NURSERY AND SEED

Volume 8, Number 2 Winter, 1995 1

Seed and Seedling Extension Topics

Eric van Steenis — Editor

The FNABC annual meeting is behind us, as is Module IV of the Conifer Seedling Growing Course (Alberta). Both were well attended and offered valuable take home messages for participants. The proceedings for the former is to be compiled by yours truly and should be out sometime by spring 1996. Anyone interested in obtaining a copy of Module IV should contact Al Nanka @ Forestry Canada, Northwest Region, 5320 - 122 Street, Edmonton, Alberta Canada T6H 3S5... phone... 403-435-7210.

It seems the "forest nursery baby boom" is not over yet! Congratulations to Paul and Patricia O'Neill (Beaver Plastics) on the birth of their first, Monica, on September 28, 1995. Also to Les and Crystal Shurtliff (Peace River Greenhouses) a baby boy on November 03,1995. Nephi Ray... their seventh... don't tell us the NORTH is not productive!!

Eric van Steenis
Nursery Extension Services

Forest Genetic Resource Management...

A recent issue of "Western Forester" (October, 1995 -Vol 40, #7) has been almost completely devoted to the above subject, covering it in eloquent detail by a number of respected professionals in the industry. Some of the individual topics include; "forest genetic resource conservation in the northwest", "tree improvement and genetic diversity", and "progeny rating". Contributors include Jess Daniels, Daniel W. Cress and our own Jack H. Woods. Copies of this particular issue or subscription information can be obtained from: Western Forester, Society of American Foresters, 4033 S.W. Canyon Rd. Portland, Oregon 97221 Ph: 503-224-8046.

David Reid
Coastal Seed Orchards

Seed Pest Management Group Grows

The Seed Pest Management group of the BC Ministry of Forests (Silviculture Practices Branch) has grown by one new biologist. As of January 1996 Dr. Ward Strong joined Bev McEntire and Michelle Hall in working under the supervision of Robb Bennett. Ward is handling Interior operations out of the Kalamalka Seed Orchard facility; Bev and Michellle are looking after Coastal operations from the Saanich Seed Orchard. All members of the group continue to work together on the development of new and continuing cone and seed pest management projects.

Ward has two graduate degrees in entomology: an M.Sc. earned under John Borden's supervision at Simon Fraser University and a Ph.D. from Oregon State University under Brian Croft. His research has produced successful biological control programs for thrips on greenhouse cucumbers and spider mites on hops. Additionally he has owned and/or managed several pest management companies including MonAgro Consulting (Langley, B.C.) and the Pro-Tect Department of the East Chilliwack Agricultural Co-op (Abbotsford, B.C.)

The Seed Pest Management Group can be contacted at:

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Province of British Columbia
Ministry of Forests

GROWER'S NOTES

Seed Coat Structure

For those interested in conifer seed coat structure, but frustrated by the lack of information available these two articles will be of interest to you. Citations and some brief notes on the research findings are presented below.

Tillman-Sutela, E. and A. Kappi. 1995. The morphological background to imbibition in seeds of *Pinus sylvestris* L. of different provenances. Trees 9: 123-133.

- the seed coat layers did not restrict water uptake (imbibition) to any extent
- imbibition was chiefly regulated by the membranes surrounding the megagametophyte
- a deviation from the standard triple-layer seed coat was found in the most northern provenance - a double multicellular layer in the outer seedcoat layer was found

Tillman-Sutela, E. and A. Kappi. 1995. The significance of structure for imbibition in seeds of the Norway spruce, *Picea abies* (L.) Karst. Trees 9: 269-278.

- the seed coat layers did not restrict water uptake (imbibition) to any extent, despite the presence of wax filled cells
- imbibition was chiefly regulated by the membranes surrounding the megagametophyte
- *Picea abies* and *Pinus sylvestris* consist of the same structures, but differences in seed coat and membrane structure are significant for imbibition
- the authors hypothesize that the waxy layer in *Picea abies* may explain why it is difficult to bring the moisture content up to the 30% required for IDS incubation
- the authors hypothesize that the way the micropyle (point of radicle emergence) opens may cause the difficulty noted in achieving a sufficient difference in density between viable and non-viable spruce seeds by the IDS method

These papers are an important contribution to the literature on seed coat morphology and its relation to the process of imbibition. The papers are quite detailed and assume a good knowledge of conifer reproductive biology. For those interested in these subjects please obtain copies directly from the author as the included electron micrographs and coloured plates do not photocopy well. Requests can be addressed to E. Tillman-Sutela, The Finnish Forest Research Institute, P.O. Box 16, SF-96301 Rovaniemi, Finland.

Dr. Tillmann-Sutela is continuing this work with *Larix* spp. and is interested in the possibilities of performing similar seed coat work with yellow cypress and western white pine. These are the species which we suspect have a degree of seed coat dormancy in British Columbia. We are currently trying to secure funding and samples for projects on yellow cypress and western white pine for the upcoming fiscal year. Due to gains in white pine stratification [in this issue] the highest priority for this work will be with yellow cypress. If any one is interested in more information or contributing samples (at regular intervals) for this project please contact Dave Kolotelo at the TSC (604-541-1683).

Dave Kolotelo
Surrey Tree Seed Centre

Province of British Columbia
Ministry of Forests

Western White Pine Stratification Treatment

The Tree Seed Centre (TSC) has currently changed the standard procedure used to test and operationally prepare seed of western white pine (Pw). The new procedure consists of a 14-day soak and 98 days of cold stratification. The soak portion consists of two days in running water followed by 12 days in standing water with a daily water exchange during weekdays. The procedure was recommended based on trials performed at the TSC and the initial work of prolonged soaks by Dr. George Edwards.

