Winter Chill Requirement in Coastal Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco)

Publication reference:

K D Jermstad[1], D L Bassoni, K S Jech, N C Wheeler, G A Ritchie, D B Neale[2] (2003) Mapping of quantitative trait loci controlling adaptive traits in coastal Douglas fir. III. Quantitative trait loci-by environment interactions. Genetics 165: 1489-1506

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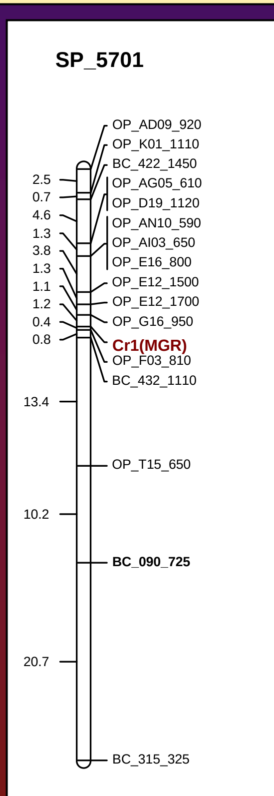
[2] Department of Plant Sciences, UC Davis, Davis, CA

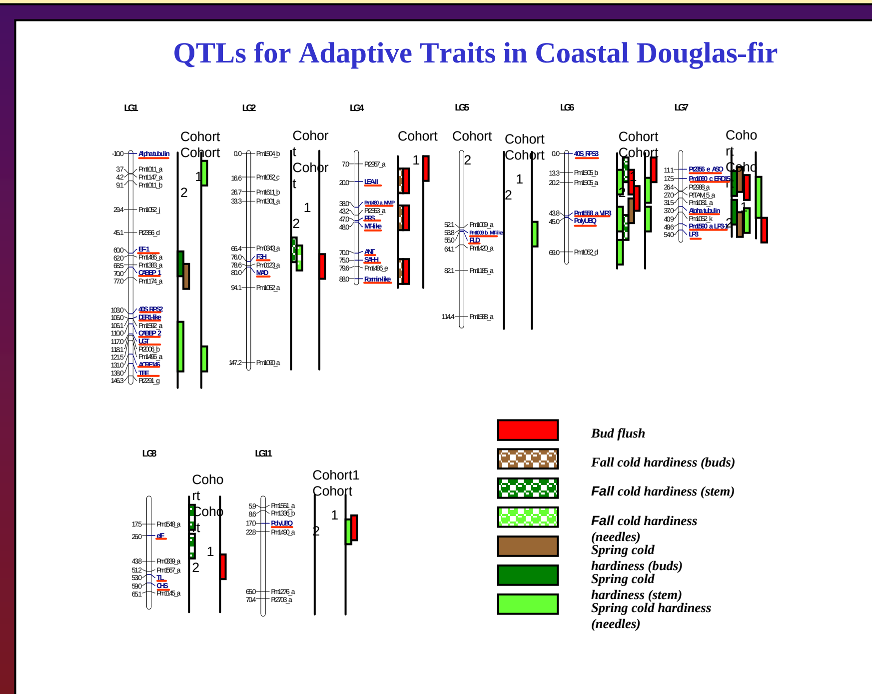
Simply Inherited Traits

***Cr1:* Major gene of resistance in sugar pine to white pine blister rust**

Complex Traits

Most adaptive traits:
- ***phenology (dormancy related)***
- ***cold-hardiness***
- ***drought-tolerance***
- ***incremental height***





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Environmental Signals Influencing Adaptive Traits

