Department of Soil, Water and Environmental Science
College of Agriculture and Life Sciences

THE UNIVERSITY OF
ARIZONA®
TUCSON ARIZONA

429 Shantz Building, #38
1177 E. Fourth St. POB 210038
Tucson, AZ 85721-0038 USA
(520) 621-1646
FAX: (520) 621-1647
sw@ag.arizona.edu

TO: Julian Leal
FROM: Martha Hawes
ATTN: Final technical report; Grant No. DE-FG02-04ER15551

Analysis of Factors Controlling Cell Cycle that Can Be Synchronized Nondestructively During Root Cap Development

Summary

Publications and presentations during the final funding period, including progress in defining the substrate specificity, the primary goal of the project, are listed below. Both short-term and long-term responses mediated by PsUGT1 have been characterized in transgenic or mutant pea, alfalfa, and Arabidopsis with altered expression of PsUGT1. Additional progress includes evaluation of the relationship between control of the cell cycle by PsUGT1 and other glycosyltransferase and glycosidase enzymes that are co-regulated in the legume root cap during the onset of mitosis and differentiation. Transcriptional profiling and multidimensional protein identification technology ('MudPIT') have been used to establish the broader molecular context for the mechanism by which PsUGT1 controls cell cycle in response to environmental signals. A collaborative study with the Norwegian Forest Research Institute (who provided $10,000.00 in supplies and travel funds for collaborator Dr. Toril Eldhuset to travel to Arizona and Dr. H. H. Woo to travel to Norway) made it possible to establish that the inducible root cap system for studying carbohydrate synthesis and solubilization is expressed in gymnosperm as well as angiosperm species. This discovery provides an important tool to amplify the potential applications of the research in defining conserved cell cycle machinery across a very broad range of plant species and habitats. The final work, published during 2009, revealed an additional surprising parallel with mammalian immune responses: The cells whose production is controlled by PsUGT1 appear to function in a manner which is analogous to that of white blood cells, by trapping and killing in an extracellular manner. This may explain why mutation within the coding region of PsUGT1 and its homolog in humans (UGT1) is lethal to plants and animals. The work has been the subject of invited reviews. A postdoctoral fellow, eight undergraduate students, four M.S. students and three Ph.D. students have been supported.

Publications resulting from DOE support, 2004-2009

Wen F, White GJ, VanEtten HD, Xiong Z, Hawes MC (2009) Extracellular DNA is required for root tip resistance to fungal infection. Plant Physiology 151: 820-829.

Wen F, Celoy R, Price I, Ebolo JJ, Woo HH, Hawes MC (2008) Identification and characterization of a rhizosphere beta-galactosidase from *Pisum sativum* L. Plant and Soil 304: 133-144.

Wen F, Celoy RM, Nguyen T, Zeng W, Keegstra K, Woo HH, Pauly M, Immerzee P, Hawes MC (2008) Altered cell wall structure and function in pea hairy roots expressing *Pisum sativum* xyloglucan fucosyltransferase (Psfut1) antisense mRNA. Plant Cell Reports 27: 1125-1135.

Wen F, Woo HH, Pierson EA, Eldhuset TD Fossdal CG, Nagy NE, Hawes MC (2008) Synchronous elicitation of development in root caps induces transient gene expression changes common to legume and gymnosperm species. Plant Molecular Biology Reporter 27: 58-68.

Woo HH, Jeong BR, Koo KB, Hirsch AM, Hawes MC (2007) Modifying expression of closely related UDP-glycosyltransferases from pea and Arabidopsis results in altered root development and function. Physiologia Plantarum 130: 250-260.

Wen F, Curlango-Rivera G, Hawes MC (2007) Proteins among the polysaccharides: a new perspective on root cap 'slime.' Plant Signaling & Behavior 2: 410-412.

Wen F, VanEtten H, Tsaiprailis G, Hawes MC (2007) Extracellular proteins in *Pisum sativum* L. root tip and border cell exudates. Plant Physiology 143:773-783.

Woo HH, Byeong RJB, Hirsch AM, Hawes MC (2007) Characterization of Arabidopsis AtUGT85A and AtGUS gene families and their expression in rapidly dividing tissues. Genomics 90: 143-153.

Hamamoto L, Hawes MC, Rost TL (2006) The production and release of living root cap border cells is a function of root apical meristem type in dicotyledonous angiosperm plants. Annals of Botany 97: 917-923.

Gunawardena U, Zhao X, Hawes MC (2006) Update on Roots: Contribution to the Rhizosphere. Encyclopedia of Life Sciences 1. http://www.els/net.

Hawes MC, Wen F, Woo HH (2006) Roots and Soil Management: Interactions between roots and the soil. Agronomy monograph #48, Chapter 6, pp 107-119. Co-Editors R.W. Zobel, S.F. Wright, American Society of Agronomy, Madison Wisconsin.

Wen F, Laskowski M, Hawes MC (2006) Cell separation in roots: A common role for pectinmethylesterase? Annual Plant Reviews Series, Blackwell Publishing, Cell Separation in Plants, J. Roberts, ed. (invited review)

Hawes MC, Woo HH, Wen F (2005) Root border cells: A delivery system for chemicals controlling plant health. *Soil Science* (invited review)

Woo HH, Jeong BR, Hawes MC (2005) Flavonoids: From cell cycle regulation to biotechnology. Biotechnology Letters 27: 365-374.

