

ORG Project Details

Award Year 2006

4 Research Projects

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1. [Crop Plant Nutrition and Insect Response in Organic Field Crop Production: Linking Farmer Observation to University Research and Extension](#) Grant No: 2006-51106-03750
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Crop Plant Nutrition and Insect Response in Organic Field Crop Production: Linking Farmer Observation to University Research and Extension

Accession No.	0207138
Subfile	CRIS\
Project No.	WIS01049
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Project Status	TERMINATED
Contract / Grant No.	2006-51106-03750
Proposal No.	2006-02048
Start Date	01 SEP 2006
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Fiscal Year	2009
Grant Amount	\$374,478
Grant Year	2006
Investigator(s)	Cullen, E. M.
Performing Institution	ENTOMOLOGY, UNIV OF WISCONSIN, MADISON, WISCONSIN 53706

NON-TECHNICAL SUMMARY

A largely informally held concept, based on practical experience and observations of organic farmers around the world is that crop plants grown in organically managed crop rotations receiving biological sources of nutrients such as livestock manure, legume nitrogen, and green manure cover crops are more resistant to insect pests than are conventionally produced crop plants. The emphasis that organic farmers place on insect pest prevention rather than pest control merits serious attention by integrated pest management (IPM) science researchers and Cooperative Extension educators. The purpose of this project is to evaluate two different organic fertility management systems in a grain crop/forage legume rotation under both transition and certified organic systems by comparing soil and crop nutrient profiles with insect response. Research and Extension activities of the project team are structured to increase awareness of how organic fertility management influences field crop plant nutrition and insect pest management, and provide innovative IPM strategies to end-users of the research based information (organic and transitional farmers; extension educators; agricultural consultants; and non-profit organizations providing educational resources to organic farmers).

OBJECTIVES

1. Evaluate different organic fertility management practices in a grain crop and forage legume rotation under both transition and organic systems by comparing soil and crop health indicators with insect response.
2. Conduct simple experiments on working certified organic farms with growers to test emergent hypotheses that integrate organic fertility management strategies with other NOP compliant pest management tactics.
3. Develop a multi institutional partnership between Wisconsin organic farmers, UW Madison, Cooperative Extension, and UW Marathon County which allows full integration of research, Extension, and higher education project goals to increase awareness among end-users about the effects of organic fertility management and crop nutrition on insect pest management in organic grain and forage crops.

APPROACH

Two organic fertility management systems will be evaluated in this study to test the general hypothesis that insect pest populations are less variable and stabilize at lower densities under organic fertility management systems which afford crop plant tissue a regulated and balanced supply of nutrients. First, under the standard organic fertility treatment, nitrogen and other crop nutrients are supplied by use of livestock manure, alfalfa hay in the rotation, and small grain/legume winter cover crop green manure. Soil pH corrections are achieved with addition of locally supplied crushed dolomitic limestone as determined by soil test need. Second, the soil balance organic fertility treatment also relies on a combination of livestock manure, alfalfa hay and green manure cover crops, but includes application of high-calcium lime or gypsum soil amendments, regardless of soil pH levels. A controlled experiment will be conducted on approximately 30 acres of land under transition to organic certification at the UW Arlington Agricultural Research Station. Based on recommendations provided by organic grain crop grower project advisors, a four year Small Grain/Alfalfa, Alfalfa, Corn, Soybean rotation was chosen. Each phase of the rotation will be grown each year of the study, replicated four times in a factorial experimental design at the long-term study site. In addition, the project team will conduct on-farm research and data collection under Objectives 1 and 2 from working certified organic farms with similar rotation. Six farms will be grouped into the two organic fertility management categories as described above, three following the standard organic fertility management treatment and three the soil balance treatment. Both the controlled transition experiment and research with growers on certified organic farms will examine grower selected crop-insect associations of economic concern including Soybean and soybean aphid; Alfalfa and potato leafhopper; and Corn and European corn borer. Soil fertility, crop tissue nutrient profiles and pest and beneficial insect response variables will be assessed for each crop/pest association. Greenhouse and laboratory studies will be conducted to further define mechanisms of pest insect and beneficial insect response patterns emerging from field studies. The project focus represents efforts and research priorities of a diverse stakeholder group comprised of a University of Wisconsin-Madison Extension specialist (entomology); a UW-Madison outreach program manager and organic farmer with soil and crop nutrient emphasis; Eight Wisconsin organic farmers from a mix of grain and legume forage crop farming enterprises; a WI Department of Agriculture grazing and organic agriculture specialist; Superintendent of the UW Arlington Agricultural Research station; and a Professor of Biological Sciences at UW- Marathon County, a two year A.A. degree institution in north central Wisconsin.

PROGRESS

2006/09 TO 2011/08 OUTPUTS: The long-term experiment (LTE) site at Arlington Agricultural Research Station, Arlington, WI, USA, completed three-year transition and received USDA organic certification Fall 2009. Organic certification has been renewed each year, 2009 to present. Project researchers completed the first four years of the LTE research activities. Data collection and analyses, under project Objective 1, include soil fertility system whole plot treatment (soil balance, standard organic) x crop rotation (oat/alfalfa/grass - alfalfa/grass - corn - soybean) with analyses of mineral composition and organic matter soil chemistry properties, crop plant nutrient profiles, and pest and beneficial insect population response variables. Project will continue for second four-year term under a new USDA NIFA OREI grant WIS01533 awarded September 1, 2010. One PhD student, Robin Mittenthal, with Cullen (PI) and thesis advisory committee, are completing two manuscripts for peer review publication for early 2012 submission. Significant product outputs include the following. First, Cullen (PI), Mittenthal (graduate student), and Christine Mason (member of organic farmer advisory board to this project) presented project information and results as an eOrganic webinar to a national audience March 29, 2011. Our webinar was selected for Certified Crop Adviser Continuing Education Credit as an eExtension.org campus website audio/video product titled Integrated Pest Management in Organic Field Crops at <http://www.extension.org/pages/60988>. Second, a new UW Colleges curriculum and course (BOT/SOC 291) titled Social and Scientific Aspects of Organic Agriculture were created. This 3 credit semester-long course, offered each fall since 2009, fulfills UW Colleges' interdisciplinary requirement for A.A. students. BOT/SOC 291 curriculum and course are the result of collaboration between UW Madison (E. Cullen) and UW Marathon County (P. Whitaker) under project Objective 3. BOT/SOC 291 is offered at UW Marathon County and simultaneously to UW Fox Valley (via interactive distance education technology). Partnerships incorporate guest lectures by USDA NRCS, UW Extension, and organic farmers. Community Supported Agriculture farmers Kat Becker and Tony Shultz (Stoney Acres Farm, Athens WI) serve as on-farm research mentors to UW Marathon County summer interns under the direction of P. Whitaker (under project Objectives 2 and 3). Project information was disseminated to Midwestern U.S. farmers, extension educators, land-grant university ag research station workers, government organizations, and students at 11 field days and workshops over three years reaching 520 individuals face-to-face. National and International invited symposia presentations to researchers included

Entomol. Soc. America, San Diego, CA (2010); Tri-Society Annual Meeting, Pittsburgh, PA (2009); Sixth International IPM Symposium, Portland, OR (2009); SARE Annual Meeting, Kansas City, KS (2008) and Ministry of Agriculture, Quebec, Canada (2008). The 8-member organic farmer advisory board to this project met with project PIs three times during the life of the project, plus additional partial group meetings and field visits periodically.

PARTICIPANTS: INDIVIDUALS: EILEEN M. CULLEN (PI), Associate Professor/Extension Specialist, University of Wisconsin-Madison Entomology Department. Roles: Project coordination and responsibility, experimental research design and oversight, graduate student advising, generate, analyze, publish and disseminate results through research/Extension field crops IPM program. KEVIN B. SHELLEY, University of Wisconsin-Madison Nutrient and Pest Management Program Outreach Coordinator, Project Co-director. Roles: Organic crop management at the 30-acre Arlington Agricultural Research Station long-term experiment (LTE) site and organic grower advisory board communications/educational outreach coordination. PAUL WHITAKER, Professor, Biological Sciences and KAT BECKER, Associate Lecturer of Sociology, University of Wisconsin-Marathon County. Roles: Responsible for development, coordination and teaching of a UW Colleges interdisciplinary course curriculum titled Scientific and Sociological Aspects of Organic Agriculture. Whitaker and Becker mentor undergraduate research interns during summer on-farm research collaboration with organic farmers in North Central WI.

COLLABORATORS: Soil science components of field and greenhouse experiments are strengthened by collaboration with PHILLIP BARAK, Professor, University of Wisconsin-Madison Soil Science Dept., to improve interpretation of plant-insect interaction data under Standard Organic and Soil Balance fertility regimes.

TRAINING OR PROFESSIONAL DEVELOPMENT: ROBIN E. MITTENTHAL, PhD Graduate Student Research Assistant, University of Wisconsin-Madison Entomology Dept. Role: Conduct entomology and soil science field and laboratory experiments, data analyses, assistance with organic farming duties at LTE site, coordination of organic record-keeping for certification purposes at LTE study location.

PARTNER ORGANIZATIONS: DARWIN FRYE, JEFF BRUER, PAUL BERGUM, UW Arlington Agricultural Research Station, Arlington, WI. Roles: Assist, advise and provide logistical/technical farming support for all aspects of organic production and certification transition at LTE study site. Additionally, a Wisconsin Organic Farmer Advisory Board meets formally once per year with project individuals in a winter/spring project meeting and a second time each summer at a field day or other Extension venues. Members: DAN and DARLENE COEHOORN, Viewpoint Farm, Rosendale, WI; CHRISTINE MASON/DARREN PAULSON, Standard Process Farms, Palmyra, WI; TOM AND JIM MILLER, R & G Miller and Sons, Columbus, WI; STEVE SLINGER, Randolph, WI; TIM ZANDER, Columbus, WI; TOM WEAVER, Weaver Feeding and Management, Cuba City, WI; GARY WEDIG, Platteville, WI. Roles: Input on determining and pursuing project objectives to meet the needs of organic grain/forage crop producers. Guide researchers on best management practices for organic field crop production systems.

TARGET AUDIENCES: Target audiences include Wisconsin, Upper Midwest, and U.S. organic and transitional grain and forage crop farmers, land-grant university Extension educators and county agents, IPM researchers at land-grant universities and colleges, undergraduate students at the freshman/sophomore campuses of the UW Colleges system, and educators and agricultural professionals who serve or interact with a diversity of organic farmers and farmers or educators interested in learning more about insect pest management in organic systems. Efforts to reach target audiences included extension and outreach field day presentations, research presentation and proceedings publications at organic farming conference research symposia, roundtable meetings with organic farmer advisory board to project, and March 2010 eOrganic webinar presentation by project PI, graduate student, and organic farmer advisor to national audience.

PROJECT MODIFICATIONS: Not relevant to this project.

2009/09/01 TO 2010/08/31 OUTPUTS: This project is designed to improve integrated pest management (IPM) paradigm in theory and practice for U.S. organic grain and forage cropping systems.

OBJECTIVE 1: The long-term experiment (LTE) established in 2006 received USDA organic certification Fall 2009. 2010 marked the first field season of data collection at the LTE as a certified organic system, as compared to transitional system baseline data collected during the first three project years. Half of the LTE plots, Soil Balance crop X fertility system treatments, received fall 2009 gypsum ($\text{CaSO}_4 \cdot (\text{H}_2\text{O})$) application, while the remaining Standard Organic crop X fertility system treatments did not. All plots received legume N credits, and liquid dairy manure based on soil test analyses and sufficiency level nutrient requirements for corn, soybean and alfalfa. We analyzed soil samples for macro and micronutrients, organic matter, pH, total mineral N, and Ca:Mg:K cation ratios. Corn, soybean and alfalfa yield data, and forage quality analyses for 2nd year alfalfa plots, were collected. We assessed paired soil and plant tissue samples in season for plant nutrient profile analysis and correlation with insect data. Plots were sampled weekly June-August for soybean aphid and predators in soybean, potato leafhopper in alfalfa, and periodically assessed for Lepidoptera corn pest abundance.

OBJECTIVE 2: On-farm data (paired soil and plant tissue with insect sampling data) from four organic advisory farms (two Soil Balance; two Standard Organic) collected during the first three project years were analyzed for comparison with data from the LTE during organic transition.