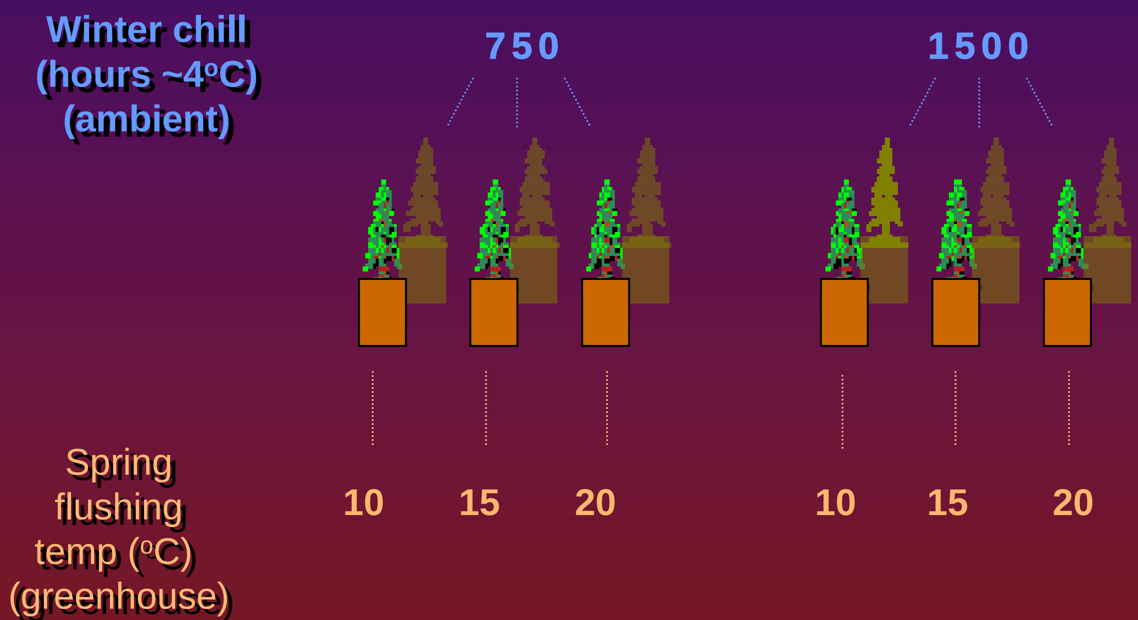
winter chilling | spring temperature | moisture availability | photoperiod

Growth Initiation √

Growth Cessation

Growth Initiation Experiment: 2x3 Factorial Design

429 progeny from a full-sib cross segregating for date of budflush
Vegetative propagation (32 cuttings per progeny)
Treatments were replicated

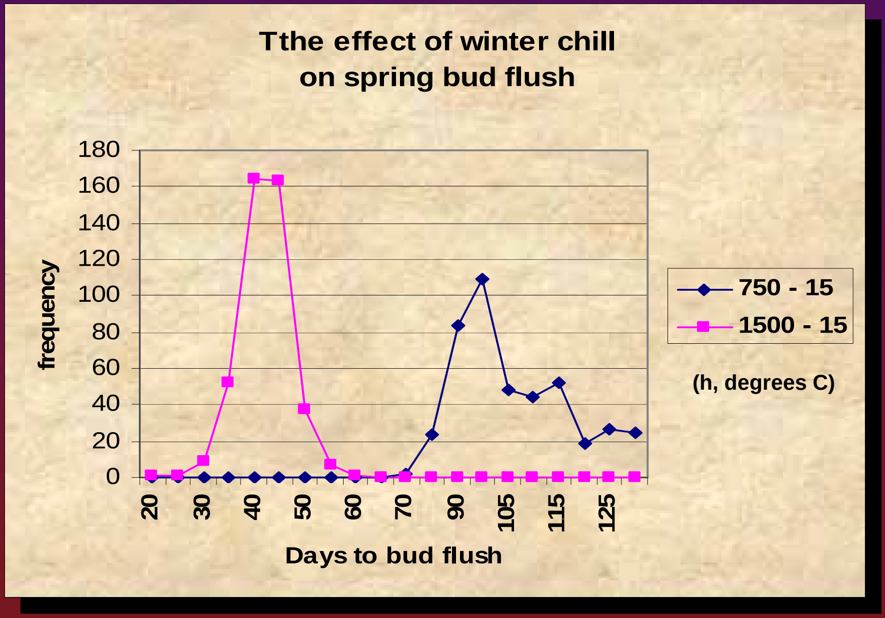


Recorded the number of days to budflush

Winter chill treatments had a significant effect on days to budflush ($p \leq 0.0001$).

