ANDREA J. CARDINAL

1. Education background:

Ph.D., Plant Breeding, 1999, Iowa State University, IA

M.S., Crop Science, 1996, NC State University, NC

B.S., Agronomy, 1993, University of Buenos Aires, Argentina

2. Professional experience:

Associate Professor, 2008-present, NC State University, Department of Crop Science, NC.

Assistant Professor, 2001-2008, NC State University, Department of Crop Science, NC.

Post-Doctoral Research Associate, 2000-2001, NC State University, Department of Crop Science, NC.

Graduate Research Assistant, 1996-99, Iowa State University, Department of Agronomy, IA.

Graduate Research Assistant, 1993-95, NC State University, Department of Crop Science, NC.

3. TEACHING AND MENTORING OF UNDERGRADUATE AND GRADUATE STUDENTS

Mentoring Activities

- Graduate College Representative, Ph.D., (Schaff), 2003-2006 and (Murugananam), 2006-2007.
- Advised one Postdoctoral Research Associate (Dr. Jérôme Auclair), 2004-2007.
- Research mentor BCH 429 Internal Learning experience (Meredith Vaccaro), 2003.
- Trained 5 undergraduate students in molecular biology techniques and field activities, 2002-2003.
- Consulted about thesis research projects with 1 M.S. student (Walter Thomas) and 1 Ph.D. student (Keith Robinson), 2001-2003.
- Mentored M.S. student (Jihyung Yang) 4 hours each week about material and homeworks covered in CS 741, 2001.

Graduate Student Professional Accomplishments

- Ph. D. Student Eleni Bachlava was awarded the AOCS Biotechnology Student Excellence Award (2^{nd}) for the presentation: E. Bachlava, R.E. Dewey, J.W. Burton and A.J. Cardinal. Mapping the microsomal omega-6 fatty acid desaturase genes controlling oleic acid seed content in soybean. 98th AOCS annual meeting & Expo. Québec City, QC, Canada (May 13-16th, 2007).

Master's and doctoral theses directed

- Chair Ph.D. Thesis research project (Carrin Carlson), 2008-present.
- Member M.S. thesis research project (Jill Recker), 2008-present.
- Co-Chair Ph.D. thesis research project (Eleni Bachlava), 2004-2008.
- Member Ph.D. thesis research project (Jesús Garcia Zavala), 2006-2008.
- Chair M.S. thesis research project (Ana María Camacho-Roger), 2004-2006.
- Chair M.S. thesis research project (Jihyung Yang), 2001-02. She did not complete her M.S. degree due to poor coursework performance and the withdrawal of her Departmental assistantship.

4. SCHOLARSHIP IN THE REALMS OF FACULTY RESPONSABILITY

Scholarly Accomplishments

Research Articles Accepted or In Press in peer reviewed journals

- Bachlava, E. and A. J. Cardinal. 2009. Correlation between Temperature and Oleic Acid Seed Content in Three Segregating Soybean Populations. Crop Sci. 49: In Press.
- Bachlava, E., R. E. Dewey, J. W. Burton, and A. J. Cardinal. 2009. Mapping and Comparison of Quantitative Trait Loci for Oleic Acid Seed Content in Two Segregating Soybean Populations. Crop Sci. 49: 1-10.
- Bachlava, E., R. E. Dewey, J. W. Burton, A. J. Cardinal. 2009. Mapping candidate genes for oleate biosynthesis and their association with unsaturated fatty acid seed content in soybean. Mol. Breeding 23:337-347.
- Bachlava E., J. W. Burton, C. Brownie, S. Wang, J. Auclair, and A. J. Cardinal. 2008 Heritability of Oleic Acid Content in Soybean Seed Oil and Its Genetic Correlation with Fatty Acid and Agronomic Traits. Crop Sci. 48:1764-1772.
- Cardinal, A.J. 2008. Molecular genetics and breeding for fatty acid manipulation in soybean. Plant Breed. Rev. 30:259-294.
- Barrière, Y., C. Riboulet, V. Méchin, S. Maltese, M. Pichon, A. Cardinal, J.P. Martinant, T. Lübberstedt, C. Lapierre. 2007. Genetics and genomics of lignification in grass cell walls based on maize as a model system. Genes, Genomes and Genomics 1(2):133-156.
- Bachlava, R. E. Dewey, J. Auclair, S. Wang, J. W. Burton, and A. J. Cardinal. 2008. Mapping Genes Encoding Microsomal ω-6 Desaturase Enzymes and Their Cosegregation with QTL Affecting Oleate Content in Soybean. Crop Sci. 48:640-650.
- Balint-Kurti, P. J., J.C. Zwonitzer, R. J. Wisser, M. E. Pè, G. Pea, M. Lee and A. J. Cardinal. 2008. Identification of quantitative trait loci for resistance to Southern leaf blight and days to anthesis in two maize recombinant inbred line populations. *Accepted.* Phytopathology 98:315-320.
- Cardinal, A.J., R.E. Dewey, and J.W. Burton. 2008. Estimating the individual effects of the reduced palmitic acid alleles *fap$_{nc}$* and *fap1* alleles on agronomic traits in two soybean populations. Crop Sci. 48:633-639.
- Cardinal, A.J. and J.W. Burton. 2007. Correlations between palmitate content and agronomic traits in soybean populations segregating for the *fap1, fap$_{nc}$,* and *fan* alleles. Crop Sci. 47:1804-1812.
- Cardinal, A.J., J.W. Burton, A.M. Camacho-Roger, J.H. Yang, R.F. Wilson, and R.E. Dewey. 2007. Molecular analysis of soybean lines with low palmitic acid content in the seed oil. Crop Sci. 47:304-310.