We have just completed the double-testing of 66 seedlots of Pw with the old (G52) and the current (G55) pretreatment. The results are very promising as the current procedure produced **an average gain in germination capacity of 21%** over the old procedure. Gains for individual seedlots ranged up to 43%. The cost for this gain is four additional weeks of pretreatment (at the TSC) which means that the planning of Pw sowing requests must be in SPAR one month earlier.

All seedlots with balances above 500 grams were tested, but about 20 seedlots remain untested with the new treatment. If you are planning on growing seedlings from a Pw seedlot that does not have a current G55 test please advise the TSC and we will initiate the testing of this seedlot. If you have any questions about this new procedure or background information on Pw stratification techniques please contact Dave Kolotelo at the TSC (541-1683).

The following two (2) tables on pages 4 & 5 are the first draft summaries of the 1995 Coastal Seed Orchards seed production. These are estimates since extraction is still ongoing. Yield estimates were calculated using the following averages:

	Kg/Hl	# Seedlings/Kg
Fdc	0.388	47,000
Hw	1.010	238,000
Cw	0.955	294,000
Se	0.523	204,000
Ss	0.694	213,000
Cy	1.446	29,161

Dave Reid
Coastal Seed Orchards

1995 Coastal Seed Orchards Cone Crop Summary by Species

Owner	Orchard Number	Location	Species	Seedlot	Cones collected (Hl)	Breeding Value	Estimated yield (kg)	Estimated seedlings
Mof	149	Bowser	Fdc	60103	14.0	12.9	5.43	255,304
Mof	149	Bowser	Fdc	60104	12.4	11.4	4.81	226,126
Mof	120	Dewdney	Fdc	60303	174.8	3.0	67.82	3,187,653
Mof	120	Dewdney	Fdc	60304	301.6	3.0	117.02	5,499,978
Mof	120	Dewdney	Fdc	60305	52.8	3.0	20.49	962,861
Mof	146	Surrey	Fdc	60306	4.4		1.71	80,238
Fdc Sub-total					**560.0**		**217.28**	**10,212,160**
Mof	143	Quinsam	Hw	60123	12.0	0.0	12.12	2,884,560
Mof	131	Cobble Hill	Se	60301	9.8	3.0	5.13	1,045,582
Mof	131	Cobble Hill	Sx	60302	0.8	3.0	0.42	85,354
Sub-total Ministry orchards					**582.6**		**234.94**	**14,227,655**
Private Orchards								
MB	139	Yellow Point	Cw	60049	0.67	1.0	0.64	188,116
WFP	155	Lost Lake	Cw	60217	13.0	1.3	12.42	3,650,010
	128	Lost Lake	Cw	60218	3.6	1.3	3.44	1,010,772
	128	Lost Lake	Cw	60219	11.0	1.3	10.51	3,088,470
PFP	171	Saanichton	Cw	60310	0.8	1.0	0.76	224,616
TWest	152	Mt. Newton	Cw	60317	3.5	1.0	3.34	982,695
	152	Mt. Newton	Cw	60318	16.3	1.0	15.52	4,562,513
Sub-total for Cwr					**48.8**		**46.62**	**13,707,191**
PFP	164	Saanichton	Cy	60311	0.1585		0.23	6,683
CFP	116	Sechelt	Fdc	60107	70.5	0.3	27.35	1,285,638
	109	Saanichton	Fdc	60186	33.3	2.5	12.92	607,259
PFP	111	Nootka	Fdc	60188	81.4	6.1	31.58	1,484,410
	166	Saanichton	Fdc	60189	3.8	10.0	1.47	69,297
	121	Saanichton	Fdc	60307	57.2	6.5	22.19	1,043,099
	121	Saanichton	Fdc	60308	72.2	3.3	28.01	1,316,639
TWest	154	Mt. Newton	Fdc	60320	49.0	22.0	19.01	893,564
	134	Mt. Newton	Fdc	60321	15.6	15.0	6.05	284,482
	134	Mt. Newton	Fdc	60322	30.3	10.0	11.76	552,551
	134	Mt. Newton	Fdc	60323	111.6	6.0	43.30	2,035,138
	154	Mt. Newton	Fdc	60324	50.6	14.0	19.63	922,742
	154	Mt. Newton	Fdc	60325	25.3	11.0	9.82	461,371
Sub-total for Fdc					**600.8**		**233.11**	**10,956,189**
MB	132	Yellow Point	Hw	60051	6.5		6.57	1,562,470
WFP	126	Lost Lake	Hw	60220	7.2	1.3	7.27	1,730,736
	126	Lost Lake	Hw	60221	0.4	1.3	0.40	96,152
	127	Lost Lake	Hw	60222	6.8	1.3	6.87	1,634,584
	127	Lost Lake	Hw	60223	14.2	1.3	14.34	3,413,396
	156	Lost Lake	Hw	60224	2.0	1.3	2.02	480,760
	126	Lost Lake	Hw	60227	0.3	1.3	0.30	72,114
PFP	165	Saanichton	Hw	60309	1.5		1.52	360,570
TWest	130	Mt. Newton	Hw	60319	5.5		5.56	1,322,090
Sub-total for Hw					**44.4**		**44.84**	**10,672,872**
WFP	142	Lost Lake	Ss	60225	28.0	1.3	19.43	4,139,016
	157	Lost Lake	Ss	60226	11.2	1.3	7.77	1,655,606
Sub-total for Ss					**39.2**		**27.20**	**5,794,622**
Sub-total Private orchards:					**733.4**		**352.01**	**41,137,558**
Total all Coastal orchards:					**1316.0**		**586.96**	**55,365,213**

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Sub-total for Fdc					**247.9**		**96.19**	**4,520,704**
PFP	165	Saanichton	Hw	60309	1.5		1.52	360,570
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Copper Treated Container Culture... Just a little more?