	WC1500_FT10	WC1500_FT15	WC1500_FT20	WC750_FT10	WC750_FT15	WC750_FT20
No. of Days	53.1 (0.2)	39.9 (0.2)	23.3 (0.2)	106.4 (0.4)	101.0 (0.7)	82.8 (1.2)

Number of days (SE) to budflush under different treatments

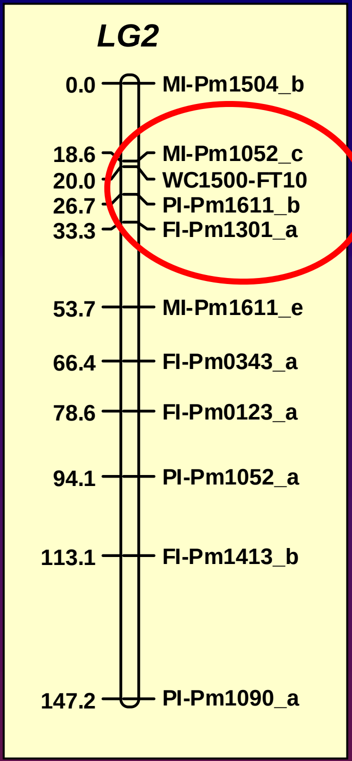


"On average, trees receiving 750 hours of chilling took over 60 days longer to achieve terminal bud flush (dormancy release) than trees that received 1500 hours of chilling. Perhaps more importantly, only 76% of the trees receiving 750 h actually broke bud during the study, compared to 98% for those receiving "normal" chill sums of 1500 hours <u>The 750 hour winter chill treatment was apparently inadequate to break dormancy in nearly a quarter of the trees and retarded bud flush in the remainder</u>."

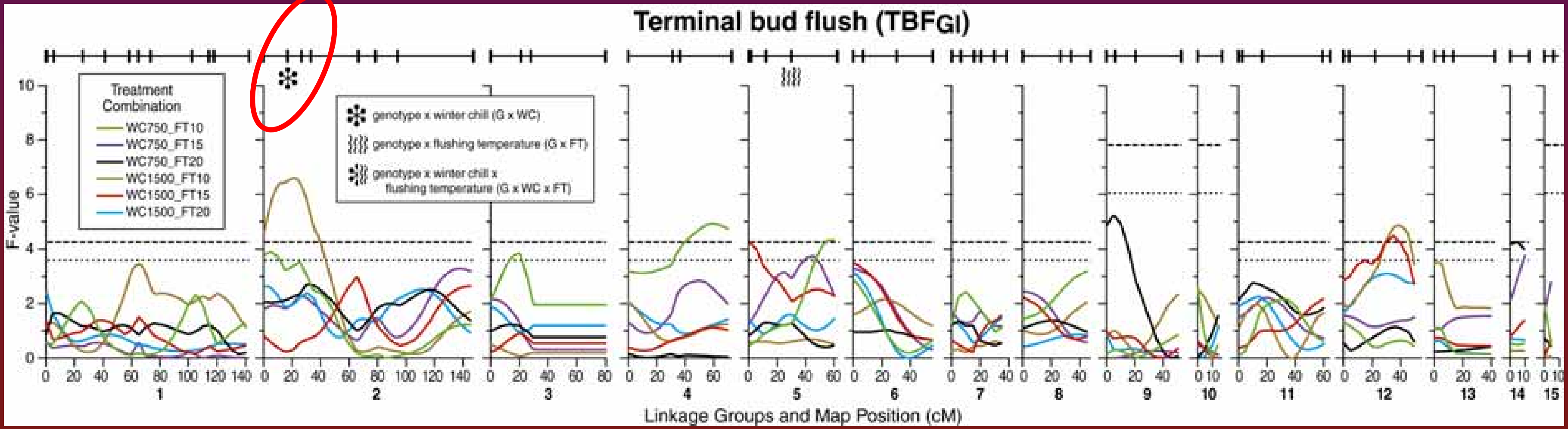
http://dendrome.ucdavis.edu/NealeLab/supplemental.html

Genetic Mapping Growth Initiation

- DNA extracted from progeny needle tissue
- Progeny genotyped for 74 informative and evenly spaced markers
- QTL mapping
- ANOVA (QTL x Environment)



