

FY 97 Task Book Report

1. Title

NASA Specialized Center of Research and Training in Gravitational Biology.
"Calcium, Signaling and Gravity: An Integrated Molecular, Cellular and
Physiological Approach to Plant Gravitational Biology".

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5. Task Info

94-OLMSA-04

Ground

199-93-17-14

NAGW-4984

None

Plant Biology

6. Funding

1/96 - 12/00

\$999,634

Pre-college - 40

Undergraduate - 15

Graduate - 10

Post Docs - 4

7. NA

8. Abstract - See attached Original Abstract

9. Progress

The NSCORT is a consortium of institutions including North Carolina State University (College of Agriculture and Life Sciences and School of Forestry), Wake Forest University, Baruch College (City University of New York), NASA's Kennedy Space Center and Dynamac Corporation (which runs the Life Science Support contract at KSC). Faculty, staff and/or students from all of the institutions participate in various aspects of the program. It consists of three major components: **Education, Outreach and Research**. Considerable progress has been made in all three areas.

Education: Offered the graduate-level course "Gravitational and Space Biology" to 15 graduate and advanced undergraduate students (Fall 1996). This course originated from the NC State University campus and was available on a real-time basis at 5 other campus locations throughout the state via the NC Regional Electronics Network microwave system. A new undergraduate level course "Space Biology" was initiated and taught to 16 students (Fall 1997) at the NC State University campus. A portion of this course was taught remotely from the Kennedy Space Center using real time audio and video link-ups. Experts in space biology (including an Astronaut/Physician Dr. Chuck Brady) were brought in to expose students to current activities and opportunities in the field.

Outreach: A summer workshop for high school teachers entitled "Plants and Gravity" was offered. Ten teachers from five states spent time at the NC State University campus interacting with project leaders and research associates in the program. Some of the teachers have utilized the experience to develop new curricula at their schools. Additionally, a two day workshop was sponsored and held at the NC State University campus to train teachers for the educational opportunities associated with the Collaborative Ukrainian Experiment. As a group, the NSCORT participated in two separate science and technology symposia that offered middle school students, particularly girls, an opportunity to conduct hands-on experiments in a wide range of scientific areas. The NSCORT offered activities and tours at the North Carolina Science Olympiad and the National Science Olympiad. NSCORT scientists presented demonstrations and activities during science fairs at two local elementary schools and hosted a workshop on plant gravitational and space biology for middle and high school students attending the Imagination Station Summer Science Camp.

Research: In order to take an integrated approach to studying graviperception and response, six postdoctoral fellows were hired. These individuals possess skills in molecular biology, electrophysiology, biochemistry and cell biology. Four graduate students are currently in the program and one or two more will be recruited. The physical set-up of the laboratories is complete, including the renovation of the electrophysiology laboratory and the acquisition of a Leica DMRXA confocal microscope with a rotatable stage. This piece of equipment

will allow us to examine the real time *in-vivo* response of graviresponding plant tissue.

Focus has been placed on the maize pulvinus and the pine seedling compression wood systems as models to dissect biochemical and morphological response to gravity. Initial characterization is complete and detailed studies are underway. To understand the molecular genetic component of the gravity response in plants, we have chosen three proteins (calreticulin, calmodulin and phosphatidylinositol kinase) to clone. These clones will then be used to transform *Arabidopsis* plants for studies on the influence of altered calcium homeostasis in the gravity response.

10. Earth Benefits

This research will determine the mechanisms by which plants perceive and respond to several environmental stimuli, especially gravity. It will provide a fundamental understanding of basic plant processes, especially at the cellular, molecular and developmental levels. A deeper understanding of how plants respond to gravity and other environmental conditions, will improve our understanding of how they grow in various space conditions (Earth orbit, Mars) and how their growth can be modified to maximize yields on Earth. More applied work on specific plants should yield valuable by-products of enhanced paper quality (pine seedling system and its formation of compression wood) and yield of seed grains (reorientation of corn plants blown over in strong winds).

11. Bibliography

Published Papers

Allen, N.S., and Bennett, M.N. Electro-optical imaging of F-actin and endoplasmic reticulum in living and fixed plant cells. Invited Chapter. In "Science of specimen preparation for microscopy and microanalysis." M. Malecki, G. Roomans (eds.) SMI Press, AMF O'Hare, Chicago, IL. USA. 10 p. (in press)

Butler, J.A., Hu, S., Brady, S., Dixon, M.W., and Muday, G.K.. In vitro and in vivo evidence for actin association of the NPA binding protein. *Plant Journal* (in press).

Croxdale, J.G., Cook, M., Tibbitts, T.W., Brown, C.S., and Wheeler, R.M. Structure of potato tubers formed in microgravity. *J. Exp. Bot.* (in press).

Holzwarth, G., Webb, S.J., Kubinski, D.J., and Allen, N.S. 1997. Improving DIC Microscopy with Polarization Modulation. *Journal of Microscopy* (in press).

MacKay, J. O'Malley, D.M., Presnell, T., Booker, F.L., Campbell, M.M. Whetten, R.W., and Sederoff, R.R. 1997. Inheritance, gene expression, and lignin characterization in a mutant pine deficient in cinnamyl alcohol dehydrogenase. PNAS 94:8255-8260.