A workshop on the subject is not materializing, but perhaps some brainstorming sessions between willing participants would be as beneficial, so please don't hesitate! Some people wonder what steps I would take if faced with actually having to grow a copper treated pine crop *myself* (God forbid). Well, at this point my main objectives would be to **keep the copper at the container wall and the root system actively growing!** Consequently the following points would be pondered ad nauseam:

- To facilitate primary root growth down the centre of the plug, furthest away from the pruning agent, seed should be placed in the centre of the cavity. If accurate seed placement is not possible then multiple sowing, even at high germination percentages, may be a viable alternative. The latter increases the chances of one seedling being placed in the centre and allows thinning out of the unlucky germinants which land too close to the edge.

- Water (a continuous channel thereof) is required for copper ions to be transported from the container wall into the plug. Increased aeration porosity reduces media saturation time, and the effective media/container wall contact surface area. Hence the ability of copper ions to migrate into the media and ultimately occupy all available space within a plug is reduced. Increased aeration/oxygenation also facilitates new root growth.

- Growing medium Cation Exchange Capacity (CEC) I am not sure about. Low-CEC components such as sawdust reduce the maximum number and concentration of copper ions the media can hold at saturation without reducing the total amount of growing media. Perhaps this could result in permanent "copper-free" channels for roots to explore. However, a low CEC media may be completely occupied by cations more quickly than a high CEC media, copper being one possibility. Basically a low CEC media would tend to be less buffered, more reactive.

- Copper ions which diffuse away from the immediate vicinity of the container wall cannot serve their intended purpose and need to be inactivated or discarded. Charging the media CEC with a full complement of nutrient ions prior to this point prevents occupation of the CEC by these "break-away" copper ions. Keeping them in solution allows leaching or complexing with certain anions. Fertilizer amendments can be added prior to container loading. This ensures that once moisture is added (and every time thereafter in the case of slow release fertilizers), competing cations (and complexing anions) are present.

- Copper culture provides greater than optimum levels of copper nutrition, possibly resulting in relative deficiencies of competing ions such as iron, zinc, etc. Perhaps ionic balance in the feeding solution can be adjusted to help compensate.

- After sowing the containers are "watered in". This is the first time plugs are wetted (usually saturated), and when dissolution and migration of copper ions begins in earnest. If pure (non-fertilized/low alkalinity) water is used the dissolution and migration of copper ions will be highest. Pure water contains no competitors for CEC sites, leaving the media wide open to occupation by copper. Watering in with full strength nutrient solution will combat this.

- Misting to maintain humidity levels and/or cool crops can lead to continuously saturated growing media. **If** mist cycles are necessary, they don't need to be pure water. Mild nutrient solutions have been employed by some without detriment.

- Water quality will largely dictate need for acidification or lime addition. Dolomite lime additions raise pH and add cations (Ca + Mg) and bicarbonates. Calcium and Magnesium compete with other cations for media CEC sites and thereby help reduce excessive occupation of CEC sites by copper. The elevated pH and bicarbonate levels may reduce copper availability and dissolution from the container walls. However, elevating pH and bicarbonate levels has similar effects on other cations such as iron hence might actually worsen a copper induced iron deficiency. Ionic balance may need to be adressed. Calcium-sulphate (gypsum) adds Ca^{++} and $SO4^{--}$ without affecting pH and alkalinity. Superphosphate or Triple Superphosphate mixed into the growing media could benefit root growth as well as provide a complexing agent (Phosphate) to help "scavenge" excess copper ions?

- Water management... Rain cannot be controlled. Wet and dry cycles are a must. A substitute for using pure water irrigation to avoid E.C. buildup can be to practice adequate "overdrain" with a nutrient solution. Replacing the media solution *completely* with applied solution will replenish nutrient supply at the desired E.C., maintain competition for CEC and drive free copper that has moved away from the wall down and out of the plug. Not enough overdrain if copper has occupied the media or is abundant in solution will only serve to move it to lower portions of the plug.

- Temperature and Humidity... A stagnant environment leads to stagnant plants. Active growth maintains the ability to overcome stresses, etc.

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Ministry of Forests

NURSERY AND SEED

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TECH TALK

Biotic and Abiotic Factors involved in Douglas-fir Root Disease

INTRODUCTION

Root decay in Douglas-fir seedlings continues to plague container nurseries. The objectives of this project were to monitor cultural practices, environmental events and fungal pathogen levels of Douglas-fir crops at three nurseries and identify possible factors causing root death or predisposing trees to fungal infection.

METHODS

Three B.C. forest nurseries provided crops for continuous examination. At each sampling time, observations were made on the general seedling health: needle color, presence of root hairs and plug firmness were recorded. Trees were selected randomly and taken to the laboratory for morphological and pathological assessment. Morphological measurements (shoot height, stem diameter, root volume and dry weights) were made biweekly. Pathological tests (growing media and root fungal isolations) were conducted monthly. When root necrosis occurred at Nursery 1, additional assessments were made to obtain information on the extent and nature of the disease. Identification of potential factors causing or predisposing roots to decay was done by examining cultural or environmental events which occurred prior to the first observation of root necrosis.

RESULTS

A. Observations on seedlings' health

Foliage color at Nursery 1 at each sampling varied from dark green to chlorotic. In contrast, Nursery 2 and 3 foliage color was uniform (green) throughout the season. Examination of root systems showed abundant root hair development at Nurseries 2 and 3. Lack of root hairs and poor root growth was observed at Nursery 1. End of season root plug firmness was lowest at Nursery 1.

B. Morphometric Seedling Measurements

Table 1 shows statistical analysis of morphometric parameters using data at 246 days from sowing, and results of Duncan's multiple range test showing means of morphometric parameters.

nursery	shoot length (cm)	stem diam. #1* (mm)	stem diam. #2* (mm)	stem taper **	shoot dry weight (g)	root dry weight (g)	root volume (ml)
1	29.5a	3.6b	1.6b	2.4a	1.93c	1.28b	4.88b
2	27.0b	4.6a	2.4a	2.0b	2.85a	1.48b	5.32b
3	21.5c	3.5b	2.2a	1.7c	2.37b	1.56a	6.79a

Note: Reading down, numbers followed by a common letter are not significantly different. P= 0.05.
* #1 = stem diameter at the cotyledon;
* #2 = stem diameter at the tip;
** stem taper = diameter #1 / diameter #2.