Genetic mapping of QTL that interact with the environment



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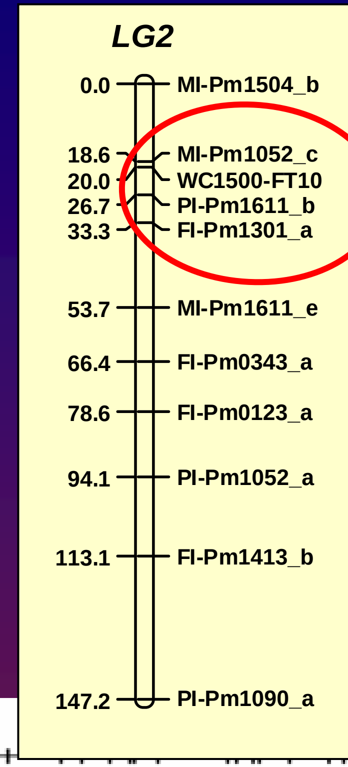
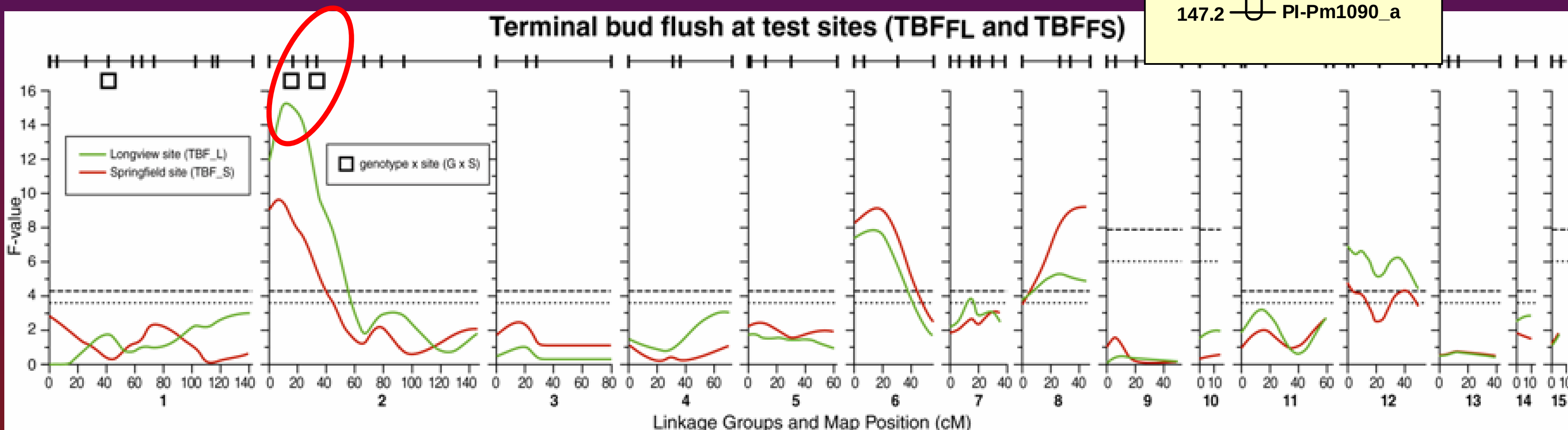


Genetic mapping of QTL that interact with the environment (field sites)



NCBI BLASTn (EST db)

Accession	Description	Query coverage	E value	Max ident
PmIFG_1301	**no function found (numerou**			
ES425653.1	pm_OSU_shoot_ 005D07 Douglas-fir cold deacclimating cDNA library 2003-2004 (CD_2003-04)	60%	6e-147	90%
ES425055.1	pm_OSU_shoot_ 053D11 Douglas-fir maximum cold hardiness cDNA library 2003-2004 (MH_2003-04)	60%	3e-145	90%
EX412585.1	GQ03613.B7_K09 GQ036 - Shoot tip - Active growth Picea glauca cDNA	46%	5e-28	69%

Accession	Description	Query coverage	E value	Max ident
PmIFG_1611	**similar to plasma membrane major intrinsic protein 3 (numerous hits among conifers & plants)**			
ES428844.1	pm_OSU_shoot_ 053A11 Douglas-fir cold deacclimating cDNA library 2003-2004 (CD_2003-04)	75%	4e-179	92%
CN641130.1	294H05_556833 Douglas-fir cDNA library PmIFG_73-6	57%	4e-120	90%
DR552780.1	WS03224.C21_C20 WS-MC-N-A-20 Picea glauca cDNA clone WS03224	75%	3e-118	89%