OBJECTIVE 3: Fall semester 2009 Co-PI Dr. Paul Whitaker and Kat Becker, (UW-Marathon County) taught a new interdisciplinary 3-credit course as Bot/Soc 291 titled Scientific and Social Aspects of Organic Agriculture. Curriculum product and UW Colleges approval milestones for this course were

achieved during year 3 of this project. Bot/Soc 291 was offered at UW Marathon County and via interactive distance education video to UW Fox Valley. Forty students (20 on each campus) enrolled. With instructors Whitaker and Becker, organic farmers, Extension (Cullen), and local USDA NRCS partners participated as guest speakers. Student evaluations were positive and UW Colleges approved the course for fall semester 2010. Summer 2010, two UW Marathon County undergraduates participated in mentored research with Whitaker and Becker engaging with organic farmers to conduct on-farm IPM research projects on topics relevant to organic farmers in North Central WI. Eileen Cullen (PI) presented at an invited research symposium on Organic and Sustainable Systems for Pest Management at the 2009 Agronomy, Crop Science, and Soil Science societies of America meeting (Pittsburgh, PA); and an invited extension talk at University of Minnesota Southwest Research and Outreach Center's Organic Field Day (Lamberton, MN, July 8, 2010). We met with organic farmer advisory board individually and in small groups during grant renewal proposal preparation submitted to USDA NIFA OREI February 2010, and disseminated an annual project report to farmer advisors January 2010. PARTICIPANTS: INDIVIDUALS: EILEEN M. CULLEN (PI), Associate Professor/Extension Specialist, University of Wisconsin-Madison Entomology Department. Roles: Project coordination and responsibility, experimental research design and oversight, graduate student advising, generate, analyze, publish and disseminate results through research/Extension field crops IPM program. KEVIN B. SHELLEY, University of Wisconsin-Madison Nutrient and Pest Management Program Outreach Coordinator, Project Co-director. Roles: Organic crop management at the 30-acre Arlington Agricultural Research Station long-term experiment (LTE) site and organic grower advisory board communications/educational outreach coordination. PAUL WHITAKER, Associate Professor, Biological Sciences and KAT BECKER, Associate Lecturer of Sociology, University of Wisconsin-Marathon County. Roles: Responsible for development, coordination and teaching of a UW Colleges interdisciplinary course curriculum titled Scientific and Sociological Aspects of Organic Agriculture. Whitaker and Becker mentor undergraduate research interns during summer on-farm research collaboration with organic farmers in North Central WI. COLLABORATORS: Soil science components of field and greenhouse experiments are strengthened by collaboration with PHILLIP BARAK, Professor, University of Wisconsin-Madison Soil Science Dept., to improve interpretation of plant-insect interaction data under Standard Organic and Soil Balance fertility regimes. Alfalfa forage production and agronomic guidance (planting, stand assessment techniques, forage quality analyses, and harvest) provided by KENNETH ALBRECHT, Professor, University of Wisconsin-Madison Agronomy Dept. TRAINING OR PROFESSIONAL DEVELOPMENT: ROBIN E. MITTENTHAL, PhD Graduate Student Research Assistant, University of Wisconsin-Madison Entomology Dept. Role: Conduct entomology and soil science field and laboratory experiments, data analysis, assistance with organic farming duties at LTE site, coordination of organic record-keeping for certification purposes at LTE study location. PARTNER ORGANIZATIONS: DARWIN FRYE, JEFF BRUER, PAUL BERGUM, UW Arlington Agricultural Research Station, Arlington, WI. Roles: Assist, advise and provide logistical/technical farming support for all aspects of organic production and certification transition at LTE study site. Additionally, a Wisconsin Organic Farmer Advisory Board meets formally once per year with project individuals in a winter/spring project meeting and a second time each summer at a field day or other Extension venues. Members: DAN and DARLENE COEHOORN, Viewpoint Farm, Rosendale, WI; CHRISTINE MASON/DARREN PAULSON, Standard Process Farms, Palmyra, WI; TOM AND JIM MILLER, R & G Miller and Sons, Columbus, WI; STEVE SLINGER, Randolph, WI; TIM ZANDER, Columbus, WI; TOM WEAVER, Weaver Feeding and Management, Cuba City, WI; GARY WEDIG, Platteville, WI. Roles: Input on determining and pursuing project objectives to meet the needs of organic grain/forage crop producers. Guide researchers on best management practices for organic field crop production systems. TARGET AUDIENCES: Target audiences include Wisconsin, Upper Midwest, and U.S. organic and transitional grain and forage crop farmers, Extension educators and county agents, IPM researchers at land-grant universities and colleges, undergraduate students at the freshman/sophomore campuses of the UW Colleges system, and educators and agricultural professionals (non-profit or nongovernmental organization) who serve or interact with a diversity of organic farmers and farmers or educators interested in learning more about insect pest management in organic systems. Efforts to reach target audiences included extension and outreach field day presentations, research presentation and proceedings publications at organic farming conference research symposia, and roundtable meeting with organic farmer advisory board to project. PROJECT MODIFICATIONS: Nothing significant to report during this reporting period.

2008/09/01 TO 2009/08/31 OUTPUTS: The long-term experiment (LTE) established for this project at Arlington Agricultural Research Station, Arlington, WI, (summer 2006) received organic certification following fall 2009 inspection. OBJECTIVE 1: Organic fertility treatments, Standard Organic (STD) and Soil Balance (SB) were applied fall 2009. STD plots received legume nitrogen credits, and liquid dairy manure based on soil test analyses and sufficiency level nutrient requirements for corn, soybean, and alfalfa. SB plots received legume N credits and manure, plus gypsum ($\text{CaSO}_4 \cdot (\text{H}_2\text{O})$) at 2,600 lb/ac. Gypsum rate, relative to target Ca:Mg:K soil balance hypothesis ratios, was determined in consultation with collaborator Dr. Phillip Barak, UW Madison Soil Science Dept.; organic farmer advisory board; and according to soil test values for basic cation saturation ratio (BCSR)

obtained from a commercial soil analysis laboratory. Summer 2009, soil/crop plant tissue samples were collected from STD and SB corn, soybean and second-year alfalfa. Soil samples were analyzed for macro and micronutrients, total mineral N, and Ca:Mg:K BCSR. Plant tissue nutrient profiles were obtained for corn, soybean, and alfalfa tissue; and forage quality analysis for alfalfa. Corn, soybean, and alfalfa fertility x crop treatment replicates (0.77 acre plots) were sampled weekly 06/15 - 09/02/09 for Lepidoptera larvae, soybean aphid/predators and potato leafhopper, respectively. Predator exclusion caged plant experiments were conducted in soybean to determine whether organic soil fertility regimes result in plant nutrient-mediated effects on soybean aphid population dynamics. Field soil from STD fertility plots at the LTE was modified in our laboratories (Cullen/Mittenthal and Barak) to specific ratios of exchangeable Ca and Mg (cmolc/kg) using methods from Favaretto et al. (2006). Three BCSR soil treatments were prepared fall 2008-09 (unamended LTE soil, 2.1 Ca:Mg; "medium" ratio, 2.95 Ca:Mg; and "high" ratio, 4.65 Ca:Mg). The first greenhouse experiment was initiated winter 2010 to obtain estimated life table parameters of soybean aphids raised in clip-cages on soybean plants grown in the modified soil treatments. OBJECTIVE 2: Project PIs consulted with organic farmer advisory board at the UW Madison CALS Organic Agriculture Field Day 08/26/09; and 01/25-29/09 during project renewal proposal preparation to be submitted 02/16/10 to USDA-OREI. Archived soil samples from advisory board farms (collected in 2007) were analyzed with corresponding plant tissue and insect response data, and reported to farmers. OBJECTIVE 3: Fall 2009, Co-PIs Paul Whitaker and Kat Becker, UW Marathon County, taught a new interdisciplinary course "Scientific and Sociological Aspects of Organic Agriculture". It was taught on two UW College campuses simultaneously, at UW Marathon County (Wausau, WI) and via compressed video at UW Fox Valley (Appleton, WI). Forty students enrolled, with 30 students completing the course for credit. Organic farmers, Extension and government agency (NRCS) personnel participated as guest instructors. Student evaluations for the course were positive. UW Colleges has approved the course for Fall 2010. PARTICIPANTS: INDIVIDUALS: EILEEN M. CULLEN, Associate Professor/Extension Specialist, University of Wisconsin-Madison Entomology Dept., Project Director. Roles: Project coordination and responsibility, experimental research design and oversight, graduate student advising, generate, analyze, publish and disseminate results through research/Extension field crops IPM program. KEVIN B. SHELLEY, University of Wisconsin-Madison Nutrient and Pest Management Program Outreach Coordinator, Project Co-director. 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Soil science components of field and greenhouse experiments are greatly strengthened by collaboration with PHILLIP BARAK, Professor, University of Wisconsin-Madison Soil Science Dept., to improve interpretation of plant-insect interaction data under Standard Organic and Soil Balance fertility regimes. Alfalfa forage production and agronomic guidance (planting, stand assessment techniques, forage quality analyses, and harvest) provided by KENNETH ALBRECHT, Professor, University of Wisconsin-Madison Agronomy Dept. TRAINING OR PROFESSIONAL DEVELOPMENT: ROBIN E. MITTENTHAL, PhD Graduate Student Research Assistant, University of Wisconsin-Madison Entomology Dept. Role: Conduct entomology and soil science field and laboratory experiments, data analysis, assistance with organic farming duties at LTE site, coordination of organic record-keeping for certification purposes at LTE study location. 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at organic farming conference symposia, and round-table meeting with organic farmer advisory board to project.
PROJECT MODIFICATIONS: Not relevant to this project.

2007/09/01 TO 2008/08/31 OUTPUTS: 1) Summer 2007, paired soil and crop plant tissue samples were collected from four certified organic farms operated by farmer-members of the Organic Farmer Advisory Board to this project. Two farms practice the Standard Organic Fertility approach, and two farms practice the Soil Balance approach. Soybean aphids were sampled weekly Jul-Aug from soybean fields on the four farms from which paired soil/plant tissue samples were obtained. European corn borer population densities were determined in corn fields from which paired soil/plant tissue samples were obtained on these same farms. Data were analyzed for comparison with the same variables collected in 2008 at the controlled long term experiment (LTE) at the Arlington Agricultural Research Station. 2) The LTE (25 acres plus buffer areas) has completed two of the three-year transition to organic certification. 09/2007-09/2008 field experiments were conducted at the LTE organic transition site to determine whether populations of soybean aphid (soybeans) and European corn borer or western bean cutworm (field corn) differ between Standard Organic Fertility and Soil Balance treatments. Experiments were conducted to determine whether there are differences in populations of soybean aphid natural enemy insects in the different fertility treatments. An experiment was initiated at the LTE site to explore effects on potato leafhopper (PLH) populations of establishing alfalfa direct seeded, with an oat companion crop, or with a forage grass. These three establishment factors were combined with alfalfa variety (PLH-resistant glandular haired alfalfa or non-resistant smooth stem alfalfa) for six treatments. Greenhouse experiments were initiated Fall 2008 to create varied Ca:Mg:K base saturation ratios in soil to determine effect on soybean aphid intrinsic growth rate and a Lepidoptera species weight gain on soybeans grown in the base saturation soil media treatments. 3) Paul Whitaker, UW Marathon County, drafted a new interdisciplinary course "Scientific and Sociological Aspects of Organic Agriculture." The target audience will be students of the UW Colleges Freshman/Sophomore campuses. The course, to include organic farmer-instructors, will be submitted for approval to the UW Colleges Senate Curriculum Committee 2009. Once approved, the course will be included in the UW Colleges distance education schedule for Spring 2010, offered to live on the UW Marathon County campus with synchronous compressed video connections on five other UW Colleges campuses. EVENTS: Project progress, objectives, and current knowledge presented to 52 organic farmers at the Feb. 2008 Upper Midwest Organic Farming Conference, LaCrosse, WI (Cullen); 82 organic and transitional farmers at the Sept. 2008 UW-Madison CALS Organic Field Day, Arlington, WI (Cullen/Shelley); 36 organic farmers and A.A. degree students at the Feb. 2008 Eastern Ontario Crop Conference, University of Guelph Ontario, Canada (Cullen), and 63 land-grant university researchers, organic farmers, and non-government organization educators at the Mar. 2008 Integrated Organic Program Symposium during the national SARE meeting, Kansas City, MO (Cullen). PARTICIPANTS: INDIVIDUALS: EILEEN M. CULLEN, Assistant Professor/Extension Specialist, University of Wisconsin-Madison Entomology Dept., Project Director. Roles: Project coordination and responsibility, experimental research design and oversight, graduate student advising, generate, analyze, publish and disseminate results through research/Extension field crops IPM program. KEVIN B. SHELLEY, University of Wisconsin-Madison Nutrient and Pest Management Program Outreach Coordinator, Project Co-director. Roles: Organic crop management at the 30-acre Arlington Agricultural Research Station long-term experiment (LTE) site and organic grower advisory board communications/educational outreach coordination. PAUL WHITAKER, Associate Professor, Biological Sciences and KAT BECKER, Associate Lecturer of Sociology, University of Wisconsin-Marathon County. 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WI; STEVE SLINGER, Randolph, WI; TIM ZANDER, Columbus, WI; TOM WEAVER, Weaver Feeding and Management, Cuba City, WI; GARY WEDIG, Platteville, WI. Roles: Input on determining and pursuing project objectives to meet the needs of organic grain/forage crop producers. Guide researchers on best management practices for organic field crop production systems. TARGET AUDIENCES: Target audiences include Wisconsin, Upper Midwest, and U.S. organic and transitional grain and forage crop farmers, Extension educators and county agents, IPM researchers at land-grant universities and colleges, undergraduate students at the freshman/sophomore campuses of the UW Colleges system, and educators and agricultural professionals (non-profit or non-governmental organization) who serve or interact with a diversity of organic farmers and farmers or educators interested in learning more about insect pest management in organic systems. Efforts to reach target audiences included extension and outreach field day presentations, presentations and proceedings publications at organic farming conference symposia, and roundtable meeting with organic farmer advisory board to project. PROJECT MODIFICATIONS: Not relevant to this project.

