

NORWAY SPRUCE SOMATIC EMBRYOGENESIS: IMPROVEMENT OF SOMATIC EMBRYO MATURATION

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REFERENCES

- ADAMS G. W., DOIRON M. G., PARK Y. S. (1994). Commercialization potential of somatic embryogenesis in black spruce tree improvement. *Forestry Chronicle*, 70: 593-598.
- BARBEAU M. A. (2002). The chromosome squash. *In*: Barbeau M. A. (Ed.). Application of biological principles, a lab manual for Biology 1006. University of New Brunswick, Fredericton, NB Canada: 9-7.
- BEARDMORE T., CHAREST P. J. (1995). Black spruce somatic embryo germination and desiccation tolerance. I. Effects of abscisic acid, cold, and heat treatments on the germinability of mature black spruce somatic embryos. *Canadian Journal of Forest Research*, 25: 1763-1772.
- BELMONTE M. F., MACEY J., YEUNG E. C., STASOLLA C. (2005). The effect of osmoticum on ascorbate and glutathione metabolism during white spruce (*Picea glauca*) somatic embryo development. *Plant Physiology and Biochemistry*, 43: 337-346.
- BROWNING K. S. (1996). The plant translational apparatus. *Plant Molecular Biology*, 32: 107-144.
- CHAN R. L., GAGO G. M., PALENA C. M., GONZALEZ D. H. (1998). Homeoboxes in plant development. *Biochimica and Biophysica Acta*, 1442: 1-19.
- CHATTHAI M., SANTOSH M. (1998). Sequence and expression of embryogenesis-specific cDNAs encoding 2S seed storage proteins in *Pseudotsuga menziesii* (Mirb.) Franco. *Planta*, 206: 138-145.
- CHELIAK W. M., KLIMASZEWSKA K. (1991). Genetic variation in somatic embryogenesis response in open-pollinated families of black spruce. *Theoretical and Applied Genetics*, 82: 185-190.
- DEVERNO L. L., PARK Y. S., BONGA J. M., BARRETT J. D. (1999). Somaclonal variation in cryopreserved embryogenic clones of white spruce [*Picea glauca* (Moench) Voss.]. *Plant Cell Reports*, 18: 948-953.
- DONG J. Z., DUNSTAN D. I. (1997). Characterization of cDNAs representing five abscisic acid-responsive genes associated with somatic embryogenesis in *Picea glauca*, and their responses to abscisic acid stereo structure. *Planta*, 203: 448-453.
- DUNSTAN D. I., BEKKAOUI F., PILON M., FOWKE L. C., ABRAMS S. R. (1988). Effects of abscisic acid and analogues on the maturation of white spruce (*Picea glauca*) somatic embryos. *Plant Science*, 58: 77-84.
- FARRELL R. E. (1993). *RNA Methodologies: A Laboratory Guide for Isolation and Characterization*. Academic Press Inc., San Diego, CA, USA, 331 pp.
- FEHER A., PASTERNAK T. P., DUDITS D. (2003). Transition of somatic plant cells to an embryogenic state. *Plant Cell, Tissue and Organ Culture*, 74: 201-208.
- FIND J. I. (1997). Changes in endogenous ABA levels in developing somatic embryos of Norway spruce (*Picea abies* (L.) Karst.) in relation to maturation medium, desiccation and germination. *Plant Science*, 128: 75-83.
- FINKELSTEIN R. R., GAMPALA S. S., ROCK C. D. (2002). Abscisic acid signaling in seeds and seedlings. *Plant Cell*, 14 Supplement: S15-S45.
- FLINN B. S., ROBERTS D. R., NEWTON C. H., CYR D. R., WEBSTER F. B., TAYLOR I. E. P. (1993). Storage protein gene expression in zygotic and somatic embryos of interior spruce. *Physiologia Plantarum*, 89: 719-730.
- FLINN B. S., ROBERTS D. R., WEBB D. T., SUTTON B. C. (1991). Storage protein changes during zygotic embryogenesis in interior spruce. *Tree Physiology*, 8: 71-81.
- FOOTITT S., INGOUFF M., CLAPHAM D., VON ARNOLD S. (2003). Expression of the viviparous 1 (Pavp1) and p34^{cdc2} protein kinase (cdc2Pa) genes during somatic embryogenesis in Norway spruce (*Picea abies* [L.] Karst). *Journal of Experimental Botany*, 54: 1711-1719.
- HAKMAN I., VON ARNOLD S. (1985). Plant regeneration through somatic embryogenesis in *Picea abies* (Norway spruce). *Journal of Plant Physiology*, 121: 149-158.
- HOLLUNG K., ESPELUND M., JAKOBSEN K. S. (1994). Another Lea B19 gene (Group1 Lea) from barley containing a single 20 amino acid hydrophilic motif. *Plant Molecular Biology*, 25: 559-564.
- INGOUFF M., FARBOS I., LAGERCRANTZ U., VON ARNOLD S. (2001). PaHB1 is an evolutionary conserved HD-GL2 homeobox gene expressed in the protoderm during Norway spruce embryo development. *Genesis*, 30: 220-230.
- KAWAHARA R., SUNABORI S., FUKUDA H., KOMAMINE A. (1992). A gene expressed preferentially in the globular stage of somatic embryogenesis encodes elongation-factor 1 alpha in carrot. *European Journal of Biochemistry*, 209: 157-162.
- KERMODE A. (2005). Role of abscisic acid in seed dormancy. *Journal of Plant Growth Regulation*, 24: 319-344.