- Oliva, M.L., J.G. Shannon, D.A. Sleper, M.R. Ellersieck, A.J. Cardinal, R.L. Paris, and J.D. Lee. 2006. Stability of fatty acid profile in soybean genotypes with modified seed oil composition. Crop Sci. 46:2069-2075.
- Cardinal A.J., M. Lee., W.D. Guthrie, J. Bing, D.F. Austin, L.R. Veldboom, and M.L. Senior. 2006. Mapping of factors for resistance to leaf-blade feeding by European corn borer (*Ostrinia nubilalis*) in maize. Maydica 51:93-102.
- Holland J.B., P.K. Bretting, D.M. Bubeck, A.J. Cardinal, R.N. Holley, and D.V. Uhr. 2006. Major M. Goodman: A laudation. Maydica 51:3-13.
- Cardinal A.J. and Michael Lee. 2005. Genetic relationships between resistance to stalk-tunneling by the European corn borer and cell wall components in maize population B73 x B52. Theor. Appl. Genet. 111:1-7.
- Cardinal A.J., M. Lee, and K. J. Moore. 2003. Genetic mapping and analysis of quantitative trait loci affecting fiber and lignin content in maize. Theor. Appl. Genet. 106:866-874.
- Cardinal A. J., M. Lee, N. Sharopova, W. L. Woodman, and M. J. Long. 2001. Genetic mapping and analysis of quantitative trait loci for resistance to stalk tunneling by the European corn borer in maize. *Crop Science* 41:835-845.

Book Chapter

- Holland, J.B. and A.J. Cardinal. 2008. Harnessing quantitative genetics and genomics for understanding and improving quantitative traits in crops. *In Drought-Resistant Rice for Increased Production in Rainfed Systems.* R. Serraj, J. Bennett & B Hardy (Eds). World Scientific Publishing, Singapore.

Cultivars Releases

- Cardinal, A.J., S. Wang, and V.T. Pantalone. 2007. Release of NCC02-307 soybean. Approved by the NCSU Release board.
- Cardinal, A.J., S. Wang, and V.T. Pantalone. 2007. Release of NCC01-69 soybean. Approved by the NCSU Release board.

Abstracts

- Bachlava E., R.E. Dewey, J.W. Burton and A.J. Cardinal. Cosegregation of candidate genes for oleate biosynthesis with quantitative trait loci for oleic acid seed content in soybean. ASA-CSSA-SSSA annual meeting, October 5-9th, 2008, Houston, TX.
- Bachlava E. and A.J. Cardinal. Temperature and oleic acid seed content: Correlation in soybean populations with different maturity profiles. ASA-CSSA-SSSA annual meeting, October 5-9th, 2008, Houston, TX.
- Bachlava E., J. Auclair, J. Burton, R. E. Dewey, A. J. Cardinal. Genetic Control of High Oleic acid content in Soybean. Plant and Animal Genome XVI. The international Conference of the Status of Plant & Animal Genome Research. January 12-16, 2008, San Diego, CA. Abstracts Guide p. 217.