2006/09/01 TO 2007/09/01 Eileen Cullen, UW Madison Extension Entomologist, developed an organic field crop research and Extension group around a proposal funding idea to examine the link between grain crop plant nutrition and insect response, and the premise that organic soil fertility management plays a sizeable role in controlling insect pests in organic systems. This group includes an Extension Specialist (Cullen), a UW Madison Nutrient and Pest Management Outreach Program Manager (Kevin Shelley), eight organic farmer stakeholders/advisors from a mix of grain and legume forage crop farming enterprises, UW Extension County Agents, University of Wisconsin- Arlington Agricultural Research station, and a Professor of Biological Science (Paul Whitaker) at UW Marathon County, a small-sized two year college in north central WI. The project began September 2006. It will address effects of organic soil and crop nutrient management practices (cover crop green manure, livestock manure, and for some treatments a crop plant mineral balance hypothesis which emphasizes addition of calcium) on crop plant resistance to insect pests. Grower selected crop-insect associations of economic concern include Soybean - soybean aphid; Alfalfa - potato leafhopper; and Corn - European corn borer. Soil fertility, crop tissue nutrient profiles, and pest and beneficial insect response variables will be assessed for each crop in an organic grain crop/forage legume rotation. The objective is to develop science-based recommendations that integrate organic fertility management strategies with other National Organic Program-compliant pest management tactics (crop rotation, pest resistant or tolerant crop plant selection, biological control and natural enemy habitat enhancement and attractant methods to suppress insect pests, and allowed botanical or biorational insecticides). This project is in its early stage of development, but with important accomplishments to describe. 30 acres of land at the University of Wisconsin Arlington Agricultural Research Station (ARS) were entered into the three-year transition to organic certification in September 2006. A statistical experimental design has been determined for the site, and baseline soil samples have been taken from all plots and submitted for laboratory analysis. A winter rye cover crop was planted to 14 acres and winter wheat to the remaining 16 acres in fall 2006. Farmer-Researcher/Educator team members will meet February 2007 to discuss fall 2006 soil sample test results from ARS transition plots and determine farmer-relevant organic fertility treatments for both the standard organic (legume based grain rotation, cover crop and animal manures) and soil balance (plant mineral balance hypothesis) treatments. Data will be collected by farmers, using a participatory research framework, on their certified organic farms beginning in 2007. Greenhouse studies will be initiated fall 2007 to test emergent hypotheses of crop plant nutrition-pest and beneficial insect response observed during the summer 2007 field season. A PhD student (Robin Mittenthal, M.S.) hired to this project will begin work with the farmer-researcher team in June 2007.

IMPACT

2006/09 TO 2011/08 CHANGE IN KNOWLEDGE: 127 individuals participated in the March 29th, 2011 eOrganic webinar presented by this project team titled Integrated Pest Management (IPM) in Organic Field Crops. Content included information from this USDA project and IPM concepts and practices/recommendations for organic systems. Presenters included Cullen (project PI), Mittenthal (graduate student) and Mason (organic farmer). eOrganic organizers administered a survey to participants with the following results indicating change in knowledge. Of 127 respondents invited, 86 completed the survey for a response rate of 67.72%. The majority of survey respondents were farmers (22%) or Extension personnel (13%) with the remainder University researcher/educator or non-profit organization staff. Respondents were from all regions of the U.S. as well as Canada, Greece and Chile. Two-thirds of respondents significantly (23%) to moderately (40%) improved their understanding of organic field crop IPM and soil and crop nutrient management as part of a pest management approach. One-third (33%) improved their understanding a little, and only 5% indicated no improvement at all. 70% of respondents intend to apply the knowledge they gained in this webinar to their work with the remainder

opting to apply a little (24%) or none (6%) of the information. 84% felt the information presented was just right, not too technical and not too basic. 72% would definitely recommend this webinar to others and 27% may recommend it to others. Examples of comments from respondents include: I liked having the farmer talk practicality and the research backing up the topic. I would like more from the farmer, discussing the impact of the research; I think it was very helpful to have research-based speakers as well as speakers who are using methods on their farms. I liked the mix of practical and academic. In addition to the eOrganic webinar at the end of this project term, face-to-face contacts were made with target audience at 11 field days and workshops over four years. These contacts allowed over 520 individuals (Upper Midwestern and U.S. farmers, educators, researchers and agriculture professionals) to gain knowledge and expand their concept of applying the IPM paradigm to organic field and forage crops. CHANGE IN ACTIONS: eOrganic and eXtension created an audio/video product of our webinar and project PI Cullen wrote CCA study questions to accompany this distance education product. CCAs now have the option to utilize this product as a resource specific to organic agriculture pest management, earn CCA continuing education units and apply this knowledge in pest management decision-making on farm or in the field. CHANGE IN CONDITIONS: Our UW Colleges interdisciplinary Bot/Soc 291 curriculum and 3-credit fall semester course titled Social and Scientific Aspects of Organic Agriculture is the first interdisciplinary course offering on organic agriculture through UW Colleges. Entering its third year fall 2011, it is an established offering of the UW Colleges institution. **PUBLICATIONS (not previously reported):** 2006/09 TO 2011/08 No publications reported this period

2009/09/01 TO 2010/08/31 CHANGE IN KNOWLEDGE: Between 09/01/09 and 08/31/10, approximately over 200 organic farmers, extension educators, crop consultants, technical service providers, and undergraduate students in the Upper Midwest and U.S. gained knowledge of the role of crop host plant mineral nutrition and organic soil and crop nutrient management role in insect IPM in organic systems. CHANGE IN CONDITIONS: Our curriculum product and 3-credit semester course titled Scientific and Social Aspects of Organic Agriculture (first taught to 40 students Fall semester 2009, and approved for subsequent fall semesters) marked the first interdisciplinary course offering on organic agriculture offered through UW Colleges system.

2008/09/01 TO 2009/08/31 This project seeks to understand how applied organic fertility management practices influence crop plant-mediated population dynamics of pest and beneficial insects. Determining which factors among current organic grower practices of crop rotation, cover crops and animal manure nutrients, and addition of calcium employed under a crop plant mineral balance hypothesis have a significant influence (if any) on pest and beneficial insect population dynamics will help determine how to manipulate these practices for improved insect pest suppression in organic systems. Between 09/01/08 and 08/31/09, an estimated 175 organic farmers, extension educators, crop consultants, and undergraduate students in the Upper Midwest U.S. gained knowledge of the role of crop host plant resistance and plant mineral nutrition in insect IPM in organic systems.

2007/09/01 TO 2008/08/31 This project seeks to understand how applied organic fertility management practices influence crop plant-mediated population dynamics of pest and beneficial insects. Determining which factors among current organic grower practices of crop rotation, cover crops and animal manure nutrients, and addition of calcium employed under a crop plant mineral balance hypothesis have a significant influence (if any) on pest and beneficial insect population dynamics will help determine how to manipulate these practices for improved insect management in organic systems. Between 09/01/2007 and 08/31/2008, 233 organic farmers, extension educators and undergraduate students in the Upper Midwest U.S. and Canada (eastern Ontario) gained knowledge of the role of crop host plant resistance and plant mineral nutrition in insect IPM in organic systems. (Please see EVENTS under OUTPUTS section of this report.

2006/09/01 TO 2007/09/01 Wisconsin is second in the nation for the number of certified organic farms. Market demand has increased for organic corn, soybeans, grains and hay to support growth in the organic livestock sector. This project seeks to understand how applied organic fertility management practices influence population dynamics of pest and beneficial insects. Determining which factors among current practices of crop rotation, cover crops and animal manure, and addition of calcium and other amendments employed under a crop plant mineral balance hypothesis have significant influence on pest and beneficial insect population dynamics will help determine how to manipulate these practices for improved insect pest management and profitable integration of National Organic Program-compliant insect management tactics.

PUBLICATIONS

2009/09/01 TO 2010/08/31 No publications reported this period

2008/09/01 TO 2009/08/31 No publications reported this period

2007/09/01 TO 2008/08/31 Mittenthal, R., Cullen, E., and Shelley, K. 2008. Relationship of organic fertility management, plant nutrition, and insect response. pp. 33-34 in Proc. Midwest Organic Research Symposium. Midwest Organic and Sustainable Education Service, USDA CSREES, and Organic Farming Research Foundation, LaCrosse, WI. http://ofrf.org/networks/midwest_organic_rschr_symposium.html

2006/09/01 TO 2007/09/01 No publications reported this period

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Developing Wheat Varieties for Organic Agricultural Systems

Accession No.	0207321
Subfile	CRIS\
Project No.	WNP00645
Agency	NIFA WN.P
Project Type	OTHER GRANTS
Project Status	TERMINATED
Contract / Grant No.	2006-51106-03525
Proposal No.	2006-02057
Start Date	01 SEP 2006
Term Date	31 AUG 2011
Fiscal Year	2009
Grant Amount	\$690,557
Grant Year	2006
Investigator(s)	Jones, S. S.; Baik, B. K.; Carpenter-Boggs, L.; Goates, B. J.
Performing Institution	CROP & SOIL SCIENCES, WASHINGTON STATE UNIVERSITY, PULLMAN, WASHINGTON 99164

NON-TECHNICAL SUMMARY

Our principal goal is to breed wheat varieties that are uniquely adapted to organic agricultural systems in the Pacific Northwest (PNW) that has the potential to benefit organic farming systems and breeding programs around the country. Very little attention has been paid by wheat breeders to address the needs of the organic sector. Wheat can be grown on any scale and in any environment in the PNW and most of the United States and appropriate varieties can be selected for in non-traditional wheat producing regions to improve yield, disease resistance, weed competitiveness, quality and nutrition. Our preliminary research shows that the characteristics required of a wheat variety for use in organic production is significantly different from those required for use in conventional production. Many of these characteristics may be absent from modern wheat cultivars because they generally have been bred and selected under conditions of intense chemical management. It is our goal to reintroduce into modern wheats the traits of potential value to organic cropping systems that are found in these historical wheats.

OBJECTIVES

Our primary goal is to breed wheat varieties that are uniquely adapted to organic agricultural systems in the PNW that have the potential to benefit organic farming systems and breeding programs across the country. Our specific goals are to breed wheat varieties that: 1) improve yield and stability in organic systems through enhanced nutrient-use efficiency; 2) contain long-lasting disease resistances to stripe rust and common bunt pathogens; 3) improve competitiveness against weeds; 4) contain quality and nutritional characteristics beneficial to organic bakers, millers and consumers.

APPROACH

Our goal is to partner with organic growers in order to compare the performance of current cultivars and breeding lines under conventional and organic conditions. This diversity of management practice will be essential if we are to determine whether there are general characteristics required for organic wheat production. Field experiments for nitrogen uptake efficiency will be conducted using a split-plot design with four replications and organic nitrogen sources. Tissue analysis of aboveground plant material will provide data on biomass, nutrient uptake, concentration and partitioning. This analysis will include nutrients important to wheat yield and quality under organic systems. Breeding for durable resistance to rust requires breeding plots in several sites over multiple years. Common bunt is eliminated from conventionally grown wheat populations through chemical seed treatments. Our breeding plots do not use chemical seed treatment, and we hope to determine cultivars and lines with resistance to common bunt. In addition we will begin sending advanced lines to the dwarf bunt nursery run by the USDA-ARS. Dr. Tim Murray will assist us in screening for these two important diseases as well as in screening for eyespot and cephalosporium stripe resistance. We will use a seven parent Griffins diallel analysis and parent-offspring regression analysis to determine heritability of coleoptile length. We will determine the response to selection by selecting the top fifteen percent of long coleoptile plants and statistically comparing this with a random selection of plants for five generations. Our growth chamber coleoptile study will help us assess the correlation between field emergence and coleoptile length. We are currently conducting two experiments to determine variations in genotypic ability to compete with weeds and withstand mechanical harrowing. The first evaluates 40-60 breeding lines under certified organic conditions. This experiment compares the yield and test weight of the breeding lines under weed-free and weed intensive conditions. The second experiment is a randomized split plot design with three replications. One treatment includes aggressive harrowing with a minimum tillage rotary hoe. The other treatment is the control, using no weed management strategy. In evaluating for allelopathic root exudates, we will use the equal compartment agar method (ECAM) described in detail by Wu et al. Once varieties with high levels of allelopathic activity have been found, they will be used as parental material in crosses and progeny will be evaluated and screened for high allelopathic activity. Baking and milling tests are performed on all wheats from the organic fields. Dr. Byung-Kee Baik will perform full evaluation of bread, cookie, cake and noodles. Dr. Phillip Reeves, a research chemist with the USDA at the Grand Forks Human Nutrition Research Center in North Dakota will continue to evaluate micronutrient levels of wheat varieties and breeding lines. This will enable us to potentially improve the nutritional quality of wheat varieties through classical breeding techniques.