C. Seedling Pathology

Some seedlings at Nursery 1 were affected by *Fusarium* disease at the end of June. Trees wilted, foliage turned red-brown, and plants decayed from the cotyledon down. Less than 1% of the trees were affected. Those that were not affected appeared to grow normally.

Shoot symptoms indicative of root disease occurred at Nursery 1 but not Nurseries 2 or 3. Sampling done at Nursery 1 on October 20 showed root decay in 40% of sampled seedlings. Frequencies of root disease in subsequent samples were 55% on November 4, 45% on November 17 and 26% on December 1 (n=20 seedlings). Most affected trees exhibited all or some of the expected shoot characteristics such as small terminal and lateral buds, strongly tapered stems, distorted needles and dull green foliage. Some trees with root disease showed none of these

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symptoms. In general, foliage chlorosis appeared not to be related to root disease. To determine if the disease could be recognised solely from shoot characteristics, trees suspected of having either healthy or diseased roots were selected from each block. Trees with healthy looking shoots had root disease 22% of the time. Suspected trees had root disease 56% of the time. No root necrosis or shoot symptoms indicative of root rot were found in crops monitored at Nursery 2 or 3.

Levels of *Fusarium* in the growing media of Nurseries 1 and 2 rose sharply in September and were highest for all nurseries by November. Root colonization by *Fusarium* was highest in September for Nursery 1, October for Nursery 2 and November for Nursery 3. The percentage of roots colonized was approximately the same for all nurseries. The difference appeared to be that 22% of the roots at Nursery 1 were colonized by *Fusarium* a month before Nursery 2 and 2 months before Nursery 3.

The highest levels of *Cylindrocarpon* in the growing media were in October for Nursery 2 and in November for Nurseries 1 and 3. Root colonization by *Cylindrocarpon* rose steadily during the season, peaking at 83%, 58% and 73% for Nurseries 1, 2 and 3 respectively.

Extent of Root Rot at Nursery 1...

In order to determine the extent and impact of root rot at Nursery 1, an additional 50 seedlings were sampled and assessed in December. Root systems lost an average of 35% of their volume and 19% of their dry weight to root rot. Stem taper in the diseased group was larger (2.59) than in seedlings from the regular samplings (2.35 for Nursery 1, 1.80 for Nursery 2 and 1.75 for Nursery 3).

D. Environmental and Cultural Conditions

Temperature

Ambient and container medium temperatures differed at the three nurseries over the summer months. Outside temperatures were highest in July, then decreased only to rise again in the second week of September. Temperatures inside greenhouses were higher than outside. Inside temperatures at Nursery 1 exceeded 30 ^{O}C (maximum of 35.5 ^{O}C) 31 times from mid-June to the end of August. Greenhouse temperatures never exceeded 29.2 ^{O}C at either Nursery 2 or 3.

Soil temperature comparisons showed that readings at Nursery 1 and 3 were higher than at Nursery 2 (Maximum temp: Nursery 1 was 41 ^{O}C, Nursery 2 was 26.3 ^{O}C and Nursery 3 was 38.8 ^{O}C). Soil temperature data for Nursery 3 was not available while the crop was outside. Roof sprinklers were used at Nursery 2 to maintain cooler inside temperatures. At Nursery 1 misting was utilized to cool the crop when soil temperatures exceeded 32 ^{O}C.

Moisture

The crop at Nursery 1, started in a greenhouse, shared a sprinkler system with an adjacent western hemlock crop. System constraints prevented correction for differences in water requirements of the two crops. The greenhouse roof was removed at Nursery 1 from August 15th to October 31, unlike Nursery 2 or 3. Either as a result of rainfall or irrigation, water was applied to the crop at Nursery 1, 42 times compared to 19 times at Nursery 2 and 14 times at Nursery 3.

Seedling Culture

Cultural practices varied. Common to all nurseries was the styroblock size (415B) and computer control system. Nurseries 1 and 3 used the same seedlot and grew it in polyethylene covered greenhouses. Nursery 2 employed a glass house. Nurseries 1 and 2 used sodium metabisulfite for cleaning styroblocks, but at different concentrations. Container ages and configurations differed between and even within crops at each nursery (i.e., a mixture of Econo, Trimroot and Vent blocks). Irrigation booms were used throughout the growing season at Nursery 2 and when the crop was indoors at Nursery 3. Fixed irrigation was used at Nursery 1 throughout the growing season and at Nursery 3 when the crop was outside.

Growing Medium pH and Electrical Conductivity

All nurseries used a peat based growing medium, Nursery 1 used 100% peat, Nursery 2 used peat/vermiculite/perlite at 8:1:1 v/v and Nursery 3 used peat/vermiculite at 3:1 v/v. Nursery 1 incorporated Osmocote and Nursery 3 included dolomite lime and Micromax micro nutrient into the growing medium.

(Continued)

pH was uniform throughout the season at Nursery 2 (ranging from 4.6 to 5.1) and Nursery 3 (ranging from 5.2 to 6.3) Growing media pH at Nursery 1 was below 5.4 until late August then rose to above 7.0 in October and stayed at this level until seedlings were lifted. Nursery 2 recorded the highest EC readings throughout the growing season, with peak values in August (3940 uS/cm). Nursery 3 had consistently low EC values (57 to 556 uS/cm). Nursery 1 EC readings were over 900 uS/cm until the end of August, then dropped to below 380.

