal of hiding places can reduce slug and snail problems. Mow tall grass around ditches, ponds, fences and buildings. Traps can provide effective control in small areas. Zinc or copper barriers can be effective in preventing access to raised beds and greenhouses. Baits can be used where slugs and snails are a serious problem but are also attractive to pets. Place baits in cans with holes only large enough for the slugs to enter. Coffee cans with replaceable lids work well. Place bait underneath a board with a heavy weight on top to prevent access to bait by pests or birds.

Field Mice (Voles)

Field mice, also known as voles, are small rodents (about 13 – 23cm long) including the tail. They have small, furry ears and relatively short tails that are up to ½ the length of the body. They eat almost any kind of plant matter including grass, root vegetables, plant roots and in winter the bark of trees and shrubs. In the winter, they will frequently girdle the roots, crown and stems of field-grown trees, especially if there is grass or snow cover around the base of the plants. They build underground burrows, and the small burrow openings are a sure sign of field mouse activity.

The best control, where possible, is removal of tall grasses and weed patches adjacent to the nursery, by the use of cultivation or mowing. Field mice prefer the cover of tall grasses and avoid areas that do not provide adequate cover. There are no “Domestic” labelled rodenticides registered for field mice, and rodenticides intended for house mice are ineffective for field mice. If poison baits are used they must be placed in covered bait

stations to protect them from weather and to prevent accidental poisoning of other animals. Bait stations can be easily built from metal or plastic pipes, tin cans, and pieces of wood, or may be purchased commercially. They should be placed at 3-4m intervals in areas where there are signs of mouse activity. The disappearance of the contents will indicate that mice are still present.

House Mice and Norway Rats

The house mouse, found nearly throughout Canada, is a small rodent (16-18 cm long), which differs from field mice by having a longer, naked tail, larger ears and a more pointed snout. The Norway rat or brown rat, found in coastal areas only, is a much larger rodent (36-40cm), which also has a long, hairless tail. Both house mice and rats may invade indoor nursery facilities. Although they sometimes damage growing plants, they are mainly pests of stored food products and are also undesirable because they carry a number of diseases that are transmissible to humans.

Rodent-proofing buildings and eliminating sources of food, water and shelter for rodents are the best means of control. Trapping and poisoning will provide only temporary relief. Buildings can be made rodent-proof by installing tight fitting doors and windows, and wire screens over basement windows and vents. Sheet metal kick plates on wooden doors will stop rodents from gnawing through. Trapping is useful when only a few rodents are present. Numerous rodenticides are available for controlling house mice and Norway rats.

Deer

Deer feed on grasses, shrubs and trees although some plant species are preferred over others. In spring and summer, most damage is done to new, leafy growth. In winter, buds and twigs may be eaten and bark stripped off trunks and branches of trees. Antler rubbing may break branches and remove bark. Damaged plants are set back in growth and may never develop properly.

Fencing is the best solution for chronic deer damage. Woven wire fences should be at least 2.4m high with a 15cm wire mesh. The mesh should be secured as close to the ground as possible to prevent deer from crawling underneath. Solid board or panel fences need only be 1.5m high, because the deer are much less likely to jump over them. Electric deer fences are also effective and are considerably less expensive. Electric fences should be 1.5 – 2.1m tall with 7 to 9 strands of smooth high-tensile wire at 20 – 30cm spacing. A high voltage energizer must be used with this type of fence.

Chemical repellents may effectively repel deer. Dormant trees and shrubs should be dusted when moist, so that the repellent will adhere to the leaves and twigs. Repellents may not work if deer are numerous or hungry.

Rabbits (Cottontails) and Hares

Two kinds of rabbits, the eastern cottontail and the snowshoe hare, sometimes damage nursery crops. The eastern cottontail damages a wide variety of ornamentals and fruit trees, mainly in the winter. Bark may be chewed; twigs and buds eaten and small shrubs or seedlings may be clipped off at the base. Twigs clipped off neatly indicate rabbit damage; twigs with a ragged edge, deer damage. The snowshoe hare is a somewhat larger animal, with longer hind legs, and is usually white in the winter. It sometimes damages young conifers in forest nurseries.

Fencing or tree guards may be necessary for severe rabbit problems. A low 60cm high poultry wire fence with a 25mm mesh, supported by stakes or posts every 2m, will exclude rabbits and hares if it is fastened tight to the ground; these animals do not burrow. Alternatively, tree guards made of 6mm hardware cloth or hard plastic tree-guards, placed around the base of each tree or shrub will prevent damage. Repellents may be painted or sprayed on trunks and twigs of vulnerable plants.

Neither eastern cottontails nor snowshoe hares are protected by law on private land, thus both may be killed without permits. (A permit to kill snowshoe hares is required on Crown Land). In winter, both are fairly easy to catch in live traps, which can be bought commercially or made by the grower. Trapped rabbits may either be killed or released in a non-farming area.