PROGRESS

2006/09 TO 2011/08 OUTPUTS: This project developed germplasm and techniques and is helping to revitalize regional grain communities. Germplasm from the program has gone to several public programs throughout the US. We developed twenty elite wheats being considered for variety release that have done well locally. 3rd year yield, disease, and nutrition results are awaiting publication. Samples were submitted to the genotyping and quality and nutritional labs. In 2011, organic trials were grown at three locations in grower's fields. Prior to that, trials were grown in up to 7 fields in eastern, central and western WA. Wheat was milled organically and is being evaluated for quality through laboratory analysis, and a group of various sized commercial bakers. Results indicate unique qualities and flavors. An economic analysis of this system is currently underway and a formal survey is being analyzed to assess the potential market for local organic flour among bakers. The results will be valuable not only for WA, and the northwest but for other communities nationwide trying to reinvent decentralized small grain production and distribution systems outside of the commodity market. Select oral presentations are: Hills, and Jones. Effectiveness of Late Spring Topdressing for Increasing Protein Quantity and Quality in Organic Hard Red Winter Wheat in Western WA at CSSA 2011. Patzek, WA Tilth producer's 2011 Early Season Farm Walk Series: Current Research in Organic Farming; Hills, Panel Member, Issues of Scale: Values, sustainability and prosperity. Kneading Conference West, (2011); Hills, Corbin and Jones. Poster presented at meeting of Food, Agriculture and Human Values Society, Missoula MT (2011); Bringing Grains Back to the Coastal Pacific Northwest. Hills, Talk at Mother Earth News Fair, Puyallup WA (June 4); Jones, Murphy, Matanguihan, Hills, and Endelman. Organic Small Grains for Small Farms: Breeding for Diverse Systems. Poster at USDA Organic Grant Recipients Meeting, Washington DC (2011); Jones, The Redecentralization of Grain Systems in the Coastal Pacific Northwest. Presentation at Food Justice Conference, Eugene OR (2011); Murphy, Hills, Hayes, Jones (2010). Organic grain research in the Pacific Northwest. CSSA Annual Meeting, 2010; Murphy, K., L. Yan, L. Hoagland, S.S. Jones (2010). Genotype x environment interactions for mineral nutrient concentration and yield in organic wheat. Murphy, (2010). Growing wheat east and west of the Cascades. Farmer to Farmer Workshop, Walla Walla, WA, 2010; Murphy, Huber (2009). Organic wheat breeding in Washington State. WA State Borlaug Fellows Program. 2009; Murphy, Jones (2009). Evolutionary participatory breeding in wheat. IFOAM Conference on Organic Plant and Animal Breeding. Santa Fe, New Mexico, 2009; Murphy, Reeves, Jones (2009). Mineral nutrition and end-use quality in organic and conventional wheat. 3rd Int Cong on Food and Nutrition. Quality Low-Input Food Conference, Antalya, Turkey. A bread conference was convened at Mount Vernon in 2011 with 200

bakers, millers and farmers from 12 states and 3 Canadian provinces. PARTICIPANTS: Nothing significant to report during this reporting period. TARGET AUDIENCES: Nothing significant to report during this reporting period. PROJECT MODIFICATIONS: Nothing significant to report during this reporting period.

2009/09/01 TO 2010/08/31 OUTPUTS: We developed twenty hard red and soft white wheats that we are considering for germplasm or variety release. These underwent continued evaluation in 2010. Third year yield, disease, and nutrition results from this project are awaiting publication. We are submitting these samples to the genotyping lab, quality lab and nutritional lab for analysis. In 2010, soft white and hard red organic spring wheat trials were grown at six locations in farmers' fields and at Mount Vernon, WA. Three organic spring wheat sites were continued in Western WA in farmers' fields. Wheat from the trials was milled by an organic mill and is currently being evaluated for baking quality not only through laboratory analysis, but also through testing by cooperating artisan bakers and a decentralized group of home bakers. An economic analysis of this organic management system is currently underway. In addition, a survey is being created to assess the potential market for local organic whole wheat and white flour among artisan bakers in Northwestern WA and the needs of the bakers. The results of this research will be valuable not only for Washington, but for other communities nationwide that are trying to reinvent decentralized small grain production and distribution systems outside of the commodity market. Oral presentations are: Murphy, K., K. Hills, P. Hayes, S.S. Jones (2010). Organic grain research in the Pacific Northwest. CSSA-ASA-SSSA Annual Meeting, Long Beach, CA, Nov. 3, 2010; Murphy, K., L. Yan, L. Hoagland, S.S. Jones (2010). Genotype x environment interactions for mineral nutrient concentration and yield in organic wheat. CSSA-ASA-SSSA Annual Meeting, Long Beach, CA, Nov. 1, 2010; Murphy, K. (2010). Growing wheat east and west of the Cascades. Farmer to Farmer Workshop, Walla Walla, WA, March 6, 2010; Murphy, K., N. Huber (2009). Small scale grain production. Washington Tilth Producers Annual Conference. Yakima, WA, Nov. 15, 2009; Murphy, K. (2009). Organic wheat breeding in Washington State. Washington State Borlaug Fellows Program. Pullman, WA, Sept. 20, 2009; Murphy, K., S.S. Jones (2009). Evolutionary participatory breeding in wheat. IFOAM Conference on Organic Plant and Animal Breeding. Santa Fe, New Mexico, August 27, 2009; Murphy, K., P. Reeves, S.S. Jones (2009). Mineral nutrition and end-use quality in organic and conventional wheat. 3rd International Congress on Food and Nutrition. Quality Low-Input Food Conference, Antalya, Turkey, April 6, 2009. Hoagland, L., Mazzola, M, Murphy, K., Jones, S., 2010. Wheat cultivar selection for biological remediation of apple replant disease. International Horticulture Congress, Lisbon, Portugal. The following participants are collaborators of this project with Dr. Stephen Jones, Washington State University: Stephen Machado, Oregon State University; Yan Lin, USDA ARS, North Dakota Human Nutrition Research Center; Lori Hoagland, Purdue; Kevin Murphy, WSU; Nash Huber, Dungeness Organic Farm; Erick Haakensen, Jubilee Farm; Melissa Barker, Evergreen State College Farm; Wilbur Bishop, Ebey Road Farm; Woody Deryckx, Mt. Baker Organic Seed Growers Association; Keith Kisler, Finn River Farm. PARTICIPANTS: Nothing significant to report during this reporting period. TARGET AUDIENCES: Nothing significant to report during this reporting period. PROJECT MODIFICATIONS: Nothing significant to report during this reporting period.

2008/09/01 TO 2009/08/31 OUTPUTS: Progress made toward outputs include multiple grain workshops, talks, and field days for growers, extension agents, consumers and bakers from WA, OR and Canada throughout 2009. In 2009, soft white and hard red organic winter wheat trials were grown at six locations in farmers' fields and one at Mount Vernon, WA. Three organic spring wheat sites were established in Western WA in farmers' fields. Second year yield, disease, and nutrition results from this project are awaiting publication. We identified 20 each of hard red and soft white wheats in 2008 that we are considering for germplasm or variety release. These underwent continued evaluation in 2009. We are submitting these samples to the genotyping lab, quality lab and nutritional lab for analysis. We published a popular press article in Washington Tilth Producers Quarterly titled: "Wheat Varieties in Western Washington". Dr. Kevin Murphy and Dr. Lori Hoagland, both postdoctoral fellows in the program, have attended and given oral presentations at numerous conferences, workshops and meetings. Numerous PhD students also attended conferences and gave oral presentations. The list of oral presentations are: Murphy, K., N. Huber, S. Jones (2009) "Small scale grain production." Washington Tilth Producers Annual Conference. Yakima, WA, Nov. 15, 2009. Murphy, K. (2009). "Organic wheat breeding in Washington State." Washington State Borlaug Fellows Program. Pullman, WA, Sept. 20, 2009. Murphy, K., S. Jones (2009). "Evolutionary participatory breeding in wheat." IFOAM Conference on Organic Plant and Animal Breeding. Santa Fe, New Mexico, August 27, 2009. Murphy, K., S. Jones (2009). "Mineral nutrition and end-use quality in organic and conventional wheat." 3rd International Congress on Food and Nutrition. Quality Low-Input Food Conference, Antalya, Turkey, April 6, 2009. Matanguihan, J. 2009 XVIth Biennial Workshop on Smut Fungi, June 11-13, in Beltsville, Maryland. "The return of an ancient foe: common bunt in organic wheat". Matanguihan, J. 2009 APS Annual Meeting, August 1-5, Portland, Oregon. Poster entitled: "Genetic diversity of *Tilletia caries* isolates from wheat in Washington State." PARTICIPANTS: The following participants are collaborators of this

project with Dr. Stephen Jones- Washington State University (WSU). Stephen Machado, Oregon State University; Yan Lin, USDA ARS, North Dakota Human Nutrition Research Center; Lori Hoagland, WSU; Kevin Murphy, WSU; Nash Huber, Dungeness Organic Farm; Erick and Wendy Haakensen, Jubilee Farm; Melissa Barker, Evergreen State College Farm; Wilbur Bishop, Ebey Road Farm; Woody Deryckx, Mt. Baker Organic Seed Growers Association; Keith Kisler, Finn River Farm. TARGET AUDIENCES: Our target audiences for this research are anyone associated with organic agricultural systems in the Pacific Northwest (PNW) that have the potential to benefit organic farming, such as breeding programs, and wheat producers who are transitioning to organic production. PROJECT MODIFICATIONS: Nothing significant to report during this reporting period. PROJECT MODIFICATIONS: Nothing significant to report during this reporting period.