- Bachlava E., R.E. Dewey, J.W. Burton, A.J. Cardinal. Mapping the microsomal omega-6 fatty acid desaturase genes controlling oleic acid seed content in soybean. The 98th America Oil Chemists' Society annual meeting & expo, May 13-16, 2007, Quebec City, Canada.
- Bachlava E., J. Auclair, J. Burton, R. E. Dewey, A. J. Cardinal. Genetic Control of High Oleic acid content in Soybean. Plant and Animal Genome XVI. The international Conference of the Status of Plant & Animal Genome Research. January 12-16, 2008, San Diego, CA. Abstracts Guide p. 217.
- Bachlava E., J. Auclair, J. Burton, A. J. Cardinal. Heritability of Oleic and Linolenic Acid Seed Content and Their Genetic Correlations with Quality and Agronomic Traits in Soybean. American Society of Agronomy International Annual Meeting, November 4-8, 2007, New Orleans, LA. (Verified 1/1/2008, http://a-c-s.confex.com/a-c-s/2007am/techprogram/P32906.HTM).
- Bachlava E., J. Burton, R. E. Dewey, and A. J. Cardinal. Quantitative Trait Loci Mapping for Oleic Acid Seed Content in Soybean. American Society of Agronomy International Annual Meeting, November 4-8, 2007, New Orleans, LA. (Verified 1/1/2008, http://a-c-s.confex.com/a-c-s/2007am/techprogram/P32907.HTM)
- Villagarcia M.R., A. J. Cardinal, T.E. Carter Jr., J. G. Shannon, and H. R. Boerma. Salt tolerance in the genetic base of U.S. and Canadian soybean. Crop Science Society of America-American Society of Agronomy Annual Meeting, November 12-16, 2006, Indianapolis, IN.
- Bachlava E., R.E. Dewey, J.W. Burton, A.J. Cardinal. Single Nucleotide Polymorphisms for the Microsomal Omega-6 Desaturases in Soybean. American Society of Agronomy Annual Meeting, November 12-16, 2006, Indianapolis, IN.
- Camacho-Roger, A.M., A.J. Cardinal, J.W. Burton, R.F Wilson, and R.E. Dewey. Molecular markers and genes associated with low palmitic and low linolenic acid content in N97-3681-11 and N97-3708-13 soybean lines. Arthur M. Sackler Colloquia of the National Academy of Sciences: "From Functional Genomics of Model Organisms to Crop Plants for Global Health", April 3-5, 2006. National Academy of Sciences Building, 2100 C Street NW, Washington, DC. Program/Abstracts p. 11.
- Carter, Jr., T.E., H.R. Boerma, G.J. Lee, X. Zhou, M.R. Villagarcia, A.J. Cardinal, and J.G. Shannon. 'On Farm' QTL mapping of salt tolerance in the genetic base of North American soybean. The 11th Biennial Conference on the Cellular & Molecular Biology of the Soybean (Soy2006), August 5-8, 2006, Lincoln, Nebraska.
- Cardinal A.J, R. E. Dewey, J. Burton. Molecular analysis of soybean lines with favorable oil traits. 10th Biennial Conference of the Cellular and Molecular Biology of the Soybean, August 8-11, 2004, Columbia, MO. Program/Abstracts p.55.
- Dewey R.E., A.J. Cardinal, J. Burton. Molecular analysis of soybean lines with favorable oil traits. VII World Soybean Research Conference, February 29-March 5, 2004, Foz do Iguassu, Brazil. EMBRAPA Documentos 228: Abstracts of contributed papers and posters p. 200.

- Cardinal A.J. and M. Lee. Genetic analysis of resistance to the European corn borer and cell wall components in maize. 8th Interregional Corn Conference, February 22, 2000, Baltimore, MA.
- Cardinal A.J., W.D. Guthrie, J. Bing, D.F. Austin, L.R. Veldboom, M.L. Senior, and M. Lee. QTL and candidates genes for resistance to first generation European corn borer in maize. Plant and Animal Genome Meeting VI, January 18-22, 1998, San Diego, CA. p. 175.
- Cardinal A.J, W.D. Guthrie, J. Bing, D.F. Austin, L.R. Veldboom, M.L. Senior, and M. Lee. QTL and candidates genes for resistance to first generation European corn borer in maize. Crop Science Society of America-American Society of Agronomy Annual Meetings, November 1997, Anaheim, CA. Agronomy Abstracts p. 148.
- Cardinal, A.J. and R. E. Dewey. Molecular analysis of anther-derived plants of *Nicotiana tabacum*. 8th Annual Retreat of the North Carolina Plant Molecular Biology Consortium, 1994, Morehead City, NC.

Other publications (Non-peer reviewed)

- Ad-hoc volunteer writer of report from the section on "Excellence in science and technology" of the Plant Breeding Coordinating Committee Workshop, February 2007, Raleigh, NC.
- National strategic plan for the coordination and integration of soybean rust research. Version 1.3. April 2005. USDA-ARS (ftp://ftp.nps.ars.usda.gov/rwilson-2/ verified 01/06/2006). Member of the ad hoc working group and strategic plan writing team.

Invited Oral presentations

- Cardinal A.J. High Protein Report. Soybean Breeders' Workshop, February 17-20, 2008, St Louis, MO.
- Cardinal A.J., J. Auclair, A. M. Camacho, R.E. Dewey, J.W. Burton, B. Novitzky, and R. Wilson. Altering the fatty acid composition of soybean seed oil through genetics and breeding. Robert E. Allan Plant Breeding Symposium, April 2006, Pullman, WA.
- Cardinal A.J. Breeding for resistance to soybean rust. North Carolina Crop Improvement Association and Foundation Seed Meeting, January 28, 2005, Raleigh, NC.
- Cardinal A.J. Marker assisted selection in soybean. Soybean Breeders' Workshop, February 17-20, 2003, St Louis, MO.

Oral presentations

- A.J. Cardinal, Dewey R.E., J. Burton. Molecular analysis of soybean lines with favorable oil traits. VII World Soybean Research Conference, February 29-March 5, 2004 Foz do Iguassu, Brazil.