Fertilization

Nitrogen was applied to the seedlings in Nursery 1 at 100 ppm from June 4 to September 21 (39 applications). Nursery 2 applied 100 ppm nitrogen to seedlings from July 14 until August 20 (9 applications). and Nursery 3 applied 100 ppm nitrogen on September 6 and 23 (2 applications).

DISCUSSION

Root rot of Douglas-fir greatly impacts on plantation success. Seedling buyers judge a crop's health by examining root systems in late summer/early fall. If the cortex strips easily and the stele is dark seedlings are considered unacceptable. This test is unreliable because only a few seedlings can be examined and root necrosis can develop after the assessment. It is important to detect the potential for root rot as early as possible since seedling replacement due to losses is not possible.

Shoot symptoms may/may not accompany root rot. During the active shoot growth phase, classic symptoms of *Fusarium* infection are usually evident. Progressive foliage discolouration and shoot tip deformation enable rapid diagnosis. If root function is hampered just before bud development and hardening off, small buds, swollen stem bases and dull green foliage will be present. When root damage occurs after bud development, shoot symptoms may not be evident.

Root disease at Nursery 1 became visible on October 20. It is suggested that the onset of root rot took place undetected at least a month prior. The increased incidence of *Fusarium* noted in September coinciding with the presence of environmental conditions favourable to the spread of this fungus supports this statement.

Nitrogen is thought to play a major role in the interaction of nutrition and disease. Excess can result in the production of succulent growth which renders plants more susceptible to pathogens. Higher levels are used during the exponential growth phase to promote shoot production. In the fall levels are reduced to slow shoot growth and encourage tissue maturation . Nursery 1 sowed their crop later (March 29) and maintained higher nitrogen fertilization until the end of September. We suggest that this was one factor affecting disease susceptibility.

A threshold level of *Fusarium* in container growing medium which could be used to signal a potential for root disease was not identified. However, in studies with bareroot seedlings, levels of *Fusarium* in field soils exceeding 1000 colony forming units increase damping-off (McElroy pers. comm.). In this survey of container seedlings, *Fusarium* counts exceeded that level in September at both Nurseries 1 and 2. Detecting high levels in summer can alert nurseries to the potential for root decay later on. Growers can then try to prevent the occurrence environmental conditions conducive to root decay.

In essence, the root disease that occurred in this trial was not caused by a single fungus or growing condition. In the case of Nursery 1, the onset of root rot may have occurred due to a disease complex in the crop. In the summer, when high temperatures encouraged fungal growth, *Fusarium* infected the root system, though the absence of severe plant stress caused it to remained latent. In the fall, lower temperatures, neutral pH and saturated growing media favoured root colonization by *Cylindrocarpon*. Though the numbers of *Fusarium* and *Cylindrocarpon* did not indicate a disease condition, in retrospect the high numbers of *Fusarium* in the growing medium and roots in summer was more of an indicator that root problems could occur in the fall with conditions of high moisture and high pH.

Studies by Axelrood and Chapman (1992) showed that *Cylindrocarpon*, when introduced on planted seedling stock, survives on reforestation sites and is a principal cause of poor performance in the field. As such the reduction in root mass (due to biotic or abiotic factors) in the nursery phase may be more influential in the performance and survival of seedlings in the field than just the levels of root infection by *Cylindrocarpon*. In our study, the extent of root rot at Nursery 1 averaged 38% (based on root volume). In the past, Douglas-fir seedlings with 20 to 30% of the root system necrotic have been planted in the field resulting in poor

(Continued)

survival and performance. Seedlings without root disease from crops in which there are many seedlings with root rot, do not perform as well as seedlings from crops without root disease (pers. comm. P. Axelrood). We do not believe that this is the result of high levels of *Cylindrocarpon* in the roots. Prolonged stress during the nursery growing phase produces poor quality seedlings, which will not grow well in forest plantations.

This survey identifies several factors involved in the Douglas-fir root disease complex. However, there is still a need to determine threshold levels of these factors. It is not always possible to prevent high temperatures or the introduction of high levels of pathogenic fungi. How many periods of high temperature are required to incite root decay? Does pH have to be low initially to encourage *Fusarium* and high later in the season to allow *Cylindrocarpon* to inhibit root growth? There are many complex interactions between fungi and environmental factors. If continuous saturation of the growing media is prevented, will other factors lose their impact on disease expression?

This survey presents biological and environmental variables which can be studied in more precise experiments. Understanding the interactions between these variables will allow us to produce healthy crops without the need for pesticides. Following are recommendations on how to prevent Douglas-fir root disease and some suggestions on how to recognize diseased plants. If required, a copy of the complete report can be obtained from the first author.

RECOMMENDATIONS

Prevention of Douglas-fir Root Disease

Based on our results we can make the following recommendations:

1) Keep initial pathogen levels low by proper sanitation.

2) Sow seeds early enough so high nitrogen fertilization for long periods is not required.

3) Maintain growing media pH at 5 to 5.5. Below 4 and over 7 may cause plant stress and encourage disease.

4) Keep air and media temperatures below 30 ° C. When using water for cooling, keep the water off the crop by spraying the greenhouse roofs or use very short bursts of water so the soil does not remain saturated for long periods.

5) Manage water such that growing media is allowed to dry between irrigations. In high precipitation areas, especially during fall and winter, seedlings will benefit from protection by roofs. Minimize growing medium saturation time.

Identifying Root Rot

Obtaining a bioassay on roots and growing media from a representative crop sample early in the growing season may be a good way to identify crops at risk. Based on the information from this survey, it would appear that the best time to submit samples for testing is mid-September.

Where a crop experiences damping off, hypocotyl rot or root rot early in the season, special attention should be paid to environmental factors such as temperature, moisture, pH, and RH as well as nitrogen levels, to minimize further stress.