2007/09/01 TO 2008/08/31 OUTPUTS: Progress made toward outputs include a grain workshop for 25 growers from WA and Canada in March of 2008; a field day in August of 2008 at Nash Huber's Dungeness Farm, 30 growers, extension agents, and bakers were in attendance from WA, OR, BC. In September of 2008, Softwhite, Hard Red, organic winter wheat trials were established, six locations in farmers fields and one at Mount Vernon, WA. Three organic spring wheat sites were established in Western WA in farmers' fields. The first yield, disease, and nutrition results from this project are awaiting publication. An acre of organic wheat was sown at Lind, WA, over 400 entries, 1000 plots. Organic winter wheat was also sown on 3.5 acres at Spillman Farm, Pullman, WA. Over 400 head rows, 400 plots and a bulk population were generated. We identified 20 each of hard red and softwhite wheats that we are considering for germplasm or variety release. We are submitting these samples to the genotyping lab, quality lab and nutritional lab for analysis. An advanced softwhite nursery was established in St. Andrews, WA. We also published a popular press article on the Rodale Institute on-line version titled: Seeking Beneficial Genetic Diversity in the Field. PARTICIPANTS: The following participants are collaborators of this project with Dr. Stephen Jones- Washington State University (WSU). Stephen Machado, Oregon State University; Yan Lin, USDA ARS, North Dakota Human Nutrition Research Center; Lori Hoagland, WSU; Kevin Murphy, WSU; Nash Huber, Dungeness Organic Farm; Erick and Wendy Haakensen, Jubilee Farm; Melissa Barker, Evergreen State College Farm; Wilbur Bishop, Ebey Road Farm; Woody Deryckx, Mt. Baker Organic Seed Growers Association; Keith Kisler, Finn River Farm. Dr. Kevin Murphy and Dr. Lori Hoagland, both postdoctoral fellows in the program have attended and given oral presentations at numerous conferences, workshops and meetings. Numerous PhD students also attended conferences and gave oral presentations. The list of conferences are: The Second Scientific Conference of the International Society of Organic Agriculture Research, Modena, Italy, June 18-20, 2008. The Organic Seed Growers Conference, February 14-15, 2008, Salem, Oregon. Organic Seed Alliance, Port Townsend, WA; February 17-21, 2008. The list of oral presentations are: Murphy, K. (2008). Multi-disciplinary research for sustainable farming systems. Montana State University Seminar. Bozeman, MT, March 28, 2008. Murphy, K. (2008). Participatory research in integrated cropping systems. Northwest Agricultural Research Center, Montana State University Seminar. Kalispell, MT, March 27, 2008. Murphy, K., L. Hoagland, J. Dawson, S. Jones (2008). Selecting, growing, and marketing value-added wheat varieties in organic cropping rotations. Organic Seed Alliance Seed Growers Conference. Salem, OR, February 14-15, 2008. Murphy, K., P. Reeves, L. Hoagland, S.S. Jones (2008). Exploiting cropping system x cultivar interactions for nutritional value in wheat. CSSA-ASA-SSSA Annual Meeting. Houston, TX, October 6, 2008. Hoagland, L., K. Murphy, L. Carpenter-Boggs, S.S. Jones (2008). Improving nutrient uptake in organic dryland wheat cropping systems through cultivar specific interaction with Azospirillum. CSSA-ASA-SSSA Annual Meeting. Houston, TX, October 6, 2008. Murphy, K., L. Hoagland, P. Reeves, S.S. Jones (2008). Effect of cultivar and soil characteristics on nutritional value in organic and conventional wheat. Quality Low-Input Food Conference, June 20, 2008, Modena, Italy. Hoagland, L., K. Murphy, L. Carpenter-Boggs, S.S. Jones (2008). Improving nutrient uptake in wheat through cultivar specific interaction with Azospirillum. Organic World Congress, June 20, 2008, Modena, Italy. Murphy, K., J. Dawson, S.S. Jones (2008). Breeding for nitrogen use efficiency in organic wheat systems. Organic World Congress, June 20, 2008, Modena, Italy. Jones, S., K. Murphy (2008). Strategies for plant breeding in the public interest. Organic Seed Alliance Seed Growers Conference. Salem, OR, February 14-15, 2008. Murphy, K. (2008). Participatory extension and research for sustainable farming systems. WSU Extension Seminar. Puyallup, WA, January 29, 2008. TARGET AUDIENCES: Our target audiences for this research are anyone associated with organic agricultural systems in the Pacific Northwest (PNW) that have the potential to benefit organic farming, such as breeding programs, and wheat producers who are transitioning to organic production. PROJECT MODIFICATIONS: Nothing significant to report during this reporting period.

2006/09/01 TO 2007/08/31 OUTPUTS: Presentations: Murphy, K (2007). Multi-disciplinary research for organic systems: Integrating plant breeding, agronomy and soil science. University of Maine Research Seminar. Orono, ME, November 27, 2007. Murphy, K (2007). Participatory plant breeding for sustainable farming systems. University of Maine Extension Seminar. Orono, ME, November 27, 2007. Murphy, K., J. Dawson, P. Reeves, S. Jones (2007). Heritability and genotype x environment interactions of mineral nutrient concentration in wheat

grown in organic systems. European Association for Plant Breeding Research (EUCARPIA) Symposium. Plant breeding for organic and sustainable, low-input agriculture: dealing with genotype-environment interactions. Wageningen, Netherlands, November 9, 2007. Dawson, J., K. Murphy, S. Jones (2007). Plant breeding for organic systems: Wheat in the inland Pacific Northwest. CSSA-ASA-SSSA Annual Meeting. New Orleans, LA, November 6, 2007. Jones, S., K. Murphy (2007). Long-term breeding strategies for sustainable cropping systems. American Society of Horticultural Science (ASHS) Annual Conference. Scottsdale, AZ, July 18, 2007. Murphy, K. (2007). Breeding wheat for enhanced nutritional value. Washington State University (WSU) Departmental Crop Science Seminar. Pullman, WA, April 12, 2007. PARTICIPANTS: PI: Dr. Stephen Jones, Professor and Wheat Breeder Co-PI: Kevin Murphy, Organic and Perennial Wheat breeder Two PhD Students and two Post-Doctoral Research Associates TARGET AUDIENCES: Wheat Growers of the Pacific Northwest

IMPACT

2006/09 TO 2011/08 We expect to have sufficient data from our emergence, weed competitiveness and harrowing tolerance evaluations to develop a morphological ideotype of a wheat well suited to organic production that can be used to guide future breeding efforts nationwide. We have begun the nutrient use efficiency studies to evaluate the efficacy of including prescreening for these traits in early generation breeding lines to increase the efficiency of breeding for low input and organic systems. We are confident that the germplasm developed from this program will result in the release of cultivars especially developed for organic production. This project as a whole will help other public and private breeders evaluate the need for dedicating breeding programs for low input, organic and other alternative cropping systems, and will provide an assessment of the value of publicly developed and maintained germplasm. We repeated two winter wheat trials in 2010-11 to investigate the effects of cultivar and rate of application of a commercially available fertilizer approved for organic production. The area receives approximately 32 inches of rainfall per year, with most falling between October and April. The cultivars planted were two reds, Bauermeister and WA8022, and one white MDM. WA8022 is a breeding line that has not been commercially released, but showed promise for western WA in previous trials. An organic fertilizer was surface applied to all plots at a rate of 30 lbs N/acre in early spring and at rates of 0, 20, 40, 60, and 80 lbs N/acre at boot stage. Protein averaged across varieties, increased from 8.9 and 9.7 % at the two sites to 9.7 and 11.2 % for the plots receiving 60 lbs of N at the boot stage. Protein increases were negligible beyond 60 lbs N/acre. There were no significant differences in yield between fertility treatments. Yields at the two sites averaged 87.9 and 60.1 bushels/acre. Two other organic on-farm spring wheat variety trials found that grain yields were on average 70% of that in a conventional trial conducted in Mount Vernon, but test weights were consistently higher. The results from our field study into the effects of Azospirillum inoculation as impacted by wheat cultivar and field management conditions showed that across cultivars, wheat tended to benefit from inoculation in conventional systems, but not in organic systems. Selection conditions also impacted the ability of wheat cultivars to enhance populations of resident beneficial microbial species, as wheat cultivars under organic conditions were the best at suppressing pathogens responsible for apple replant disease. We have made great progress toward providing organic producers within each agro-climatic zone in the small grain producing regions of the PNW the data required to make informed choices among existing cultivars for weed competitiveness, seed-borne diseases, and response to low fertility environments. None of this information was previously available to organic growers. Two PhD students were graduated from this program (Murphy and Dawson) and one post doc was trained and now has a faculty position at Purdue (Hoagland). **PUBLICATIONS (not previously reported):** 2006/09 TO 2011/08 1. Dawson, J.C., K. Murphy, D.R. Huggins, S.S. Jones (2011). Evaluation of winter wheat breeding lines for traits related to nitrogen use under organic management. *Organic Agriculture* 1: 65-80. 2. Miles, C., J. Roozen, S. S. Jones, K. Murphy, and X. Chen. 2009. Growing wheat in western Washington. Washington State University Extension Publication EM022E. <http://cru.cahe.wsu.edu/CEPublications/EM022E/EM022E.pdf> 3. Murphy, K., P. Reeves, S.S. Jones. 2008. Relationship between yield and mineral nutrient content in historical and modern U.S. spring wheat cultivars. *Euphytica: The International Journal of Plant Breeding* 163: 381-390. doi: 10.1007/s10681-008-9681-x. 4. Dawson, J.C., K. Murphy, S.S. Jones. 2008. Decentralized selection and participatory approaches in plant breeding for low-input systems. *Euphytica*. Vol. 160, no. 2. pp.143-154. 5. Hoagland, L., Murphy, K., Carpenter-Boggs, L., Jones, S. 2008. Improving nutrient uptake in wheat through cultivar specific interaction with Azospirillum. In Proceedings, Second Scientific Conference of the International Society of Organic Agricultural Research (ISOFAR), Modena, Italy. pp. 526-565. 6. Murphy, K., Hoagland, L., Reeves, P., Jones, S. 2008. Effect of cultivar and soil characteristics on nutritional value in organic and conventional wheat. In Proceedings, Second Scientific Conference of the International Society of Organic Agricultural Research (ISOFAR), Modena, Italy. pp. 614-617. 7. Murphy, K., J.C. Dawson, S.S. Jones (2008). Relationship among phenotypic growth traits, yield and weed suppression in spring wheat landraces and modern cultivars. *Field Crops Research* 105: 107-115. 8. Murphy K., K.G. Campbell, S. Lyon, S.S. Jones (2007).

Evidence for varietal adaptation to organic farming systems. *Field Crops Research* 102: 172-177. 9. Murphy, K., S. Jones (2007). Genetic assessment of the role of breeding wheat for organic systems. In *Wheat Production in Stressed Environments: Proceedings of the 7th International Wheat Conference*, H.T. Buck, J.E. Nisi and N. Salomon, eds; Springer; pp. 217-222. 10. Murphy, K., S. Jones (2007). Nutritional value of spring wheat: A comparison of historical and modern varieties. *WSU Extension Bulletin. Sustaining the Pacific Northwest*, Vol. 5, no. 2, pp 7-8. <http://csanr.wsu.edu/whatsnew/SPNW-v5-n2.pdf#page=7> 11. Hills, K.M., J. Goldberger and S.S. Jones.(2011). *Rebuilding the Grain Chain: Stories from the coastal Pacific Northwest*. Rural Connections. Sept. 2011. 12. Lammerts van Bueren, T., S.S. Jones, L. Tamm, K. Murphy, J.R. Myers, C. Leifert, M.M. Messmer (2010). The need to breed crop varieties suitable for organic farming using wheat, tomato and broccoli as examples: A review. *NJAS - Wageningen Journal of Life Sciences* (in press) doi:10.1016/j.njas.2010.04.001. 13. Murphy, K., S. Jones, C. Miles (2009). Wheat variety trials in Western Washington. *Tilth Producers Quarterly*, Spring, 2009. 14. Matanguihan, G.J.B., K. Murphy, S.S. Jones (2011). Control of common bunt in organic wheat. *Plant Disease* 95:92-103.

2009/09/01 TO 2010/08/31 We expect to have sufficient data from our emergence, weed competitiveness and harrowing tolerance evaluations to develop a morphological ideotype of a wheat well suited to organic production that can be used to guide future breeding efforts nationwide. We have begun the nutrient use efficiency studies to evaluate the efficacy of including prescreening for these traits in early generation breeding lines to increase the efficiency of breeding for low input and organic systems. We are confident that the germplasm developed from this program will result in the release of cultivars especially developed for organic production. This project as a whole will help other public and private breeders evaluate the efficacy of dedicating breeding programs for low input, organic and other alternative cropping systems, and will provide an assessment of the value of publicly developed and maintained germplasm. Two winter wheat trials were planted in October 2009 to investigate the effects of cultivar and rate of application of a commercially available fertilizer approved for organic production. The area receives approximately 32 inches of rainfall per year, with most falling between October and April. The cultivars planted were all hard winter wheat and included two reds (Bauermeister and WA8022) and one white (MDM). WA8022 is a breeding line that has not been commercially released, but showed promise for western WA in previous trials. An organic fertilizer was surface applied to all plots at a rate of 30 lbs N/acre in early spring and at rates of 0, 20, 40, 60, and 80 lbs N/acre at boot stage. Protein, averaged across varieties, increased from 8.9 and 9.7 % at the two sites to 9.7 and 11.2 % for the plots receiving 60 lbs of N at the boot stage. Protein increases were negligible beyond 60 lbs N/acre. There were no significant differences in yield between fertility treatments. Yields at the two sites averaged 87.9 and 60.1 bushels/acre. Two other organic on-farm spring wheat variety trials found that grain yields were on average 70% of that in a conventional trial conducted at the WSU NWREC in Mount Vernon, but test weights were consistently higher. The results from our field study into the effects of *Azospirillum* inoculation as impacted by wheat cultivar and field management conditions showed that across cultivars, wheat tended to benefit from inoculation in conventional systems, but not in organic systems. Selection conditions also impacted the ability of wheat cultivars to enhance populations of resident beneficial microbial species, yet wheat cultivars under organic conditions were the best at suppressing pathogens responsible for apple replant disease. We have made great progress toward providing organic producers within each agro-climatic zone in the small grain producing regions of the PNW the data required to make informed choices among existing cultivars for weed competitiveness, seed-borne diseases, and response to low fertility environments. None of this information was previously available to organic growers who were basing their decisions strictly on the current variety testing system in the PNW.