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Florida Department of Agriculture
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Appendices

Appendix 1: Provincial Entomology Priorities

PROVINCIAL ENTOMOLOGY PRIORITIES														
Crop	**Pest**	**Pest Rank**	**National Rank**	**Province**										**Comments**
				BC	**AB**	**SK**	**MB**	**ON**	**QC**	**NB**	**NS**	**PE**	**NF**	
Nursery stock (container & field)	Mites	1		X										
Nursery stock (container & field)	Weevil complex, adults & larvae	1		X										
Nursery stock (container & field)	Aphids (leafhoppers)	2		X										
Nursery stock (container & field)	Gall midges (rose and daylily)	2		X										
Nursery stock (container & field)	Borers/Beetles	3		X										
Nursery Stock (field)	White grubs (European chafer, June beetle)	1						X						Outdoor ornamentals, nursery crops, Christmas trees (soil application, not containers)
Nursery Stock	Mites on outdoor ornamentals and nursery crops (spruce 2-spot, red, broad mites)	2						X						

PROVINCIAL ENTOMOLOGY PRIORITIES														
Crop	Pest	Pest Rank	National Rank	Province										Comments
				BC	AB	SK	MB	ON	QC	NB	NS	PE	NF	
Nursery Stock (field)	Pine shoot beetle on pines	3						X						
Nursery Stock	Canadian pests from US label	4						X						
Nursery Stock (container & field)	Insects on field grown & container grown trees & shrubs & perennials	1							X					
Nursery Stock (field)	Insects on field grown trees & shrubs	1							X					
Nursery Stock	Spider mites on woody ornamentals and perennials (incl. ornamental tree fruits)	2							X					
Nursery Stock	Lepidoptera on woody ornamentals	3							X					
Nursery stock (container & field)	Weevil complex, adults & larvae	1								X				
Nursery Stock	Pine shoot beetle, leafminers	2								X				
Nursery Stock	Mites	3								X				
Nursery Stock (field)	Insects on field grown trees & shrubs	1									X			
Nursery Stock	Insects on ornamentals	1									X			

PROVINCIAL ENTOMOLOGY PRIORITIES														
Crop	**Pest**	**Pest Rank**	**National Rank**	**Province**										**Comments**
				BC	**AB**	**SK**	**MB**	**ON**	**QC**	**NB**	**NS**	**PE**	**NF**	
Nursery Stock	Lepidoptera on woody ornamentals	1									X			
Nursery Stock	Mites on woody ornamentals	1									X			
Nursery Stock (field)	Insects on field grown trees & shrubs	1											X	
Nursery Stock	Lepidoptera on woody ornamentals	2											X	
Nursery Stock	Insects on ornamentals	4											X	

Appendix 2 – Provincial Pathology Priorities

Provincial Pathology Priorities													
Crop	**Pest**	**Pest Rank**	**National Rank**	**Province**									**Comments**
				BC	**AB**	**SK**	**MB**	**ON**	**QC**	**NB**	**NS**	**PE**	**NF**	
Nursery stock (container & field)	Bacterial Blight	1		X										South Coastal
Nursery stock (container & field)	Fireblight	1		X										Interior
Nursery stock (container	Downy Mildew	1		X										
Nursery stock (container & field)	Powdery Mildew	1		X										
Nursery stock (container	Root Rot	1		X										
Nursery stock (container & field)	Leaf Blights	2		X										
Nursery stock (container & field)	Rust	2		X										
Nursery stock	Daylily Rust	1						X						
Nursery stock	Bacterial blight (Pseudo-monas syringae)	2						X						
Nursery stock	Downy Mildew	3						X						
Nursery stock	Fireblight suppres-sion	4						X						
Nursery stock	Rusts, Powdery mildew, leaf blights	5						X						
Nursery stock	Rust	1							X					
Nursery stock	Root rot, downy mildew on ornament-tals	2							X					
Nursery stock	Daylily rust	1								X				

Nursery stock	Leaf blight on ornament -tal trees	1									X			

Appendix 3: Provincial Weed Science Priorities

PROVINCIAL WEED SCIENCE PRIORITIES														
Crop	**Pest**	**Pest Rank**	**National Rank**	**Province**										**Comments**
				BC	**AB**	**SK**	**MB**	**ON**	**QC**	**NB**	**NS**	**PE**	**NF**	
Nursery stock (field)	Horsetail (Equisetum arvense)	1		X										
Nursery stock (container)	Marchantia polymorpha, Cardamine oligosperma, Epilobium watsonii, moss	1		X										Broad-spectrum pre-emergence herbicide for container stock
Nursery stock (field)	Pre- and post-emergence weed control on field-grown trees	2		X										
Nursery Stock - caragana sowings	Weeds, broadleaf and grassy	1				X								
Nursery Stock - lilac seedlings, poplar and willow cuttings	Weeds, broadleaf	1				X								
Nursery Stock (container & field)	Weeds on field & container conifers & deciduous trees	1						X						
Nursery Stock	Labeled weeds on ornamental woody trees/shrubs	2						X						
Nursery Stock	Labeled weeds on ornamentals	3						X						
Nursery Stock (container)	Weeds on container grown Thuja, Buxus, Juniper, syringa, weigela sp	4						X						
Nursery Stock (container)	Weeds on container grown Thuja, Buxus, Juniper, Syringa,Weigela sp.	1							X					
Nursery Stock (container & field)	Weeds on field & container trees	1							X					
Nursery Stock	Weeds on ornamental woody trees/shrubs	1							X					

PROVINCIAL WEED SCIENCE PRIORITIES														
Crop	Pest	Pest Rank	National Rank	Province										Comments
				BC	AB	SK	MB	ON	QC	NB	NS	PE	NF	
Nursery Stock	Weeds on ornamentals, including Christmas trees	1							X					
Nursery Stock	Weeds	1								X				
Nursery Stock (container & field)	Weeds on ornamentals	1									X			
Nursery Stock (container & field)	Weeds on field and container conifers & deciduous trees	1									X			
Nursery Stock (container & field)	Weeds on field and container conifers & deciduous trees	1											X	
Nursery Stock	Weeds on ornamentals	1											X	