Late in the growing season, seedlings showing dull green needles, small buds and strongly tapered stems should be examined for root necrosis. Roots may or may not be damaged. Remember, shoot symptoms alone cannot be used to judge a crop for acceptance.

REFERENCE

Axelrood, P. and B. Chapman, 1992. Assessment of *Cylindrocarpon* and *Fusarium* Root Infection and Root Form of Douglas-fir Seedlings Outplanted for Four years in Southwestern British Columbia. B.C. Research Report No. 3-01-123 and 3-01-124.

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Ed Muckle, previously the editor/originator of *21st Century Gardener* magazine is what some might term a "free thinker". His travels and experience have uncovered countless insights into plant production in general. In the following article Ed challenges some more conventional thinking so don't be afraid to give him a call! ***Editor***

The World of Nutrition From the Plant's Eye View

Do you ever wonder what goes on in the root zone of a plant? How is water taken up? How are nutrient elements taken up? The answers contain some keys to enhanced production and plant health for all crops, including silviculture.

Current research indicates plants as having at least two water uptake systems within the root structure. There may be more mechanisms to be discovered in the future. I will refer to these two as the transpiration and respiration systems. Both are equally essential to plant growth and development.

The Transpiration System takes care of transport requirements, the flow of nutrient ions from the roots; and provides the main channel for the water of transpiration. Water is taken directly into the xylem just behind the root cap. The uptake regulation is mainly a function of transpiration rates, as this is the end-use for the majority of the water resident in this system.

The transpiration system is however influenced by other plant metabolic processes. Respiration is continuously depositing compounds into the water stream for transport to the upper portions of the plant. This affects the osmotic potential of the transpiration stream which can in turn affect the net water uptake potential.

This transport system is not part of the nutrient uptake system and is adversely affected by concentrations of what it sees as contaminants in the water. Contaminants include all ions, including nutrient elements, since they are potential "blockers" of this uptake system. High contaminant concentrations retard the uptake system by causing high osmotic pressures which combat the plant demand. One of the most common sources of problems with this uptake system is the raw water supply. Our surveys around the world show that less than 10% of commercial growers maintain a quality control program on their raw water suppplies.

Every irrigation cycle introduces additional "contaminants" which can reduce the effectiveness of the transpiration water uptake system if allowed to build up over consecutive irrigation/fertigation cycles. Under high transpiration conditions any reduction in uptake potential can cause plant stress. This stress can slow plant growth and dramatically reduce its ability to cope with the heat generated by high light levels (less transpiration water available for evaporative cooling of the leaf surface). It also reduces the plant's ability to replace water lost through excessive transpiration rates generated by high levels of air movement over the leaf surface (high Vapour Pressure Deficit), possibly leading to loss of turgor (wilting).

Growers who believe they have an "excellent" water supply but haven't checked for a few years may have a surprise in store. Raw water quality changes are some of the most common causes of sudden differences in growth chararcteristics. We usually hear about it when a grower calls and says, "My plants aren't growing anything like they did last year, and I haven't changed a thing."

While we cannot visibly see or sense changes in the quality of raw water, unless it suddenly changes colour, plants roots do sense the changes with each irrigation. Keeping this in mind can make life a lot better for your plants.

The Respiration System is used to take in the water of nutrition. This water is necessary to utilize the nutrients taken in by the plant roots. The breakdown products of water, hydrogen and hydroxyl ions as well as oxygen, are used as building blocks in a variety of metabolic processes similar to other plant nutrient ions and molecules.

This water is taken in through very specifically created openings in cell walls. These are made by specific protein chains which are individually generated by a specific DNA code sequence. DNA is the genetic material contained within every cell and is basically a sequence of individual codes preceded by an activation switch. Stimuli which activate a particular code sequence activation switch can be either external or internal and in most cases have yet to be identified. Any change inside or outside a cell could thus be the trigger which tells the DNA another opening is needed in the cell wall to accept more water.

These openings will not allow anything but a single H_2O molecule to pass. Similar openings are used to pass water from one cell to another. So much for the theory of semi-permeable membranes? Plant DNA is thus directing every drop of water within the plant's respiration system... an amazing program, making even our most capable computers look a little slow and primitive!

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The respiration system is not affected by TDS (Total Dissolved Solids) the way the transpiration system is. As long as the needed molecule of water is there it will be taken in. It is not known at this point how much energy this system can bring to bear to take a water molecule away from a competitor such as the growing media.

Research has not yet determined whether the respiration system can in any way supplement the transpiration system in times of water stress. Indications are that the differences between the two systems; transpirational designed for large volumes of uptake; and respirational for specific molecular uptake, preclude this possiblility.

The respiration water uptake system can however be indirectly affected by transpiration water stress, especially as a result of high temperatures. If stomatal closure occurs due to an inability to cope with excessive cooling requirements it will lead to decreased photosynthesis, reducing carbohydrate synthesis and subsequent energy available to the respiration water uptake system.

More will be learned about both of these systems as researchers in the USA, Australia, Germany and Japan continue to report on their progress. It is interesting to note that the original research which indicated the existence of two water uptake systems in plants came out of medical research into cancer.

Next article I will take a look at how plants see nutrient ions and how they are taken up.

M. Edward Muckle
Grower Press Inc.

The following article is the first in a series of contributions we hope to receive from Alec Mackenzie. His growing experience coupled with vast knowledge of computerized greenhouse equipment control affords him a very high standing in the field of controlled environment growing. A careful perusal of the following pages will surely reveal some excellent points to ponder.

Editor

Greenhouse ventilation and cooling

The greenhouse climate is very complex. Heating and cooling loads are much larger than for similarly sized conventional buildings, and good environmental control depends on good greenhouse design and equipment selection, along with suitable control strategies. The focus of this paper is on ventilation and cooling. Many concepts that apply to cooling systems apply to heating systems as well.