O'Malley, D.M., MacKay, J.J., Whetten, R., Campbell, M., Liu, B-H., and Sederoff, R.R. 1996. Genomic approaches to manipulating lignin composition and amount in wood. TAPPI Proceedings pp.105-109.

Ralph, J. MacKay, J. Hatfield, R., Whetten, R.W., O'Malley, D.M., and Sederoff, R.R. 1997. Abnormal lignin in a loblolly pine mutant. Science 277:235-239.

Ruegger, M., Dewey, E., Hobbie, L., Brown, D., Bernasconi, P., Turner, J., Muday, G., and Estelle, M. 1997. Reduced NPA-binding in the tir3 mutant of Arabidopsis is associated with a reduction in polar auxin transport and diverse morphological defects. Plant Cell 9:745-757.

Published Abstracts

Allona, I., Quinn, M., Sun, Y-H., Shoop, E., Swope, K., St. Syr, S., Retzel, E., and Whetter, R. 1997. Analysis of gene expression during xylem differentiation in loblolly pine. Plant Physiol. 114(3):11.

Boss, W.F., Perera, I.Y., Ransom, W.D., Stevenson, J.M., Brglez, I., Heilmann, I.H., and Gross, W. 1997. Wrapping about the cytoskeleton. Plant Physiol. 114(3):15.

Brady, S.R., Dixon, M.W., Cyr, R.J., Fisher, D.D., and Muday, G.K. 1996. BY2 protoplasts as a model for NPA sensitive auxin transport and gravitropism. Grav. and Space Biol. Bull. 10(1):78.

Brown, C.S., Sanwo, M.M., Hilaire, E., Guikema, J.A., Stryjewski, E.C., and Piastuch, W.C. 1996. Starch metabolism and ethylene production in space-grown soybean seedlings. Grav. Space Biol. Bull. 10:34.

Brown, C.S., Sanwo, M.M., Stryjewski, E.C., Peterson, B.V., Johnson, C.F., Piastuch, W.C., Hilaire, E., and Guikema, J.A. 1997. Carbohydrate metabolism and growth in space-grown soybean. Plant Physiol. 114(3):91.

Brown, D., and Muday, G. 1997. Testing the hypothesis that flavonoids regulate auxin transport in vivo. 8th International Conference on Arabidopsis Research. 4-8.

Brown, D.E., Reed, R.C., and Muday, G.K. 1996. Polar auxin transport and gravitropism in Arabidopsis thaliana. Grav. and Space Biol. Bull. 10(1):38.

Carter, C.N. and Allen, N.S. 1997. Localization of putative L-type calcium channels in living higher plant cells using the fluorescent dye DM-BODIPY DHP. *Plant Physiol.* 114(3):275.

Collings, D., Winter, H., Huber, J.L., and Allen, N.S. 1997. Structural analysis of gravistimulated maize stems. *Plant Physiol.* 114(3):86.

Croxdale, J.G., Cook, M.E., Tibbitts, T.W., Brown, C.S., and Wheeler, R.M. 1996. Structural Aspects of potato tubers formed in space. *Grav. and Space Biol. Bull.* 10(1):13.

Heilmann, I., Gross, W., and Boss, W.F. 1997. Polyphosphoinositide metabolism in *Galdieria sulphuraria*. *Plant Physiol.* 114(3):268.

Holzwarth, G. Webb, S.J., Kubinski, D.J., Allen, N.S. 1996. Improving DIC Microscopy with Polarization Modulation. *Molecular Biology of the Cell* 7:158A.

Hu, S., Dixon, M.L., and Muday, G.K. 1996. Development of a procedure to depolymerize the actin cytoskeleton for purification of associated proteins. *Grav. and Space Biol. Bull.* 10(1):27.

Huber, J.L., Winter, H. and Huber, S.C. 1997. Do Ca⁺⁺ and protein phosphorylation play a role in the gravitropic response? *Plant Physiol.* 114(3):272.

Johnson, K.M., Brown, C.S., and Piastuch, W.C. 1997. Examination of the expression patterns of genes involved in carbon metabolism in soybean seedlings grown in space. *Plant Physiol.* 114(3):253.

Luciano, R.L., and Muday, G.K. 1996. Characterization of gravity dependent growth in *Fucus* zygotes. *Grav. and Space Biol. Bull.* 10(1):26.

Muday, G.K., Butler, J.H., Hu, S., Brady, S., and Dixon, M.W. 1996. Actin association of the naphthylphthalamic acid binding protein from zucchini hypocotyls. *Grav. and Space Biol. Bull.* 10(1):55.

Muday, G.K., and Reed, R.C. 1997. Inhibition of auxin movement from the shoot into the root inhibits lateral root development in wild-type *Arabidopsis thaliana* and *alf1-1*. 8th Intl. Conf. on *Arabidopsis Res.* 4:41

Perera, I.Y., Stevenson, J.M., and Boss, W.F., 1997 Investigation of phosphoinositide metabolism in gravistimulated maize pulvini. *Plant Physiol.* 114(3):284.