Accession	Description	Query coverage	E value	Max ident
PmIFG_1052	**Ribosomal protein**			
DR745555.1	RTCU1_30_B12.g1_A029 Roots plus added copper 5', mRNA sequence	34%	9e-10	65%
DR161983.1	RTFE1_15_B12.b1_A029 Roots minus iron 3', mRNA sequence	34%	9e-10	65%
CF471742.1	RTDS1_6_D01.g1_A015 Drought-stressed loblolly pine roots 5', mRNA sequence	34%	9e-10	65%
CF401163.1	RTWW1_10_C03.g1_A015 Well-watered loblolly pine roots WW1 5', mRNA sequence	34%	9e-10	65%
CF391260.1	RTDR3_4_A08.g1_A022 Loblolly pine roots recovering from drought DR3 5', mRNA sequence	34%	9e-10	65%

Noteworthy: there are no cold-hardiness QTLs on LG 2

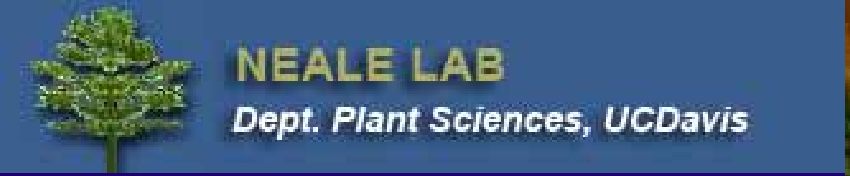
Winter chill associated with apical oxidative stress

(grape, poplar, maize)

<u>List of candidate genes for oxidative stress</u>

- Ascorbate peroxidase √ (LG 13; ABA-responsive gene)
- glutahathione reductase
- thioredoxin h √
- glutathione-S-transferase √ (LG2, 113 cM; Pm1413_b)
- sucrose synthase √
- catalase
- SNF-2
- phospholipid-hydroperoxide glutathione peroxidase
- pyruvate carboxylate
- superoxide dismutase √

- **Candidate gene work for cold-hardiness and drought tolerance**
  (Krutovsky and Neale, 2005, Genet 171:2029-204; Eckert et al. (in prep)
- **Association studies in DF**
  (Eckert et al. (in prep.)
- **JGI (DOE) award "carbon sequestration in forest trees"**
  (Jeff Dean, Glenn Howe, Deborah Rogers, Kathie Jermstad, David Neale)



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Research

Allele Discovery of Economic Pine Traits (ADEPT)

Allele Discovery of Economic Pine Traits II (ADEPT 2)

Conifer Translational Genomics Network (CTGN) (CAP) www.pinegenome.org

Conifer Comparative Genomics Project (CCGP)

Comparative RE-Sequencing in Pinaceae (CRSP)

Agenda2020 Project

Adapt Project

Ecosystem Genomics and Forest Health Network (EGFHN)

Poplar Biofuels Genome Project (PBGP)

Sequoia Sempervirens Genome Project (SSGP)

White Pine Genome Project (WPGP)

Will shorter winters severely impede growth initiation?

ScienceDaily (Apr. 16, 2008) — The world's oldest recorded tree is a 9,550 year old spruce in the Dalarna province of Sweden.

Epigenetic control of phenology in Norway Spruce

Kvaalen H, Johnsen O. 2008. Timing of bud set in *Picea abies* is regulated by a memory of temperature during zygotic and somatic embryogenesis. New Phytol. 1:49-59

Søgaard G, Johnsen O, Nilsen J, Junttila O. 2008. Climatic control of bud burst in young seedlings of nine provenances of Norway spruce. Tree Physiol. 2:311-320

Johnsen, Ø., Fossdal, C.G., Nagy, N., Mølmann, J., Dæhlen, O.G. & Skrøppa, T. 2005 Climatic adaptation in *Picea abies* progenies is affected by the temperature during zygotic embryogenesis and seed maturation Plant, Cell and Environment 28:1090-1102