Oral Presentations by Graduate students

- Bachlava E., J. Burton, R. E. Dewey, and A. J. Cardinal. Quantitative Trait Loci Mapping for Oleic Acid Seed Content in Soybean. American Society of Agronomy International Annual Meeting, November 4-8, 2007, New Orleans, LA. (Verified 1/1/2008, http://a-c-s.confex.com/a-c-s/2007am/techprogram/S4004.HTM

Report presentations

- Cardinal A.J. Soybean Cultivars and Germplasm Adapted to North Carolina Growing Conditions NC Soybean Producers' Association Board of Directors Meeting, November 20, 2008, Raleigh, NC.
- Cardinal A.J. Soybean Cultivars Resistant to Soybean Cyst Nematodes Races 2 and 4 NC Soybean Producers' Association Board of Directors Meeting, November 20, 2008, Raleigh, NC.
- Cardinal A.J. Validation and MAS for QTLs conditioning high protein content in soybean seeds. United Soybean Board-Better Bean Initiative Workshop, February 17-18, 2008, St. Louis, MO.
- E. Bachlava, J. W. Burton, R. E. Dewey and A. J. Cardinal*. Genetic Control Of High Oleic Acid Seed Content. United Soybean Board-Better Bean Initiative Workshop, February 17-18, 2008, St. Louis, MO.
- Cardinal A.J. Validation and MAS for QTLs conditioning high protein content in soybean seeds. United Soybean Board-Better Bean Initiative Workshop, February 12-13, 2006, St. Louis, MO.
- Cardinal, A.J. Validation and mapping of QTLs conditioning high protein content in soybean seeds. United Soybean Board-Better Bean Initiative Workshop, February 20, 2005, St. Louis, MO.
- Cardinal, A.J. Development of conventional and herbicide tolerant soybean varieties adapted to North Carolina growing conditions. NC Soybean Producers' Association Board of Directors Meeting, December 1, 2005, Raleigh, NC.
- Cardinal, A.J. Development of conventional and RR soybean varieties resistant to SCN races 2 and 4. NC Soybean Producers' Association Board of Directors Meeting, December 1, 2005, Raleigh, NC.

Poster presentations

- Bachlava E., R.E. Dewey, J.W. Burton and A.J. Cardinal. Cosegregation of candidate genes for oleate biosynthesis with quantitative trait loci for oleic acid seed content in soybean. ASA-CSSA-SSSA annual meeting, October 5-9th, 2008, Houston, TX.
- Bachlava E. and A.J. Cardinal. Temperature and oleic acid seed content: Correlation in soybean populations with different maturity profiles. ASA-CSSA-SSSA annual meeting, October 5-9th, 2008, Houston, TX.
- Bachlava E., J. Auclair, J. Burton, R. E. Dewey, A. J. Cardinal. Genetic Control of High Oleic acid content in Soybean. Plant and Animal Genome XVI. The international Conference of the Status of Plant & Animal Genome Research. January 12-16, 2008, San Diego, CA. Abstracts Guide p. 217.
- Bachlava E., J. Auclair, J. Burton, A. J. Cardinal. Heritability of Oleic and Linolenic Acid Seed Content and Their Genetic Correlations with Quality and Agronomic Traits in Soybean. American Society of Agronomy International Annual Meeting, November 4-8, 2007, New Orleans, LA. http://a-c-s.confex.com/a-c-s/2007am/techprogram/S4012.HTM.

- Bachlava E., R.E. Dewey, J.W. Burton, A.J. Cardinal. Single Nucleotide Polymorphisms for the microsomal omega-6 desaturases in soybean. American Society of Agronomy Annual Meeting, November 12-16, 2006, Indianapolis, IN.
- Camacho-Roger, A.M., A.J. Cardinal, J.W. Burton, R.F Wilson, and R.E. Dewey. Molecular markers and genes associated with low palmitic and low linolenic acid content in N97-3681-11 and N97-3708-13 soybean lines. Arthur M. Sackler Colloquia of the National Academy of Sciences: "From Functional Genomics of Model Organisms to Crop Plants for Global Health"**.** Organized by Diter von Wettstein, Roger Beachy and Robert Goldberg. National Academy of Sciences Building, 2100 C Street NW, Washington, DC. April 3-5, 2006.
- Cardinal A.J., R. E. Dewey, J. Burton. Molecular analysis of soybean lines with favorable oil traits. 10th Biennial Conference of the Cellular and Molecular Biology of the Soybean, August 8-11, 2004, Columbia, MO.

Seminars

- Cardinal A.J. Altering the Fatty Acid Composition of Soybean Seed Oil through Genetics and Breeding. September 2007. Tenure and Promotion Seminar, NCSU.
- Cardinal A.J. Methods in soybean breeding. Fall 2004. Plant Breeding Seminar, NCSU.
- Cardinal A.J. Marker assisted selection in soybean. Spring 2004. Plant Breeding Seminar, NCSU
- Cardinal A.J. Incorporating exotic germplasm into adapted elite inbred lines of maize and soybean breeding and molecular markers. Spring 2001. Crop Science, NCSU.