Scott, A.C., and Allen, N.S. 1997. The effect of carbonylcyanide m-chlorophenylhydrazone (CCCP) application on the gravitropic response in roots and stamen hairs. *Grav. and Space Biol. Bull.* 10(1):17.

Tibbitts, T.W., Croxdale, J.G., Brown, C.S., and Wheeler, R.M. 1996. Potato tuber growth and starch accumulation in space. *Grav. and Space Biol. Bull.* 10(1):28.

Vian, A., Henry-Vian, C., and Davies, E. 1997. Molecular analysis in tomato of stree related genes in relation to electrical signal. *Plant Physiol.* 114(3):278.

Winter, H., Huber, J.L., Collings, D., Allen, N.S. and Huber, S.C. 1996. Carbohydrate metabolism in graviresponding maize pulvini. *Grav. and Space Biol. Bull.* 10(1):extra.

Winter, H., Huber, J.L., and Huber, S.C. 1997. Sucrose metabolism during gravity induced cell elongation. *Plant Physiol.* 114(3):143.

Wyatt, S.E., Brown, D., Robertson, D., and Muday, G. 1997. The gravitropic response of the inflorescence stems of *Arabidopsis*. *Plant Physiol.* 114(3):133.

Wyatt, S.E., Tsou, P-L., Robertson, D. 1997. Manipulation of calcium homeostasis with calreticulin. *Plant Physiol.* 114(3):274.

Presentations:

Allen, N.S., 1997

Aug. 25-Sept. 4. Dept. of Medical Microbiology, Linkoping University, Linkoping, Sweden. Video Microscopy Short Course.

From Leeuwenhoek to electronic light microscopy (keynote address).

Resolution. Abbe's diffraction experiments (lecture)..

Darkfield and Phase Microscopy, the basics (lecture).

Polarization and DIC Microscopy, theory and practice (lecture).

Confocal Microscopy and GFP imaging (lecture).

Deconvolution, what is it and where should you use it (lecture).

Tip Growth, An Overview. Cytonet Conference, Breckenridge, Colorado.

Brown, C.S., 1997

Plant growth and physiology in space. Baruch College, Manhattan, NY, 4 March.

Plant metabolism in space. University of North Carolina-Pembroke, Pembroke, NC 13 March.

The Collaborative Ukrainian Experiment: Scientific Overview. Presented to the 12th Man In Space Symposium, Washington DC, 13 June.

The interaction of microgravity and ethylene on soybean growth and metabolism. Co-authors - Sanwo, M.M., Stryjewski, E.C., Peterson, B.V., Johnson, C.F., Piastuch, W.C., Hilaire, E., and Guikema, J.A.. Presented to the 12th Man In Space Symposium, Washington DC, 11 June.

Collings, D., 1997

Cytoskeletal organization in gravistimulated maize stems. Co-authors - Winter, H. and Allen, N.S. New England Society for Microscopy. Woods Hole, MA. May.

Muday, G.K., 1997

The role of Auxin transport and the actin cytoskeleton in plant gravity response. Joint NSF/NASA NSCORT Meeting, Kennedy Space Center, Florida, 17 February.

Sederoff, R.R. 1996

Horticultural Research, Auckland, New Zealand, invited seminar.
Forestry Research Institute, Rotorua, New Zealand, invited seminar.

Sederoff, R.R. 1997

Forest Tree Workshop, Plant & Animal Genome 5, Invited speaker.
Department of Chemistry, University of Ohio, Invited Seminar.
ForBio Research Ltd. Brisbane, Invited seminar.
University of Chicago, Genetics Minisymposium invited speaker.
University of Arizona, Tucson, invited seminar
Sigma Xi invited lecture, BASF, Research Triangle Park, NC.
Institute of Paper Science and Technology, Atlanta, GA, invited speaker
Chinese Academy of Forestry, Beijing, China, Invited speaker.
Nanjing Forestry University, Nanjing, China, Invited speaker.
Swedish Plant Physiology Society, Uppsala, Symposium speaker
Workshop presentation, Agricultural Biotechnology, Uppsala, Sweden
Presidents Circle, National Academy, Woods Hole Mass, Invited speaker.
Amer. Assoc. Plant Physiology, Vancouver, symposium speaker
Molecular Genetics of Forest Trees, IUFRO, Quebec, invited speaker
Eucalypt: IUFRO meeting, Salvador, Brazil, symposium speaker.
Forest Biotechnology Conf.: Blomfontein, South Africa, symposium speaker
University of Stellenbosch, South Africa, invited seminar
Internat. Soc. Plant Molecular Biology, Congress in Singapore, invited speaker

Wyatt, S.E., 1997

Gravity, Calcium, Signalling & Arabidopsis. Plant Physiology Seminar, Dept. of Botany, Duke University, Durham, NC. March.

Patents:

1997 U.S. Patent awarded. Method of altering lignin in trees. MacKay, O'Malley, Whetten and Sederoff.

1997 U.S. Patent CIP filed for Method of altering lignin in trees. MacKay, O'Malley, Whetten and Sederoff.