- KIM Y. W., MOON H. K. (2007). Enhancement of somatic embryogenesis and plant regeneration in Japanese larch (*Larix leptolepis*). *Plant Cell, Tissue and Organ Culture*, 88: 241-245.
- KLIMASZEWSKA K., PARK, Y. S., OVERTON C., MACEACHERON I., BONGA J. M. (2001). Optimized somatic embryogenesis in *Pinus strobus* L. *In Vitro Cellular and Developmental Biology-Plant*, 37: 392-399.
- KLIMASZEWSKA K., SMITH D. R. (1997). Maturation of somatic embryos of *Pinus strobus* is promoted by a high concentration of gellan gum. *Physiologia Plantarum*, 100: 949-957.
- KONG L., VON ADERKAS P. (2007) Genotype effects on ABA consumption and somatic embryo maturation in interior spruce (*Picea glauca* × *engelmanni*). *Journal of Experimental Botany*, 58: 1525-1531.
- LEAL I., MISRA S. (1993). Molecular cloning and characterization of a legumin-like storage protein cDNA of Douglas fir seeds. *Plant Molecular Biology*, 21: 709-715.
- LITVAY J. D., VERMA D. C., JOHNSON M. A. (1985). Influence of a loblolly pine (*Pinus taeda* L.) culture medium and its components on growth and somatic embryogenesis of the wild carrot (*Daucus carota* L.). *Plant Cell Reports*, 4: 325-328.
- LOUGHEED-WANG W. (2005). *Picea abies* somatic embryogenesis and gene expression during early maturation of somatic embryos. Ph.D thesis. University of New Brunswick, Fredericton, New Brunswick, Canada.
- MCCARTY D. R., CARSON C. B., STINARD P. S., ROBERTSON D. S. (1989). Molecular analysis of viviparous-1: an abscisic acid-insensitive mutant of maize. *Plant Cell*, 1: 523-532.
- NAMBARA E., NAITO S., MCCOURT P. (1992). A mutant of *Arabidopsis* which is defective in seed development and storage protein accumulation is a new *abi3* allele. *Plant Journal*, 2: 435-441.
- PALOVAARA J., HAKMAN I. (2008). Conifer WOX-related homeodomain transcription factors, developmental consideration and expression dynamic of WOX2 during *Picea abies* somatic embryogenesis. *Plant Molecular Biology*, 66: 553-549.
- PARCY F., GIRAUDAT J. (1997). Interactions between the *ABII* and the ectopically expressed *ABI3* genes in controlling abscisic acid responses in *Arabidopsis* vegetative tissues. *Plant Journal*, 11: 693-702.
- PARK Y. S. (2002). Implementation of conifer somatic embryogenesis in clonal forestry: technical requirements and deployment considerations. *Annals of Forest Science*, 59: 651-656.
- PARK Y. S., BARRETT J. D., BONGA J. M. (1998). Application of somatic embryogenesis in high-value clonal forestry: deployment, genetic control, and stability of cryopreserved clones. *In Vitro Cellular and Developmental Biology-Plant*, 34: 231-239.
- PARK Y. S., POND S. E., BONGA J. M. (1994). Somatic embryogenesis in white spruce (*Picea glauca*): genetic control in somatic embryo exposed to storage, maturation treatments, germination and cryopreservation. *Theoretical and Applied Genetics*, 89: 742-750.
- PARK Y. S., POND S. E., BONGA J. M. (1993). Initiation of somatic embryogenesis in white spruce (*Picea glauca*): genetic control, culture treatment effects, and implication for tree breeding. *Theoretical Applied Genetics*, 86: 427-436.
- SUNDAS-LARSSON A., SVENSON M., LIAO H., ENGSTROM P. (1998). A homeobox gene with potential developmental control function in the meristem of the conifer *Picea abies*. *Proceedings of the National. Academy of Sciences of USA*, 95: 15118-15122.
- SUTTON B. (2002). Commercial delivery of genetic improvement to conifer plantations using somatic embryogenesis. *Annals of Forest Science*, 59: 657-661.
- TAHIR M., BELMONTE M. F., ELHITIT M., FLOOD H., STASOLLA C. 2008. Identification and characterization of PgHZ1, a novel homeodomain leucine-zipper gene isolated from white spruce (*Picea glauca*) tissue. *Plant Physiology and Biochemistry*, 46: 1031-1039.
- VON ARNOLD S., BOZHOKOV P., CLAPHAM D., DYACHOK J., FILONOVA L., HOGBERG K-A., INGOUFF M., WIWEGER M. (2005). Propagation of Norway spruce via somatic embryogenesis. *Plant Cell, Tissue and Organ Culture*, 81: 323-329.
- VON ARNOLD S., CLAPHAM D. (2008). Spruce Embryogenesis. *In*: Suarez M. F, Bozhkov P. V. (Eds). *Plant Embryogenesis. Methods in Molecular Biology*, 427. Humana Press, Totowa NJ, USA: 31-47.