Externally and internally sponsored grants and contracts

(Total $1,392,815)

- Molecular Analysis of Soybean Lines with Favorable Oil. United Soybean Board Domestic Programs. 4/01/08-3/31/11, $213,210. PI: R.E. Dewey, Co-PI: A. J. Cardinal.
- Mapping new QTL Conditioning High Protein Content in Soybean Seeds and Part 3) Define the genomic position on LG C1 of the PI416937 QTL. United Soybean Board Domestic Programs. 4/01/08-3/31/11, $77,502. PI: A. J. Cardinal.
- Soybean cultivars and germplasm adapted to North Carolina growing conditions. NC Soybean Producers' Association. 4/01/08-3/31/09, $41,566. PI: A.J. Cardinal.
- Soybean cultivars resistant to cyst nematode races 2 and 4. NC Soybean Producers' Association. 4/01/08-3/31/09, $10,000. PIs: A. J Cardinal, S. Koenning.
- Genetic control of high oleic acid seed content in soybean. National Research Initiative Competitive Grants Program, USDA, CSREES. 6/1/03-5/31/08, $250,000. PI: A.J. Cardinal.
- Development of both conventional and herbicide tolerant soybean varieties adapted to North Carolina growing conditions. NC Soybean Producers' Association. 4/01/02-3/31/08, $173,563. PI: A.J. Cardinal.

- Development of conventional and Roundup Ready soybean varieties resistant to cyst nematode races 2 and 4. NC Soybean Producers' Association. 4/01/02-3/31/08, $37,166. PIs: A. J Cardinal, S. Koenning.
- Mapping and validation of QTLs conditioning high protein content in soybean seeds. Part 2) Marker-assisted selection for high protein QTLs. United Soybean Board Domestic Programs. 4/01/05-3/31/08, $76,845. PI: A.J. Cardinal.
- Molecular analysis of soybean lines with favorable oil traits. United Soybean Board Domestic Programs. 4/01/05-3/31/08, $213,210. PI: R.E. Dewey, Co-PI: A. J. Cardinal.
- Validation and mapping of QTLs conditioning high protein content in soybean seeds. United Soybean Board Domestic Programs. 1/01/03-3/31/05, $47,906. PI: A.J. Cardinal.
- Molecular analysis of soybean lines with favorable oil traits. United Soybean Board Domestic Programs. 1/01/03-3/31/05, $142,134, PI: R.E. Dewey, Co-PI: A.J. Cardinal.
- Equipment grant. NC Soybean Producers' Association. 4/01/04-3/31/05, $6,000. PIs: A. J. Cardinal, J. Spears, J. W. Burton, S. Koenning.
- Very early soybean production system. NC Soybean Producers' Association. 4/01/02-3/31/03, $4,250. PI: J. Dunphy, T.E. Carter, A.J. Cardinal, and J.F. Spears.
- Equipment grant. College of Agriculture and Life Sciences, NCSU. 2003, $9,556, PI: A.J. Cardinal.
- Equipment grant. NC Soybean Producers' Association. 04/01/02-10/11/02, $68,104. PI: A.J. Cardinal.
- Grant to the Soybean Program. North Carolina Foundation Seed Producers, Inc. 2002, $5,000. PI: A.J. Cardinal.
- Breeding soybeans for reduced antimetabolite content. NC Soybean Producers' Association. 2/01/01-10/31/02, $15,000. PIs: T.G. Isleib, A.J. Cardinal.

Participation in centers, consortia, institutes, interdisciplinary/multidisciplinary activities

- Collaboration with Drs. Burton and Carter (USDA-ARS, Crop Science) to develop superior soybean varieties adapted to North Carolina conditions.
- Participation in a multistate collaborative effort (two United Soybean Board grants) to improve soybean protein and oil quality and to understand the genetic regulation of these traits in soybean.
- Collaboration with Dr. Dewey (Crop Science) and Dr. Burton (USDA-ARS, Crop Science) to study the genetic control of high oleic acid seed content in soybean and to develop allele-specific markers for high oleic acid candidate genes.
- Collaboration with Dr. Dewey (Crop Science) and Dr. Burton (USDA-ARS, Crop Science) to study the genetic control of high oleic acid seed content in soybean and to develop allele-specific markers for low palmitic and linolenic acid mutants.
- Participation in a multistate USDA-ARS Southern Uniform Soybean Testing program.

- Collaboration with Dr. Koenning (Plant Pathology) to develop soybean lines resistant to soybean cyst nematode, the most important soybean pest in North Carolina.
- Collaboration with Ing. Ag. Rossi (Nidera S.A., Argentina) and Dr. Boerma (University of Georgia) on screening soybean breeding lines for resistance to Asian Soybean Rust, 2006-07.

5. EXTENSION AND ENGAGEMENT WITH CONSTITUENCIES OUTSIDE THE UNIVERSITY

Accomplishments

Most of the extension activities focused in communicating to the stakeholders (farmers, colleagues, seed producers, and soybean organizations) the goals, scope, and progress of the soybean breeding program and genetic studies started by Dr. Cardinal at NCSU. In addition, Dr. Cardinal has established that she is willing to hear about the stakeholders' needs and to address those needs in her breeding program. Efficient communication was achieved by participating and giving oral presentations in relevant meetings since 2001.