Overall greenhouse design considerations

The most important greenhouse design consideration is the **optimization of light transmission** for crop growth. All other considerations take a distant second place. This results in a building design that is usually very good at light transmission and very poor at almost all other functions normally provided by buildings. In particular, high light transmission designs have two compromises that work against the climate.

1. Large solar heat gains.
2. Inherently high thermal losses.

These produce large and rapid temperature fluctuations that are difficult to control, particularly when the effect is greater than the corrective capabilities of the greenhouse climate equipment. Greenhouse designs have much larger heating and cooling systems than similarly sized buildings, often *ten times* larger! For this reason, equipment and controls used in conventional buildings do not work very well in greenhouses. Other considerations that further constrain the greenhouse design process are:

- Low capital cost budget for the greenhouse and equipment.
- Low operating cost budget.
- High reliability and redundancy requirements for greenhouse systems. (Equipment failures can quickly result in catastrophic losses.)
- Close control tolerance for many crops.
- High humidity loads produced by crops require aggressive management.

In short, the builder faces a building design that is much more demanding than most conventional buildings, while limited by a much smaller budget. Many critical design elements are integral components of the greenhouse structure itself, hence must be addressed *before* completing the greenhouse design.

After light transmission, **energy conservation** is the single most important greenhouse design consideration. For each reduction of thermal load, there is a corresponding reduction in capital and operating costs *for the life* of the greenhouse. Reductions in thermal load *also* result in a smoother, more uniform climate, which is almost always beneficial to the crop. (Continued)

Reduce **energy gain** by actively or passively controlling solar gain to *just* meet the requirements of your crop, no more. Solar gain can be as high as 200 BTU per square foot of greenhouse per hour. Savings are achieved here through reduced requirements of the ventilating system. The following can be applied as appropriate for your particular crop and climate. Capital costs for some of these often become the limiting factor.

- Select a greenhouse design and covering appropriate for the crop.
- Use seasonal modifiers such as whitewash applied to the greenhouse covering during high light times of the year.
- Use diurnal modifiers such as external or internal movable shading systems to control light entry to the greenhouse, hour by hour.
- Use selective coatings on glazing systems to maximize and favour transmission of those portions of the solar spectrum that are important to crop growth.

Reducing energy losses lowers temperature and humidity fluctuations and reduces the need for a fast responding ventilation system.

- Thermal curtains (also usable for light control).
- Selective coatings on glazing systems to reduce heat loss.
- Glazing systems that conserve energy (e.g., double glazing).
- Control (limit) unnecessary air exchange with the outside.

Increase the thermal mass of the greenhouse. Design this thermal mass to interact quickly with the greenhouse environment so that it can absorb fluctuations in heat gain and heat loss, producing a smoother environment.

- Build the greenhouse as tall and large (area) as practicable. This will increase the volume of air in proportion to the greenhouse surface area.
- Incorporate high thermal mass components into the greenhouse structure.
- Consider adding additional passive or active thermal storage to the greenhouse (rock or water heat storage)

Other considerations

Air circulation within the greenhouse is extremely important. Residual temperature and humidity unevenness can be “mixed” and distributed around the greenhouse by good air circulation. This is particularly important for tall crops. Tall crops interfere with natural air circulation, and tend to have greater air exchange requirements because of the extra loads imposed by the crop (humidity).

Ventilation achieves several control objectives:

- Carry away excess heat (cooling).
- Replace inside air containing a high amount of moisture with outside air that has a lower moisture content (dehumidification).
- Replace CO_2-depleted inside air with outside air containing more CO_2.
- Purge the greenhouse of dangerous chemical residues after spraying or fumigating.

A greenhouse designed to properly meet its cooling requirements almost certainly can meet the other objectives. Review your design to confirm that this is true for your situation.

The following approach to **System Design** is useful in solving many control problems:

1. Reduce the magnitude of the problem. This makes the remaining tasks much easier (and less costly) to implement.
2. Buffer the system to slow down and reduce the magnitude of changes. This allows more flexibility when considering control solutions, often allowing the selection of slower responding, less expensive equipment that is easier to control.
3. Develop an *integrated* set of solutions to control a problem.

Cooling

A greenhouse must reject or expel *excess* heat produced by internal systems (e.g., lights) and by solar energy gain. Mechanical cooling systems (heat pumps) are too expensive for most applications, so the majority of greenhouses rely on **air exchange** to remove excess heat. Cool outside air replaces warm inside air. The difference in energy content between the two air-masses equals the energy transferred from the greenhouse. Air absorbs heat in two ways; sensible heat and latent heat.

Sensible heat is the energy absorbed by an air mass as it warms up. For example, doubling the temperature rise of the exchanged air will approximately double the energy transferred from a greenhouse. This fact can work to your advantage. If the crop can accept a higher temperature rise in the greenhouse, ventilating system size can be significantly reduced.

Air has a relatively low specific heat and very low density. Therefore; large volumes of air can carry away only modest

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amounts of sensible heat energy. Very approximately, 50,000 cubic feet of air raised 1 degree Fahrenheit will absorb 1,000 BTU's. Using this mechanism alone, an air exchange capacity of more than 15 cubic feet per square foot of greenhouse per minute is needed to keep the temperature rise down to 10 degrees ^{o}F! Luckily for greenhouse designers, there is another mechanism for removing heat. It involves the concept of **latent heat**.

Latent heat of vaporization (condensation) is the heat absorbed (or released) when water changes phase from water to vapor (or back). One pound of water can absorb approximately 1,000 BTU's as it changes phase from liquid to vapor. Plants apply this mechanism to cool themselves directly through transpiration. For this reason, plants need substantially more water on sunny days than on cloudy days, all other conditions being equal. Heavy, active crops such as tomatoes and cucumbers can transpire so much that they effectively become the primary cooling mechanism for the greenhouse, easily maintaining inside air temperature below outside air temperature. Other crops are not as active and require assistance from other water evaporation sources if the desire is to keep inside temperatures close to the wet bulb temperature. These evaporation sources can be as simple as wet walkways and floors, or as complex as a computer controlled high pressure fog system.