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2006/09/01 TO 2007/08/31 Our previous results (submitted in the 2006 progress report and published in Field Crops Research 2007) suggested that the highest yielding varieties in conventional systems are not the highest yielding varieties in organic systems. To identify the traits most responsible for yield in organic systems, we continued to evaluate varieties for weed suppression, allelopathic root exudates, coleoptile length and disease resistance. We identified varieties with high weed suppression ability (in press, Field Crops Research 2008), and associated allelopathic root exudates and plant height with the ability to suppress the target weed species, *Chenopodium album* (lambsquarters). We determined the gene action of, and best generation to select for, coleoptile length in wheat, depending on the parents involved. This should have a significant impact on the emergence consistency of organic wheat in low rainfall regions of WA State. In 2006 we completed a study that identified wheat varieties with high levels of mineral nutrients (currently in review at Euphytica). Here we report the preliminary results of a new study that tests the differences in nutritional value between organic and conventional wheat. We evaluated 25 advanced lines in organic and conventional systems in Pullman and Lind for mineral content of calcium (Ca), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), phosphorus (P) and zinc (Zn). Our data suggests that organic systems have increased levels of Cu, Mg, Mn, P and Zn and conventional systems had higher levels of Ca. No difference was found for Fe content. Soil analyses suggest that the increase organic matter and pH in the organic systems may play a significant role in the higher nutritional value in the organic grain.

PUBLICATIONS

2009/09/01 TO 2010/08/31 1. Matanguihan, G.J.B., K. Murphy, S.S. Jones (2011). Control of common bunt in organic wheat. *Plant Disease* (in press) xx: xxx-xxx; 2. Lammerts van Bueren, T., S.S. Jones, L. Tamm, K. Murphy, J.R. Myers, C. Leifert, M.M. Messmer (2010). The need to breed crop varieties suitable for organic farming using wheat, tomato and broccoli as examples: A review. *NJAS - Wageningen Journal of Life Sciences* (in press) doi:10.1016/j.njas.2010.04.001

2008/09/01 TO 2009/08/31 1. Murphy, K., S. Jones, C. Miles (2009). Wheat variety trials in Western Washington. *Tilth Producers Quarterly*, Spring, 2009. 2. Miles, C., J. Roozen, S. S. Jones, K. Murphy, and X. Chen. 2009. Growing wheat in western Washington. Washington State University Extension Publication EM022E. <http://cru.cahe.wsu.edu/CEPublications/EM022E/EM022E.pdf>

2007/09/01 TO 2008/08/31 1. Murphy, K., P. Reeves, S.S. Jones. 2008. Relationship between yield and mineral nutrient content in historical and modern U.S. spring wheat cultivars. *Euphytica: The International Journal of Plant Breeding* 163: 381-390. doi: 10.1007/s10681-008-9681-x 2. Dawson, J.C., K. Murphy, S.S. Jones. 2008. Decentralized selection and participatory approaches in plant breeding for low-input systems. *Euphytica*. Vol. 160, no. 2. pp.143-154. 3. Hoagland, L., Murphy, K., Carpenter-Boggs, L., Jones, S. 2008. Improving nutrient uptake in wheat through cultivar specific interaction with *Azospirillum*. In Proceedings, Second Scientific Conference of the International Society of Organic Agricultural Research (ISO FAR), Modena, Italy. pp. 526-565. 4. Murphy, K., Hoagland, L., Reeves, P., Jones, S. 2008. Effect of cultivar and soil characteristics on nutritional value in organic and conventional wheat. In Proceedings, Second Scientific Conference of the International Society of Organic Agricultural Research (ISO FAR), Modena, Italy. pp. 614-617.

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Optimizing Biological Nitrogen Fixation in Organic Cropping Systems for Sustainable Nutrient Management

Accession No.	0206939
Subfile	CRIS\
Project No.	NYC-145561
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Fiscal Year	2009
Grant Amount	\$374,627
Grant Year	2006
Investigator(s)	Drinkwater, L. E.; Buckley, D. H.
Performing Institution	HORTICULTURE, CORNELL UNIVERSITY, ITHACA, NEW YORK 14853

NON-TECHNICAL SUMMARY

Biological nitrogen fixation is the major source of new nitrogen in organic agriculture, yet there has been almost no research devoted to understanding how organic management practices impact this process. Furthermore, few widely used, temperate green manures have been characterized in terms of their nitrogen fixing traits. Our research aims to understand how organic management strategies and their resulting long-term soil legacies interact with plant and microbial species to regulate nitrogen fixation and to assess the economic consequences of these interactions.

OBJECTIVES

The main goal of our project is to discover how the unique changes in the soil environment brought about by organic management impact N-fixation and apply this knowledge to improve management of leguminous green manure. We aim to investigate the complex interactions between soil environment, legume species and soil N-fixing microorganisms and develop management tools that can be used by organic farmers. In the course of this research we also develop a model system for using on-farm experiential learning as a technique for training undergraduates. Specific objectives for this proposal: 1) We will test hypotheses about how management-induced changes in the soil environment accruing over the long-term interact with microorganisms and plants that govern biological nitrogen fixation and assess the economic consequences of these interactions on working organic farms. 2) We will assess the nitrogen-fixing potential for a variety of novel legume species and legume/non-legume species mixtures that could be used in managing biological nitrogen fixation. 3) We will develop a management tool based on a quick, visual method for estimating total nitrogen content for key legume species. 4) We will develop and test methods for training undergraduates and graduate students in organic agriculture, on-farm research and small farm management through implementation of a structured experiential learning initiative, the Sustainable Agriculture Scholars Program.

APPROACH

The research will be conducted on organic farms that we have been studying for the past five years. The field sites have been under organic management for 2-24 years and provide a management induced fertility gradient that reflects the accrual of SOM that typically occurs under long-term organic management. We believe these fields on working organic farms provide an ideal backdrop for studies aimed at understanding the dynamics of biological N fixation (BNF) in organic production systems. A complex suite of factors govern BNF making it necessary to use a holistic approach to study this process in order to understand the role of management practices, environment, and plant and microbial species. We will use mass balances as an indicator of relative N abundance and as a key defining characteristic in our studies of organic farming systems. We have used this approach combined with a number of soil measurements that characterize soil organic matter and microbial traits as the basis for characterization of the N fertility status of our study sites. We will use ^{15}N natural abundance to measure N fixation rates in a number of legume species across a variety of organically managed farms. We will also conduct exploratory work on free-living N fixation on a limited number of organically managed farms. We will characterize the rhizobium communities in soils and in root nodules. A combination of culture-independent (i.e. molecular) and culture-based techniques, as we propose here, has been shown to be the preferred method to describe the ecology of complex microbial communities. The use of such a combined approach allows us to access both the culturable and un-culturable soil microbes that are likely responsible for much of the nutrient cycling that is so critical for organic farm functioning. Because much of this work will be conducted on working farms, we will also be able to conduct an economic assessment of these green manure crops that takes environmental variation into account. Economic assessments of cover crops have focused on comparisons with inorganic fertilizer costs and few studies have compared costs and benefits of organic N amendments with leguminous green manures. Economic assessments rarely incorporate environmental variation such as soil N fertility in comparing the value and costs of particular management practices. Finally, the integrated approach to our research goes beyond scientific inquiry. By linking our on-farm research to training of undergraduates, we will test a formalized experiential teaching approach. We also impact students who are likely to become key future players in nutrient cycling research, the cornerstone of organic management. Students that are chosen to participate in our program will not only become skilled in research techniques that answer critical questions asked by organic farmers, but will also learn to link this research to current issues in organic farm management.

PROGRESS

2006/09 TO 2010/08 OUTPUTS: 1) Samples and data from the 2009 field station experiment and the two on-farm trials were analyzed for total biomass production, weeds, total N content and % N fixed. The second experiment at the Freeville Ag. Experiment Station tested the five best-performing warm season legume species identified in the first screening experiment conducted in 2008. These cover crops were planted in early July and remained in the field for 2-4 months. The experimental design was a split-plot design, with four replicate blocks per field. The main treatment was legume species and the sub-treatments were monocultures of the legumes and non-legumes, and a replacement series of legume-non legume mixtures at different seeding ratios. In 2009 the viny legumes included: Forage Soybean (*Glycine max*, var. Tyrone), Cowpea (*Vigna unguiculata*), and Chickling vetch (*Lathyrus sativus*). The non-viny legume species were Berseem clover (*Trifolium alexandrinum*) and Crimson clover (*Trifolium incarnatum*). Buckwheat (*Fagopyrum esculentum*) and Japanese Millet (*Echinochloa frumentacea*) were grown in mixtures with both the viny and the non-viny legumes. The viny species were also grown in mixtures with Sorghum-Sudan (*Sorghum bicolor*), it was expected that the high biomass production and tall stature of Sorghum Sudan (*Sorghum bicolor*) could provide structure for the viny species to grow up against. The non-viny legumes were also grown with Flax (*Linum usitatissimum*). Two additional experiments were established with a smaller number of treatments in fields of two collaborating farmers who selected the cover crops they were interested in testing. The results were analyzed and summarized in a master's thesis by van Zyl. 2) We examined the significance of free-living diazotrophs in experimental plots that spanned a gradient of agricultural intensification across a matrix of tillage and crop management practices. PARTICIPANTS: Laurie Drinkwater: Laurie is the PD and in addition to her role in helping with the planning and implementation of the overall project, she is analyzing the N fixation results from the first cover crop experiment. Dan Buckley: Co-PI, with expertise in microbial ecology. Dan assisted with the supervision of Dr. Julie Grossman who was a post-doc on the project. She conducted research to characterize the bacterial communities in soybean nodules from organic and conventionally managed fields. Meagan Schipanski conducted the on farm experiments and completed her PhD in 2009. Ann Piombino: Ann is a Research Technician in the Drinkwater lab. She helped to collect biomass samples from the cover crop experiment, process and analyze the samples. Burtie van Zyl is a graduate student in the Drinkwater lab who conducted research on warm season nitrogen fixing cover crops for use in organic rotations. He completed his Master's degree in Spring 2010. Partner organizations: Northeast Organic Farming Association, New York, PO Box 880 Cobleskill, NY 12043-0880; Farmscape Ecology Program,

Hawthorne Valley Farm, Ghent, NY 12075, many collaborating farmers. TARGET AUDIENCES: The primary target audience for our project is organic farmers in the northeast, however some of the information we have generated is broadly applicable to all organic farmers who rely on nitrogen-fixing green manures to manage soil nitrogen fertility. Our secondary audience includes extension educators, farmer organizations and other researchers who are studying legume cover crops. We have undertaken a number of efforts to reach these audiences. Throughout the project we reached regional organic farmers through the workshop we presented at organic farmer meetings, including NOFA New York and NOFA Vermont as well as numerous field days and workshops sponsored by various Cornell University affiliated extensionists and researchers. In January 2010, we sponsored a half-day workshop at the NOFA New York meeting where we reported many of our findings to growers and extension educators. The information resulting from this research has also been included in a series of columns we produced for publication in various newsletters targeting farmers and extension educators (Northeast Organic Farming Association, New York, Cornell Small Farm Center, other NY extension newsletters). These newsletters target farmers in the northeast, particularly New York, including organic as well as conventional family farms. We continued to publish newsletter columns during this past year. In June 2011, the findings of this project will be included in a feature article to be published in The Natural Farmers, the flagship publication of Northeast Organic Farming Association that reaches thousands of organic farmers in the northeast region. PROJECT MODIFICATIONS: Nothing significant to report during this reporting period.