Extension-related presentations

- Cardinal A.J. Soybean Cultivars and Germplasm Adapted to North Carolina Growing Conditions NC Soybean Producers' Association Board of Directors Meeting, November 20, 2008, Raleigh, NC.
- Cardinal A.J. Soybean Cultivars Resistant to Soybean Cyst Nematodes Races 2 and 4 NC Soybean Producers' Association Board of Directors Meeting, November 20, 2008, Raleigh, NC.
- Oral presentation "Soybean Cultivars and Germplasm Adapted to North Carolina Growing Conditions" for the NC Soybean Producers' Association Research Committee meeting, December, 2007, Raleigh.
- Oral Presentation "Soybean Cultivars Resistant to Soybean Cyst Nematodes Races 2 and 4" for the NC Soybean Producers' Association Research Committee meeting, December, 2007, Raleigh.
- NC Soybean Producers' Association meeting, explain Monsanto's new policies for RR transgenic version 1, April 2007, Raleigh.
- NC Soybean Producers' Association Research committee, explain breeding with RR technology, May 2007, Raleigh.
- Oral presentation "Development of conventional and herbicide tolerant soybean varieties adapted to North Carolina for NC" Department of Agriculture personnel, February 2006, Kinston.
- Field visit to soybean breeding nursery with new president of NC Soybean Producers' Association, August 2006, Clayton.
- Oral presentation "Development of conventional and herbicide tolerant soybean varieties adapted to North Carolina growing conditions for the NC" Soybean Producers' Association, December 2006, Raleigh.
- Oral presentation "Development of conventional and RR soybean varieties resistant to Soybean Cyst Nematode races 2 and 4" NC Soybean Producers' Association, December 2006, Raleigh.
- Alternate member of the NC Seed Board, participated in the investigation of two NC growers' cases presented to the Board in July 2006, Raleigh.

- Oral presentation “Breeding for resistance to soybean rust” NC Crop Improvement Association Foundation Seed Producers, McKimmon Center, January 2005, Raleigh.
- Oral presentation “Development of conventional and herbicide tolerant soybean varieties adapted to North Carolina growing conditions NC” Soybean Producers’ Association Board of Directors Meeting, December 2005, Raleigh.
- Oral presentation “Development of conventional and RR soybean varieties resistant to SCN races 2 and 4”, NC Soybean Producers’ Association Board of Directors Meeting, December 2005, Raleigh.
- Oral presentation “Soybean breeding program at NCSU” NC Soybean Foundation Seed Producers meeting, McKimmon Center, January 2004, Raleigh.
- Presented a report of the Soybean World Conference and visit to EMBRAPA-Londrina, Brazil, to the NC Soybean Producers’ Association executive board, July 2004.
- Oral presentation “High oleic acid QTL mapping and breeding for rust resistance” NC Southern Soybean Breeders’ Tour, September 2004, Clayton.
- Oral presentation “Soybean breeding project and DNA markers at NCSU” visit of 3 NC soybean producers and a county agent from Pasquotank County, February 2003, Raleigh.
- Oral presentation to the Executive Board of the United Soybean Board Domestic Programs, 2003, Raleigh.
- Prepared a summary of the soybean project to the NC Soybean Producers’ Association Research Committee, December 2003.
- Oral presentation “Soybean breeding program at NCSU” The Blackland Farmers Tour, Tidewater Research Station, August 2002, Plymouth.
- Hosted Drs. Paris and Smith, soybean breeders from the USDA-ARS Stoneville Research Station, one day visit to NCSU, August 2002.
- Oral presentation “Soybean breeding project at NCSU” NC Soybean Producers’ Association Research committee, November 2002, Raleigh.
- Oral presentation “Soybean breeding project at NCSU” NC Soybean Producers’ Association executive Board, July 2001, Raleigh.
- CALS nominated participant at the United Soybean Board Sponsored Workshop on the mechanics of the USDA Grant Program Initiative for Future Agriculture and Food Systems, November 2001, St. Louis, MO.
- Oral presentation “Soybean breeding project” North Carolina Foundation Seed Association meeting, December 2001, Raleigh.

Program Impact

The PI has given several oral presentations to local soybean producers and foundation seed producers in an effort to have an open discussion about the goals and progress of the cultivar development program. The NC soybean producers and foundation seed producers have financially

supported the soybean breeding program and are aware of the goals and progress of the program. Without their support the breeding program would not exist. It is extremely important for this program to involve the soybean producers and foundation seed producers in setting up goals for Dr. Cardinal's cultivar development program. It is clear that the soybean commodity group has faith in this program because they have supported and they intend to continue supporting the program.

6. TECHNOLOGICAL AND MANAGERIAL INNOVATION

Knowledge and Technology Transfer

Cultivar Releases

- Release of NCC01-69 soybean (NC-Pujals). A.J. Cardinal, S. Wang, and V.T. Pantalone. NCSU release in collaboration with University of Tennessee. 2007. Release description on pages 26-28.
- Release of NCC02-307 soybean (NC-Ernie). A.J. Cardinal, S. Wang, and V.T. Pantalone. NCSU release in collaboration with University of Tennessee. 2007. Release description on pages 24-25.