Incoming air can be **pre-cooled** using outside sprinklers, fog systems or pads. Incoming air can be cooled down to approximately the wet bulb temperature of the outside air. This temperature reduction can be tens of degrees in dry climates.

An important side benefit of using latent heat as the *primary* mechanism for heat transfer, is the corresponding *decrease* in the **Vapor Pressure Deficit** that results from adding water vapor to the atmosphere. Under high cooling conditions, greenhouse crops are often water stressed. A lower VPD will reduce growth limiting water stress. Poor nutrient uptake or translocation may occur if the VPD is too low. Consult reference material for your crop to determine what these limits might be.

Latent heat energy transfer allows a substantial reduction in air volume exchange requirements while achieving superior crop growing conditions. Some ventilation is required to bring in fresh, dry air to absorb moisture evaporated in the cooling process. The volume of air required will vary significantly with climate conditions. Minimum air exchange requirements occur when the incoming air has a very low moisture content, and the moisture content of the greenhouse air is high. Air exchange capacities can be as low as five cubic feet per square foot of greenhouse per minute (less than *one third* the sensible heat ventilation requirement). Most greenhouse designers use a figure of around ten cubic feet per square foot per minute. This provides for some margin of safety for extreme weather conditions or equipment failures. Greenhouses located in hot humid climates require higher ventilation rates because they are unable to use significant latent heat transfer. You should consult a psychrometric chart (not a psychic!) for a more detailed explanation of the relationship between air (dry bulb) temperature, water content, relative humidity, dewpoint and wet bulb temperature.

Ventilation Equipment selection

Ventilation equipment for greenhouses must be high capacity to meet peak cooling requirements, but must also be capable of quick adjustment to almost any partial level of ventilation required. Obviously a greenhouse with limited solar gain, maximum thermal buffering and good air mixing will have much less trouble, but it still faces a wide range of ventilation requirements. Greenhouses require a **'turn down ratio'** of 100:1 (maximum to minimum ventilation ratio). Two types of ventilating systems can meet these control requirements.

Variable speed fans, modulating roof vents, and movable roof systems. These ventilating systems can be fairly easily adjusted to partial ventilation positions. Unfortunately, air exchange rates can change significantly for a given ventilation setting as a result of indoor/outdoor temperature differences or wind speed and direction changes. These air exchange fluctuations can make control difficult, and the ventilation systems may 'hunt' under some conditions, particularly at low ventilation rates.

Staged Off/On ventilating fans. Off/on fan systems can produce very good results by simply *pulsing* the fans 'on' as needed to meet the demand. A small ventilation requirement may be met by pulsing one fan 'on' for a few seconds, once every few minutes. A larger demand might be met by running several fans continuously. This control strategy depends on the thermal mass of the greenhouse to absorb the pulses. Small pulses of cold air will produce only a very small change in the temperature of the much larger greenhouse air mass. A climate control computer can easily manage this control strategy, and produce very smooth and responsive control. Thermostats do a very poor job of controlling fans and usually produce large temperature upsets that also affect humidity conditions and sometimes force cycling between heating and cooling.

Horizontal Air Flow, or good air circulation is *particularly* important for fan cooled greenhouses, because fans and intake louvers tend to introduce air at concentrated points, requiring an air circulation system to mix and distribute it. Roof vents distribute air throughout the greenhouse, reducing (but not

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eliminating) the need for additional air circulation.

Positive pressure versus negative pressure fan systems, based on "swamp cooler" technology, are experiencing a resurgence in interest. This is a result of increasing interest in evaporative pad cooling and bug screening to reduce insects. Positive pressure ventilation systems are really just a variation of the standard pad and fan design. *Pay particular attention to internal greenhouse air distribution and circulation, and do not try to rely on the cooling system fans to do this job for you.* ***It will not work!*** Air circulation within the greenhouse must be a continuous process, while the cooling system is constantly adjusting its operation to meet current cooling requirements. Argus is working on a more detailed design paper covering this topic.

Alec Mackenzie
Argus Control Systems Ltd.

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For More Information Contact:
Eileen Harvey
Ph: 705-757-5740 Ext 2251 Fax: 705-759-5728
E-mail: eharvey@pmoeafpm.fpmi.forestry.ca

The North American Material Handling Show and Forum

April 15 - 16, 1996
Cobo Hall, Detroit Michigan
For More Information Contact:
Bill Capps, Rochell Miller-Abbott or Heather Harper
Ph. 800-345-1815 or 704-522-8644

Third Meeting of IUFRO Working Party Diseases and Insects in Forest Nurseries

May 19-24, 1996. Gainesville, Florida., USA.
For More Information Contact:
E.L. Barnard, Florida Division of Forestry, Forest Health Section.
P.O. Box 147100, Gainesville, Florida 32614
Ph: 904-372-3505 Fax: 904-955-2301

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26th National Agricultural Plastics Congress.

June 14-18, 1996. Atlantic City, New Jersey.
For More Information Contact:
Gene Giacomelli
Ph: 609-455-3100

Seeley Conference, June 23 - 25.

Cornell University, Ithaca, New York
call (607) 255-9998

Forest Nursery Association of B.C.

16th Annual Meeting, September 1996, Quesnel, B.C.
For More Information Contact:
Mike von Hahn
Ph: 604-992-8631 Fax: 604-992-6783

XIV Meeting of the North American Forest Biology Workshop

Theme: Forest Management Impacts on Ecosystem Processes
June 16-18,1996 Laval University
For More Information Contact:
Dominique Houde
Ph: 418-658-6755 Fax: 418-658-8850

Fifth International Plant Cold Hardiness Seminar

August 5 - 8, 1996 Oregon State University
For more information Contact:
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