2008/09/01 TO 2009/08/31 OUTPUTS: 1. The second experiment was established at the Freeville Ag. Experiment Station to test the five best-performing warm season legume species. These cover crops were planted in early July and remained in the field for 2-4 months. The experimental design in both years was a split-plot design, with four replicate blocks per field. The main treatment was legume species and the sub-treatments were monocultures of the legumes and non-legumes, and a replacement series of legume-non legume mixtures at different seeding ratios. In 2009 the viny legumes included: Forage Soybean (*Glycine max*, var. Tyrone), Cowpea (*Vigna unguiculata*), and Chickling vetch (*Lathyrus sativus*). The non-viny legume species were Berseem clover (*Trifolium alexandrinum*) and Crimson clover (*Trifolium incarnatum*). Buckwheat (*Fagopyrum esculentum*) and Japanese Millet (*Echinochloa frumentacea*) were grown in mixtures with both the viny and the non-viny legumes. Because these species have moderate growth, stature and biomass production it was expected that these two species would not out-compete the non-viny legumes, while providing sufficient structure for the viny legumes to grow up against. The viny species were also grown in mixtures with Sorghum-Sudan (*Sorghum bicolor*), it was expected that the high biomass production and tall stature of Sorghum Sudan (*Sorghum bicolor*) could provide structure for the viny species to grow up against. The non-viny legumes were also grown with Flax (*Linum usitatissimum*). Two additional experiments were established with a smaller number of treatments in fields of two collaborating farmers. 2. Samples and data from the 2008 experiment were analyzed and the results were summarized and used to design the second experiment. These data were added into our data base for cover crop assessment tool development. 3. We participated in several field days and presented findings from the first year of cover crop experiments. In August 2009, we tested a multi-dimensional cover crop evaluation tool with about 20 growers at the annual Cornell Organic Cropping Systems Field Day. PARTICIPANTS: Laurie Drinkwater: Laurie is the PD and in addition to her role in helping with the planning and implementation of the overall project, she is analyzing the N fixation results from the first cover crop experiment. Meagan Schipanski conducted the on farm experiments and completed her PhD in 2009. Ann Piombino: Ann is a Research Technician in the Drinkwater lab. She helped to collect biomass samples from the cover crop experiment, process and analyze the samples. Burtie van Zyl is a graduate student in the Drinkwater lab who is conducting research to develop additional nitrogen fixing cover crops for use in organic rotations. Partner organizations: Northeast Organic Farming Association, New York, PO Box 880 Cobleskill, NY 12043-0880; Farmscape Ecology Program, Hawthorne Valley Farm, Ghent, NY 12075, many collaborating farmers. TARGET AUDIENCES: In addition to the undergraduates who participated in the Sustainable Ag. Scholars Program, the farmers who serve on the advisory committee and the farmer research collaborators we reached additional organic farmers through the workshop we presented at the NOFA meeting and a presentation on nitrogen fixing cover crops to growers in the Hudson Valley. The information resulting from this research has been included in a series of columns we produced for publication in various newsletters targeting farmers and extension educators (Northeast Organic Farming Association, New York, Cornell Small Farm Center, other NY extension newsletters). These newsletters target farmers in the northeast, particularly New York, including organic as well as conventional family farms. Workshops: Conducting your own on-farm experiments and trials. Organized by B. van Zyl and L.E. Drinkwater. Empire State Fruit and Vegetable Expo & Farmers' Direct Marketing Conference. Rochester, NY. Jan. 2009. (Attendance: 25) What can legumes do for you Understanding biological nitrogen fixation from the ground up! Empire State Fruit and Vegetable Expo & Farmers' Direct Marketing Conference. Rochester, NY. Jan. 2009. (Attendance: 60) Presentations: Drinkwater, L.E. 2009. Nutrient cycling processes in legume-based systems. 16th International Congress on Nitrogen Fixation, Big Sky, Montana, June 2009. Drinkwater, L.E. 2009. Evaluating cover crop performance in the field. Cornell Organic Cropping Systems Field

Day. August 2009. Van Zyl, B. 2009. Warm season cover crops: field demonstration. Cornell Organic Cropping Systems Field Day. August 2009. Drinkwater, L.E. 2009. Managing biological N fixation in grain rotations. Cornell Organic Cropping Systems Field Day: Grain Systems. November 2009. PROJECT MODIFICATIONS: Nothing significant to report during this reporting period.

2007/09/01 TO 2008/08/31 OUTPUTS: 1. Two screening experiment were conducted in 2008 comparing 8 different legumes as monocultures and in mixes with 5 non-legume species. These potential cover crops target the niche in vegetable rotations following early season vegetables. These cover crops would be planted in early to late July and would grow for 2-4 months. We are focusing on these warm season covers based on feedback we received from organic vegetable farmers. Several species included in the experiment were suggested by farmers who have experimented with them intermittently and felt that they were worth further study. Sample analysis began in November 2008 and will continue into 2009. A second follow up experiment is planned for 2009. 2. The rhizobial DNA from soybean and clover root nodules has been analyzed. The extracted soybean DNA was compared to soybean reference strains were obtained from the United States Department of Agriculture (Beltsville, MD) and included type strains and accessions of Bradyrhizobia japonicum inoculating soybean: USDA 31, USDA 76, USDA 94, USDA 110, USDA 122, USDA 123, and USDA 442. Both the soybean and clover strains were analyze using rep-PCR using BOX primers, nif-H gene PCR-RFLP, and standard phenotypic characterization of cultured isolates. A manuscript is currently in preparation. 3. Collaborative legume cover crop trial: In early fall of 2006, we collaborated with a cover crop trial that had been established in July 2006 to evaluate how two warm season green manures performed in monoculture and as intercrops with grasses. The treatments included two legume monocultures (forage soybean and cowpea) and intercrops of these legumes with each of two grass species (Japanese millet and sorghum sudangrass) for a total of 6 treatments. We have completed data analysis and are preparing a manuscript for publication. 4. We continued Sustainable Agriculture Scholars program for a second year. Three Cornell undergraduates were recruited in a competitive process to be Scholars in summer of 2008. These students were engaged in our research activities and participated in weekly structured meetings as in 2007, with some slight modifications. They also carried out a service-learning project 1 day each week with an agriculturally-focused host of their choice. Hosts this year included: 1) the Cornell student organic farm 2) the Tompkins County children's garden and 3) the Drinkwater laboratory. We expanded the options this year to include research in order to accommodate one student who was really interested in laboratory research. A second focus group evaluation was organized and facilitated by our collaborators in the Education Department. Two presentations on this program were given and a manuscript has been submitted to the Journal of Natural Resources and Life Sciences Education. PARTICIPANTS: Laurie Drinkwater: Laurie is the PD and in addition to her role in helping with the planning and implementation of the overall project, she is analyzing the N fixation results from the first cover crop experiment. Julie Grossman: Julie was a Research Associate with the Department of Horticulture until May 2008. She has been working on the Rhizobium characterization and is now an Assistant Professor at North Carolina State University. Ann Piombino: Ann is a Research Technician in the Drinkwater lab. She helped to collect biomass samples from the cover crop experiment, process and analyze the samples. Burtie van Zyl is a graduate student in the Drinkwater lab who is conducting research to develop additional nitrogen fixing cover crops for use in organic rotations. Kelley McCrudden, Lindsay O'Hara, Benjamin Plowe are undergraduates who participated in the Scholars Program in Summer 2008. Partner organizations: Northeast Organic Farming Association, New York, PO Box 880 Cobleskill, NY 12043-0880; Farmscape Ecology Program, Hawthorne Valley Farm, Ghent, NY 12075, many collaborating farmers. TARGET AUDIENCES: In addition to the undergraduates who participated in the Sustainable Ag. Scholars Program, the farmers who serve on the advisory committee and the farmer research collaborators we reached additional organic farmers through the workshop we presented at the NOFA meeting and a presentation on nitrogen fixing cover crops to growers in the Hudson Valley. The information resulting from this research has been included in a series of columns we produced for publication in various newsletters targeting farmers and extension educators (Northeast Organic Farming Association, New York, Cornell Small Farm Center, other NY extension newsletters). These newsletters target farmers in the northeast, particularly New York, including organic as well as conventional family farms. Workshops: What Can Legumes do for YOU Understanding Biological Nitrogen Fixation from the Ground Up. 2008 Conference of the Northeast Organic Farming Association, New York. January 2008. Presentations: Drinkwater, L.E. Managing nitrogen fixing cover crops in organic vegetable systems. Twilight meeting of Hudson Valley Ecological Farming group. July 2008. Grossman, J.M., Patel, M., and Drinkwater L. Promoting Sustainable Agriculture Careers for Undergraduates through a Collaborative Experiential Learning and Research Program at Cornell University: The Sustainable Agriculture Scholars Program. Association for the Advancement of Sustainability in Higher Education Conference, Oral presentation, Nov 9-11, 2008, Raleigh N.C. Grossman, Julie M., Meagan E. Schipanski, Maya R. Patel, and Laurie E. Drinkwater. The Sustainable Agriculture Scholars Program: Enhancing students' summer agroecological laboratory employment through structured experiential learning and reflection. Ecological Society of America Annual Meetings, Aug 3-8, 2008, Milwaukee, WI. PROJECT MODIFICATIONS: Nothing significant to report during this reporting period.

2006/09/01 TO 2007/08/31 OUTPUTS: Activities 1. In 2007, we completed the first set of experiments in 17 on-farm grain fields in order to measure how biological N fixation (BNF) varied across soil fertility. The six treatments were as follows: Annuals--1) field pea (*Pisum sativum*), 2) oat (*Avena sativum*); Perennials- 3) red clover (*Trifolium pratense*), 4) orchard grass (*Dactylis glomerata*); Mixes-5) annuals intercropped, and 6) perennials intercropped. The aboveground biomass was sampled in fall 2006 and spring 2007. BNF results from the fall sampling were analyzed. The legumes grown in mixtures with a grass maintained higher rates of nitrogen fixation than legumes grown in monoculture. Perennial red clover fixed more nitrogen than annual field pea. 2. We have isolated and purified rhizobial DNA from soybean and clover root nodules that were collected from replicated field trials on 4 organic farms and two conventional farms. This DNA has been used to investigate if a) there are differences in rhizobia populations across a wide spectrum of organic systems and management, and b) if the rhizobia in the nodule is from indigenous non-inoculant populations of rhizobia in the soil, or from inoculant added at the time of planting. Techniques currently being used to answer these questions include rep-PCR using BOX primers, nif-H gene PCR-RFLP, and standard phenotypic characterization of cultured isolates. We will discuss these projects and recruit new farmers for involvement during a workshop event on nitrogen fixation which we have organized for this January, 2008 annual NOFA meeting. 3. In early fall of 2006, we collaborated with a cover crop trial that had been established in July 2006 to evaluate how two warm season green manures performed in monoculture and as intercrops with grasses. The treatments included two legume monocultures (forage soybean and cowpea) and intercrops of these legumes with each of two grass species (Japanese millet and sorghum sudangrass) for a total of 6 treatments. Biomass samples were collected and analyzed for ¹⁵N abundance. In early 2007 a pot study was conducted to determine the B values for the two legume species. Results from this experiment are currently being analyzed. 4. A major activity of the past year was the initiation of the innovative Sustainable Agriculture Scholars program. Three Cornell undergraduates were recruited in a competitive process to be Scholars in summer of 2007. These students were directly involved in on-farm field and lab work within the project boundaries and participated in weekly structured meetings to critically discuss and learn about the research process and the larger context of sustainable agriculture. They also carried out a service-learning project 1 day each week with an agriculturally-focused host of their choice. Hosts included 1) the Cornell student organic farm, (2 students) and 2) the Tompkins County Master Composters Program. A focus group evaluation was organized and facilitated by our collaborators in the Education department in preparation for a published manuscript on the Sustainable Agriculture Scholars program so that others can replicate our program.

PARTICIPANTS: Laurie Drinkwater: Laurie is the PD and in addition to her role in helping with the planning and implementation of the overall project, she is analyzing the N fixation results from the first cover crop experiment. Julie Grossman: Julie is a Research Associate with the Department of Horticulture. She has been working on the Rhizobium characterization and coordinated the scholars program this past summer. Ann Piombino: Ann is a Research Technician in the Drinkwater lab. She helped to collect biomass samples from the cover crop experiment, process and analyze the samples. Abha Gupta, Lauren Maghram and Suzanna Konecky are undergraduates who participated in the Scholars Program in Summer 2007. TARGET AUDIENCES: The target audience that we reached this past year includes the undergraduates who participated in the Sustainable Ag. Scholars Program and the farmers who serve on the advisory committee and who are collaborating in the on-farm research components. We expect to broaden our audiences considerably during the coming year.

IMPACT

2006/09 TO 2010/08 Several key findings resulted from our experiment with legumes growing in monocultures and mixtures. As expected, there were significant differences in the performance of the five legume species in terms of both N fixation and weed suppression. In monoculture, Crimson Clover fixed the most N and it was also the most weed suppressive legume while cowpea fixed the lowest amount of N in both years. Interestingly, cowpea still produced significant biomass by accessing more soil N than any of the other legumes. The legumes in all the mixtures, except in the Buckwheat mixture, showed increased rates of N fixation compared to monocultures. Mixtures were not consistently more effective in suppressing weeds compared to monocultures. Instead, the weed suppressive capacity of the mixtures depended on the species involved. Buckwheat mixtures were the most weed suppressive. Because of the replacement series design used in our experiment, we were able to rank the competitive ability of the non-legumes. The competitive ability of the non-legumes can be ranked as follows: Buckwheat > Sorghum Sudan > Japanese Millet > Flax. In general there was a functional trade-off between N fixation and weed suppression: mixtures that are effective at suppressing weeds (Buckwheat mixtures) also suppress legumes and legumes that are competitive (Cowpea) in mixture do not fix a lot of N. In mixtures containing species with complementary growth times (Clovers and Sorghum Sudan / Buckwheat), mowing the competitive non-legumes after they reached maximum growth increased legume biomass five-fold in

Buckwheat mixtures and two-fold in Sorghum Sudan mixtures. Nitrogen fixation increased eight- to ten-fold in clovers following Buckwheat mowing. Overall, our study showed that there is great potential to optimize N fixation while maintaining effective weed suppression through careful pairing of legume and non-legume species with complimentary functional traits. Our work on free-living N-fixation rates and diazotroph community composition showed that both were impacted by crop biomass management practices and by interactions between tillage and biomass management while soil characteristics were mainly driven by tillage. Total N-fixation attributed to free-living diazotrophs was highly dynamic both spatially and temporarily and ranged from approximately 0-20 kg N ha⁻¹yr⁻¹. The main cause of temporal variation in N-fixation rates could not be determined in the present study. However, when averaged across time, the data suggest that variation in diazotroph community composition has a greater impact on N-fixation rate than soil variables at the site. N-fixation rates displayed a saturating response to increases in diazotroph community richness and evenness and were lowest in soils with the highest levels of organic matter inputs and in which potential N-mineralization rates were greatest. These results show that changes in the community structure of free-living diazotrophs in soils can impact N-fixation rates.