Genetic studies in Soybean seed composition:

The NCSU breeding program participates in a multi-state research effort to identify and characterize genes that influence the soybean oil fatty acid composition to improve its quality for human consumption and increase its oxidative stability, and the protein content of its meal in order, to increase the competitiveness of U.S. soybeans. This research effort has been supported by the United Soybean Board for many years. The NCSU team has developed molecular markers for important fatty acid mutations (low palmitic acid, low linolenic acid, high oleic acid) that can be used to improve the efficiency of breeding methods currently used.

- We developed and tested allele-specific primers for a candidate gene responsible for the low palmitic acid seed content in soybean lines carrying the fap_{nc} (*FATB-1A* gene) mutation (collaboration with Drs. Dewey and Burton). We determined that a deletion in this gene is responsible for the reduced palmitic acid fap_{nc} mutation and the fap_{nc} locus was shown to account for over 60% of the palmitic acid content variation among F_4-derived lines. We have demonstrated that the fap_{nc} mutation (or linked genes) caused a reduction in yield. Genotypes that were homozygous for *fapnc* yielded on average 81 to 242 lbs/a less than normal or heterozygous genotypes.
- Our fap_{nc} allele-specific primers are freely available for breeders to use as a selection tool.
- We developed allele specific primers for the low linolenic acid *fan* allele inherited from PI123440 and demonstrated that the segregation of this locus explained up to 70% of the genetic variation in linolenic acid in two populations (collaboration with Drs. Dewey and Burton).
- Phytotron studies were conducted to test if two lines that are theoretically 75% identical in their genetic composition but that differ in their linolenic and palmitic acid seed content, have different fatty acid composition in their roots and leaves (collaboration with Dr. Burton). These lines were shown to have low linolenic and palmitic content in the leaves and low linolenic acid in the roots indicating that both the low palmitate and low linolenate genes have pleiotropic effects on other tissues. These results may explain why they have somewhat lower yields than their normal counterparts. Genetically modified soybeans that specifically inactivate the FATB-1A gene in the seed could potentially solve this problem.

- Two populations were developed from N98-4445A and sister lines to study the genetic regulation of the high oleic trait in soybean by mapping quantitative trait loci and studying epistatic interactions among these loci. Allele-specific markers for FAD2-1 and FAD-2 candidate genes that encode the microsomal omega-6 desaturase genes of the fatty acid biosynthetic pathway were developed to study the cosegregation of these genes with high oleic acid quantitative trait loci. We have demonstrated that two of these genes are minor oleate QTL in these populations that are segregating for oleate content. However, we still do not know which genes are responsible for the major high oleate QTLs inherited from N98-4445A. In addition, in a collaborative research project, it has been shown that the high oleate phenotype in N98-4445A is environmentally unstable so new stable sources of high oleate content are needed. We will screen 130 Plant Introductions from the USDA soybean collection to test their oleic acid content.
- Two populations segregating for seed protein content were grown in replicated yield trials to validate QTLs for protein content. One QTL for seed protein content was validated. We performed marker-assisted selection to increase protein content in a segregating population and selected lines were grown in replicated trials in 2006 and 2007.

Program Impact

Issue #1: Soybean production costs have increased dramatically over the last few years. New diseases are emerging in major world soybean production areas.

Impact #1: Improved high yielding cultivars and soybean cyst nematode resistance varieties will increase the profitability of soybean producers without increasing their costs. Developing soybean cultivars with rust resistance will increase the profitability of soybean producers or may allow the continued production of soybeans in NC if the disease becomes an epidemic of frequent occurrence in the U.S.

Breeding for improved cultivars is a very long process and it typically takes 7 to 10 years from the time a cross is made until a line is ready to be released to seed foundation producers. Additionally, sometimes new genetic tools, such as molecular markers, need to be developed to improve the efficiency of the breeding methods employed. Farmers might be able to purchase seed of a particular soybean variety two years after the seed foundation producers have received seed from us.

This program was started in 2001 and we have made a great progress towards the development of varieties adapted to North Carolina growing conditions. We have released 2 conventional cultivars in collaboration with Dr. Pantalone from the University of Tennessee. We have included our best lines in the Southern Uniform test in 2007. However, we do not know when glyphosate tolerant cultivars will be released because of ongoing intellectual property issues with Monsanto.

Issue #2: The Better Bean Initiative was launched by the United Soybean Board to develop a new commodity soybean with oil quality characteristics that would give it a competitive advantage over current soybean varieties grown in the U.S. and abroad. These oil quality traits include a reduction in palmitic acid to reduce health risks associated with the consumption of saturated fatty acids; a reduction in linolenic acid and an increase in oleic acid to improve the oil oxidative stability (shelf life) and reduce the need of hydrogenation and consequently the production of unhealthy trans-fatty acids.

Impact #2: We have specific molecular markers for the *fap*$_{nc}$ mutation and the *fan*(PI123440) mutation so tools were developed in this project and are now in place to accelerate the introduction of the reduced palmitate and reduced linolenate traits into elite cultivars. We have specific molecular markers for FAD2-1A, FAD2-1B and FAD2-2A genes involved in oleic acid synthesis, however we discovered that these genes are not responsible for the high oleate phenotype of N98-4445A, a commonly used source for this trait. We will continue to study the gene regulation of oleic acid biosynthesis in the seed, so that molecular markers can be developed to improve breeding strategies and methods.