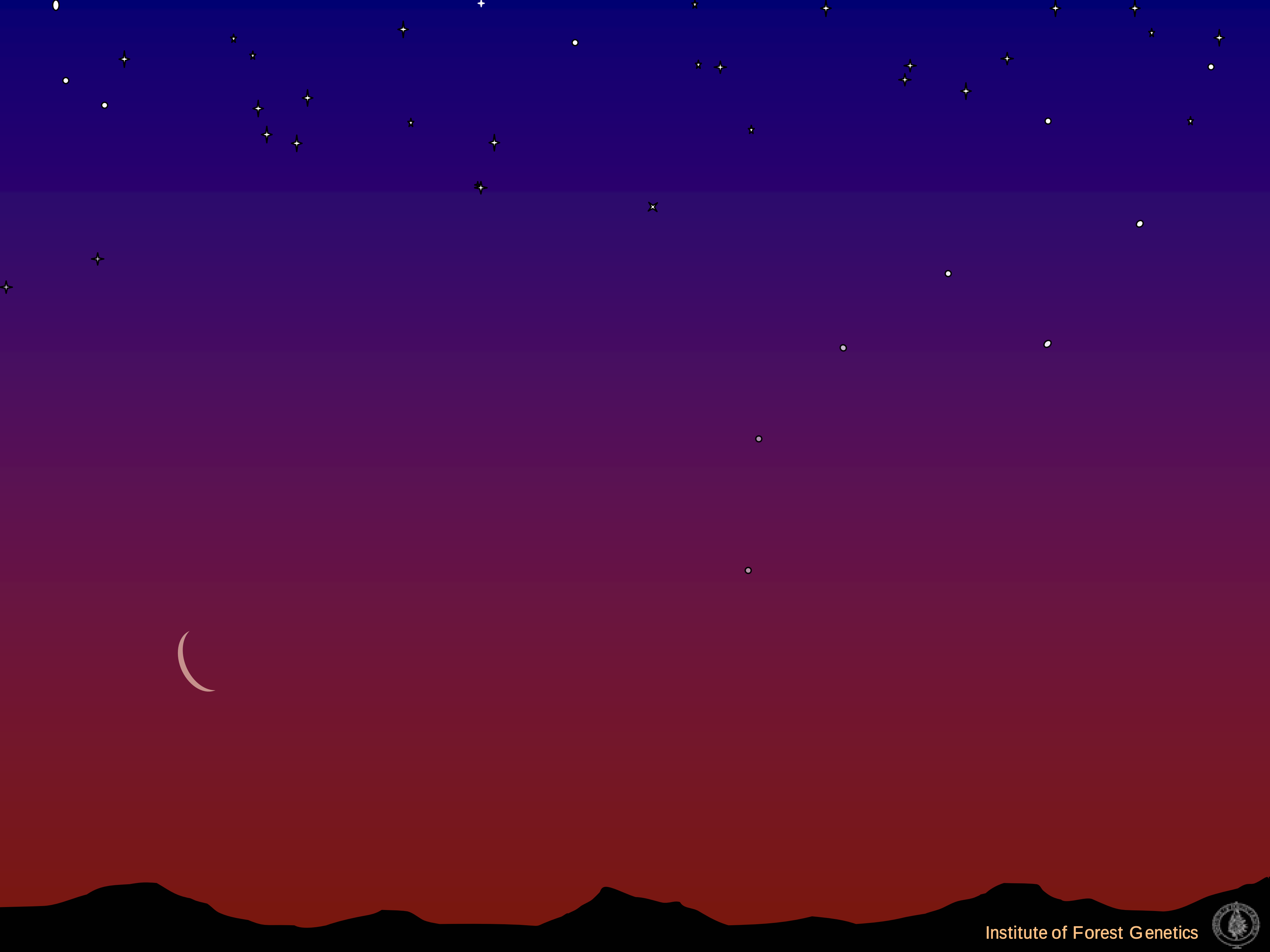
Johnsen, Ø. & Skrøppa, T. 1996 Adaptive properties of *Picea abies* are influenced by environmental signals during sexual reproduction Euphytica 92:67-71

Johnsen, Ø., Skrøppa, T., Junttila, O. & Dæhlen, O.G. 1996 Influence of the female flowering environment on autumn frost hardiness of *Picea abies* progenies Theoretical & Applied Genetics 92:797-802

ScienceDaily (Apr. 16, 2008) — The world's oldest recorded tree is a 9,550 year old spruce in the Dalarna province of Sweden.

Findings of Johnsen's work:

- Norway spruce has evolved a flexible adaptive mechanism we may call adaptive plasticity
- seedlings can adjust dormancy / growth transitions according to temperature received during embryogenesis
- this ability makes Norway spruce less vulnerable to adverse effects of climate change, and enhances the competitive ability of the species
- the ability to express adaptive plasticity is probably subjected to genetic variation
- adaptive plasticity may then be favoured during density dependent selection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