Hawes MC, Celoy RM, Nguyen T, Wen F, Zeng W, Keegstra K, Pauly M, Immerzee P 2005 Altered cell wall structure and function in pea hairy roots expressing *Pisum sativum* xyloglucan fucosyltransferase (*Psfut1*) antisense mRNA. *Asilomar Cell Wall Meeting.*

Wen F, Woo HH, Pierson EA, Hawes MC (2005) Transcriptional profiling of root cap development in *Medicago truncatula*. Proceedings, Model Legume Congress, Asilomar, June 5-9, 2005.

Wen F, Woo HH, Hirsch AM, Hawes MC (2004) Lethality of inducible, meristem-localized ectopic β-glucuronidase expression in plants. Plant Mol. Biol. Reporter 22: 7-14.

Zhu Y, Wen F, Zhao X, Hawes MC (2004) Isolation of the promoter of a root cap expressed pectinmethylesterase gene from Pisum sativum L. (rcpme1) and its use in the study of gene activity. Plant Soil 265: 47-59.

Woo HH, Hirsch AM, Hawes MC (2004) Altered susceptibility to infection by bacteria and fungi in alfalfa roots with altered cell cycle. Plant Cell Reports 22: 967-973.

Celoy RM, Gardais S, Wen F, Hawes MC (2004) Altered structure, composition, and biological activity of root exudates in transgenic roots with altered root cap gene expression. *American Phytopathological Society, Proceedings.*

Woo HH, Jeong BR, Hirsch AM, Hawes MC (2004) Invited talk. Proceedings, Biotechnology of Natural and Agricultural Products, Korea.

(Other invited talks, 2004-2009: University of Minnesota, University of Nebraska, Colorado State University, University of Missouri, The Norwegian Forest Research Institute, Ås, Norway, Noble Foundation)

Publications resulting from DOE support, 2004-current

1. Wen F, Woo HH, Hirsch AM, Hawes MC 2004 Lethality of inducible, meristem-localized ectopic β-glucuronidase expression in plants. Plant Mol. Biol. Reporter 22: 7-14.
2. Woo HH, Hirsch AM, Hawes MC 2004 Altered susceptibility to infection by bacteria and fungi in alfalfa roots with altered cell cycle. Plant Cell Reports 22: 967-973.
3. Woo HH, Jeong BR, Hawes MC 2005 Flavonoids: From cell cycle regulation to biotechnology. Biotechnology Letters 27: 365-374.
4. Hawes MC, Celoy RM, Nguyen T, Wen F, Zeng W, Keegstra K, Pauly M, Immerzee P 2006 Altered cell wall structure and function in pea hairy roots expressing *Pisum sativum* xyloglucan fucosyltransferase (*Psfut1*) antisense mRNA (in revision, Plant Cell)
5. Woo HH, Jeong BR, Hirsch AM, Hawes MC 2006 Characterization of families of Arabidopsis genes for glucuronide metabolism-regulated auxin distribution (in revision, Plant Physiology).
6. Wen F, Woo HH, Pierson EA, CG Fossdal, T Eldhuset, Hawes MC 2006 A molecular switch controlling synchronized root cap development in legumes is conserved in gymnosperms (manuscript in preparation)
7. Celoy R, Price I, Wen F, Hawes, MC 2006 Identification and characterization of a galactosidase secreted from the root tip: role in root development (manuscript in preparation)
8. Wen F, Van Etten H, Tsaiprailis G, Hawes MC 2006 Identification of extracellular proteins released during root cap development (manuscript in review)
9. Hawes MC, Woo HH, Wen F 2005 Root border cells: A delivery system for chemicals controlling plant health. *Soil Science* (in press)(invited review)
10. Hamamoto L, Hawes MC, Rost TL 2006 The production and release of living root cap border cells is a function of root apical meristem type in dicotyledonous angiosperm plants. Annals of Botany (invited review) (in press)
11. Wen F, Laskowski M, Hawes MC 2006 Cell separation in roots: A common role for pectinmethylesterase? Annual Plant Reviews Series, Blackwell Publishing, Cell Separation in Plants, J. Roberts, ed. (invited review) (in press)
12. Celoy RM, Gardais S, Wen F, Hawes MC 2004 Altered structure, composition, and biological activity of root exudates in transgenic roots with altered root cap gene expression. *American Phytopathological Society, Proceedings.*
13. Hawes MC, Celoy RM, Nguyen T, Wen F, Zeng W, Keegstra K, Pauly M, Immerzee P 2005 Altered cell wall structure and function in pea hairy roots expressing *Pisum sativum* xyloglucan fucosyltransferase (*Psfut1*) antisense mRNA. *Asilomar Cell Wall Meeting.*
14. Wen F, Woo HH, Pierson EA, Hawes, MC 2005 Transcriptional profiling of root cap development in *Medicago truncatula*. Proceedings, Model Legume Congress, Asilomar, June 5-9, 2005.
15. Woo HH, Jeong BR, Hirsch AM, Hawes MC 2004 Invited talk. Proceedings, Biotechnology of Natural and Agricultural Products, Korea.
16. (Other invited talks, 2004-2006: University of Minnesota, University of Nebraska , Colorado State University, University of Missouri, The Norwegian Forest Research Institute, Ås, Norway)