Issue #3: The Better Bean Initiative has identified the need to rapidly develop high protein and high yielding soybean cultivars in order to capture a new value-added market with soybeans grown in the U.S. Soybean producers will increase their profitability if soybean meal manufacturers pay a premium for high protein soybean cultivars.

Impact #3: Marker assisted selection can expedite the incorporation of increased seed protein content if accurate and repeatable quantitative trait loci information is available for different high protein soybean lines. One high protein QTL has been validated in our lab and new studies have been designed to provide the information needed to perform marker-assisted selection and therefore accelerate the breeding process.

7. SERVICE TO THE UNIVERSITY AND PROFESSIONAL SOCIETIES

University Service

- Participant at Research Station Strategic Planning Meeting (NCSU-NCDA), December 16, Raleigh, 2008.
- Department of Crop Science Website Development Committee, 2006-present.
- Graduate Faculty Member, 2001-present.
- Graduate school representative on 2 Ph.D. committees, 2003-present.
- Department of Crop Science, review applications of Plant Breeding graduate students, 2004-present.
- In house reviewer of scientific articles, 2002-2003.
- Department of Crop Science Greenhouse Committee, 2001-2003.

- Chair, Plant Breeding Seminar, Departments of Crop and Horticulture Science, Spring 2002.
- Department of Crop Science Social Committee, 2002.
- Departmental Review, Participant, Jan-Feb 2002.

National professional activities

- Reviewer, Molecular Breeding, (1 manuscript) 2003.
- Reviewer, Crop Science, (20 manuscripts) 2003-present.
- Reviewer, Plant Call, (1 manuscript) 2008-present.
- Reviewer, Hereditas, (1 manuscript) 2008-present.
- Reviewer Theoretical and Applied Genetics, (3 manuscripts) 2005-present.
- Grant Reviewer, USDA-CSREES National Research Initiative 56: Plant Biology: Environmental Stress Integrated Projects, 2007.
- Grant reviewer, "Bioenergy and the Environment" of The Consortium for Plant Biotechnology Research, Inc., 2004-2007.
- Participant of Plant and Animal Genomes XVI Conference and NRI-USDA meetings, January 12-16th, 2008, San Diego, CA.
- Participant and report writer, “Excellence in science and technology” group of the Plant Breeding Coordinating Committee Workshop, 2007.
- Grant reviewer, USDA-CSREES National Research Initiative 1) Agriculture Production and Value added Processing (agricultural plants and environmental adaptation (Code 22.1); 2) Genetic processes and mechanisms of agricultural plants. 52.2; 3) Biology of plant-microbe association. 51.8., 2006.
- Reviewer, Journal of Agriculture Food Chemistry, (1 manuscript) 2006.
- Chair, Crop Science Society of America Award Committee, 2005.
- Member, Crop Science Society of America Award Committee, 2004.
- Reviewer, Journal of Natural Resources and Life Sciences Education, (1 manuscript) 2004.
- Reviewer, Soil Science Society of America Journal, (1 manuscript) 2004.
- Grant reviewer, USDA-CSREES National Research Initiative conference proposals, Applied Plant Genomics Program, 2004.
- Grant reviewer, U.S. Civilian Research and Development Foundation, U.S. Department of State, 2004.
- Organizing committee, Soybean Breeders’ Workshop, St Louis, M0, Feb 17-18, 2004.
- Chair, soybean section at annual meeting of the Agronomy Society of America-Crop Science Society of America, Charlotte, NC, 2001.

Regional professional activities

- Collaboration with Drs Walker (USDA-ARS), Leandro and Cianzio (Iowa State University), Shuxian (USDA-ARS) on screening soybean breeding lines for resistance to Asian Soybean Rust.
- Alternate member of the NC Seed Board, participated in the investigation of two NC growers' cases presented to the Board, July 2006, Raleigh, NC.
- Organizing committee, Southern Soybean Breeders' Tour, September 8-9, 2004, NC.

International professional activities

- First NCSU-UFV Workshop on Plant Biotechnology for the Purpose of establishing a dual program between NCSU and Universidade Federal de Visçosa, Centennial Campus BTEC, NCSU, March 25-28, 2008.
- Program Co-chair for the proposed dual degree program between NCSU and UF Visçosa.
- Collaborative soybean rust screening project with Ing. Rossi, Nidera S.A., 2006-2007, Argentina.
- Grant reviewer, International Foundation for Science, 2005.
- Hosted Dr. Phinehas Tukamuhabwa, a Visiting Scientist from Makerere University, Uganda, September-October, 2005. Exchanged knowledge on breeding methods, taught him about molecular markers, QTL mapping and Marker assisted selection and started discussions on collaborative breeding efforts.
- Visited Soybean rust screening nursery in NE of Argentina and discussed collaborative screening methods, December 27, 2005, Misiones, Argentina.

Membership in professional organizations:

- American Society of Agronomy, 1996-present.
- Crop Science Society of America, 1996-present.