****PUBLICATIONS (not previously reported):**** 2006/09 TO 2010/08 1. Buckley, D. H. (2010) Stable Isotope Probing Techniques Using ¹⁵N. In J. C. Murrell and A. S. Whiteley (eds.). Stable Isotope Probing and Related Technologies. ASM Press, Washington, D.C. 2. Buckley, D. H. (2010) Assessing the Diversity of the Unseen Majority. In Sigurdur Greipsson (ed.). Restoration Ecology. Jones and Bartlett Publishers, Inc., Boston. 3. Hsu, S., M. M. Stone, D. H. Buckley (2009) "Evidence for the Functional Significance of Microbial Diversity among Free-living Diazotrophs in Soils of a Long Term Agricultural Site" Published in the Proceedings of the Soil Science Society of America Annual Meeting. 4. Noar, J. and D. H. Buckley (2009) *Ideonella azotifigens* sp. nov., an aerobic diazotroph of the Betaproteobacteria isolated from grass rhizosphere soil, and emended description of the genus *Ideonella*. International Journal of Systematic and Evolutionary Microbiology 59:1941-1946. 5. Schipanski M.E., L. E. Drinkwater. (2010) Nitrogen fixation of red clover interseeded with winter cereals across a management-induced fertility gradient. Nutrient Cycling in Agroecosystems. In press. 6. Hsu, S. and D. H. Buckley (2009) Correspondence between diazotroph diversity and rates of nitrogen fixation in soil. International Society for Microbial Ecology Journal 3:124-136.

2008/09/01 TO 2009/08/31 1. Our work with the warm season cover crops is producing novel information on the interplay between biomass production, N fixation rates and the ability of these various species to suppress weeds. We are finding that in general, mixes that include a legume and non-legume species are most effective at suppressing weeds while also achieving at least moderate amounts of fixed N. The most interest mixes, which are already being tested by a few growers who have seen these plots during various field days are the clover-buckwheat mixes. These have the advantage of suppressing weeds as the buckwheat grows very quickly. Then the buckwheat can be mowed at flowering allowing the clover to grow very rapidly before cold weather sets in. This year, we were able to test some of these mixes in growers fields. We will be using these findings in a workshop we are organizing for organic growers to be held in January 2010. 2. The outcomes of the Sustainable Ag. Scholars Program spanned a range of changes in knowledge and actions. We piloted an educational model, the Sustainable Agriculture Scholars Program, linking research in organic agriculture to experiential learning activities for summer undergraduate employees in 2007 and 2008. Our objectives were to: (1) further student understanding of sustainable agriculture research, (2) increase student interest in sustainable agriculture careers, and (3) use community service as a vehicle for learning. The three learning environments were on-farm and laboratory research settings, weekly meetings and field trips to discuss research and observe farming practices, and a service-learning project. We collected feedback from participants through a post-program focus-group style evaluation in Year 1 and pre/post individual evaluations with participants and a non-participant comparison group in Year 2. Students learned about linkages between research and practice within all environments. Farm visits were the primary learning site, specifically through observations of sustainable agriculture practices related to lab work and interactions with farmers. Students described how farm visits made lab work relevant; however, there were few instances describing how lab work was relevant to farming communities. Our preliminary findings from this pilot study suggest that participation in the program led to increased interest in sustainable agriculture careers and increased desire to pursue research in some students. The outcomes of this pilot study have been published in the Journal of Natural Resources and Life Sciences Education.

2007/09/01 TO 2008/08/31 1. Our work with rhizobia isolates has shown that rhizobia isolated from conventional field nodules with either continuous corn or almost continuous corn have extremely reduced diversity compared to the isolates collected in organically managed fields. Fields with a diversity of legumes in the rotation seem to have greater rhizobia diversity, perhaps due to the background of inoculant rhizobia added in the rotation. It appears that the majority of strains in nodule community are most similar to *B. japonicum*. Early results for red clove indicate that these inoculants are also diverse, however a few of the strains matched closely with the inoculants. The preliminary take home message from this work is that organically managed fields support more

diverse communities of symbiotic N fixing microbes and that the microbes colonizing nodules are mainly derived from the soil rather than the inoculants. 2. The outcomes of the Sustainable Ag. Scholars Program spanned a range of changes in knowledge and actions. We developed and piloted an educational model, the Sustainable Agriculture Scholars Program, which linked scientific research in organic agriculture to structured experiential learning activities for summer undergraduate employees in 2007 and 2008. Our objectives were to: 1) further student understanding of the role of research in supporting sustainable agriculture, 2) increase student interest in agricultural career options, and 3) use community service as a vehicle for learning. Three students were selected for the summer program in each year. The three major learning environments were on-farm and laboratory research settings, structured weekly meetings and field trips to discuss research and observe farming practices, and a facilitated service-learning project with an agricultural organization. We collected student feedback through a post-program focus-group style interview with a third party in years one and two, and added a pre-program interview and a student comparison group in year two. Students reported learning about linkages between agriculture research and practice within all three environments, with farm visits being the primary site of this learning, specifically through observations of sustainable agricultural practices related to their lab work and interactions with farmers. Though students described ways in which farm visits made lab work seem more relevant, there were few instances describing how the lab work was relevant to the farming community. Four out of the six students reported increased interest in agricultural careers as a result of participating in the Program; three reported increased desire to pursue agricultural research. Service project discussions demonstrated students' sense of ownership and satisfaction about contributing to their community. This evaluation demonstrates the potential for this and other similar programs to foster interest in sustainable agriculture and agriculture research for undergraduates.

2006/09/01 TO 2007/08/31 Outcomes/Impacts 1. Our work with rhizobia isolates has increased our knowledge about the variation in rhizobia populations found in root nodules across organic farming systems that varied in years of organic management from 0 - 20 years. Rhizobia populations varied across the three farms from where soybean nodules were taken. Isolates from different farms were found to be only 50-60% similar, while rhizobia within a field were shown to be 75-95% similar to each other. At this point, we have no reason to believe that nodules that are formed on the lateral roots of the plant have different bacteria types within them than do nodules on the central crown portion of the root. As a whole, these results demonstrate that management may have a significant effect on population structure and thus also on amount of nitrogen fixed. We will soon have data allowing us to determine source of rhizobia, specifically if it was originally from the inoculant that organic farmer rely upon to ensure that an adequate population of rhizobia is available for nodulation at the time of planting. 2. The outcomes of the Sustainable Ag. Scholars Program spanned a range of changes in knowledge and actions. The three students in the program gained knowledge not only about laboratory and field research methods and data analysis, but also about the larger context of real world sustainable agriculture issues. We did this by organizing a weekly seminar in which the students learned about: organic farming practices (especially soil management) by touring working organic farms and talking with farmers, the role of extension in agricultural development through discussions with the Cornell Small Farms Program administration, and agricultural career options by hosting a workshop with the Cornell Career Services center. The focus group results demonstrated that each of the students had either changed career paths or become more interested in agricultural careers in sustainable agriculture, including research and extension. The impact of our program went beyond the three students involved, however, as many other lab groups with summer employees have shown interest in developing similar programs to help increase student excitement about their day-to-day laboratory activities, and increase awareness of the applied nature of agricultural research. Specific actions included 2 out of the 3 students continuing to be engaged in research on organic farming systems in the Drinkwater lab into the school year, and all students taking classes that were related to sustainable agriculture the following semester. The published manuscript which we will be working on in year 2 will make the findings of this experiential learning approach available to other laboratories to replicate at a larger scale.

PUBLICATIONS

2008/09/01 TO 2009/08/31 Grossman, J. M., M. Patel, and L. E. Drinkwater. 2009. Enhancing Undergraduate Agro-Ecological Laboratory Employment through Experiential Learning. *Journal of Natural Resources and Life Sciences Education*. In press.

2007/09/01 TO 2008/08/31 No publications reported this period

2006/09/01 TO 2007/08/31 No publications reported this period

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Out-of-season Small Fruit Production for Improved Profitability of Organic Farming

Accession No.	0207479
Subfile	CRIS\
Project No.	GEO-2006-02052
Agency	NIFA GEO
Project Type	OTHER GRANTS
Project Status	TERMINATED
Contract / Grant No.	2006-51106-03615
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Fiscal Year	2009
Grant Amount	\$313,515
Grant Year	2006
Investigator(s)	van Iersel, M.; Krewer, G.; Horton, D.
Performing Institution	HORTICULTURE, UNIVERSITY OF GEORGIA, 110 RIVERBEND ROAD

NON-TECHNICAL SUMMARY

In the southeastern USA, organic fruit production is challenging due to variable weather conditions and great pest and disease pressure. Plastic tunnels offer a means of reducing these production risks, while simultaneously enhancing profit potential by extending the market season into more lucrative periods. This project examines the feasibility of using protected cultivation in plastic tunnels as a means of producing high quality, organic blueberries, blackberries, and raspberries under southeastern conditions. On-farm demonstration trials will extend the research to prospective clientele.

OBJECTIVES

The overall goal of the proposed research and outreach activities is to enhance the sustainability of organic farming using protected cultivation for high-value small fruit crops. High tunnels provide a means of 1) producing crops out-of-season for increased profitability, 2) increasing quality grade of fruit, 3) reducing delays in cultural activities and harvest due to rainfall, 4) reducing disease pressure and the need for fungicide application. By shifting production either earlier or later in the season, workload and cash flow are spread more evenly among seasons. Therefore, the proposed project addresses the following USDA-IOP Priority Areas for 2006 funding: Facilitate the development of organic agriculture production Evaluate the potential economic benefits to crop producers who use organic methods Objective 1) Determine management practices for out-of-season organic blueberry and blackberry production in high tunnels in the southeast. Existing practices for greenhouse management of raspberries will be adapted to southeastern conditions. Objective 2) Perform an economic analysis of all three crops to determine the economic feasibility of out-of-season small fruit production as a means of supplementing income of existing organic or conversion farms. Objective 3) Incorporate this research-generated knowledge of out-of-season organic small fruit production in high tunnels for the southeastern USA into a multi-dimensional Extension program.

APPROACH

The research involves multi-institutional cooperation between Georgia and Arkansas. Each institution will focus on separate crops as detailed below, so that a complete management plan can be developed at one location. Also, each institution will create an organic farm site, following certified organic regulations, on Experiment Station property to conduct the research. These areas will be 1-2 acres in size, and will contain high tunnels where crops will be grown.

A. Blueberry, Athens GA. The high density, pine bark bed method of culture will be employed for the phase 1 research. Pollination will be accomplished with bumble bee colonies. Historical data for Watkinsville, GA, where the research will be conducted, shows an average of 398 chill hours accumulated by 15 December over the last 4 years, with a minimum of 290 and maximum of 528. This is ample for the low chill southern highbush cultivars to be considered (< 300 hrs). There will be 4 treatments with 2 replications each, with a two 36-ft long parallel beds constituting a replicate. Treatment 1: Control, no tunnel application Treatment 2: Tunnel with plastic applied on 15 December Treatment 3: Tunnel with plastic applied on 2 January Treatment 4: Tunnel with plastic applied on 15 January The following data will be collected during trials in years 1 and 2: Plant growth, Fruit yield and quality, Insect and pathogen populations, Microclimate effects of tunnels, and Economics.

B. Blueberry farm trial, Homerville, GA. Horner Farms, Inc., of Homerville, GA, has been chosen for phase 2 of the study. One 3-bay Haygrove tunnel will be installed over part of the planting in the autumn prior to year 3 of the project. Each bay of the structure can be enclosed in plastic separately, allowing 3 timing treatments, similar to phase 1. Treatments will be 1) uncovered blueberries on the same farm, 2) tunnel applied after 300 chill hours have accumulated (late Dec), 3) after 400 hours (mid-January), and 4) after 550 hours (late January). Yield, quality, timing of harvest, pest and disease pressures, and labor and inputs will be measured as described for phase 1.

C. Blackberry and raspberry. Evaluation of high tunnel blackberry and raspberry production will occur in 2 phases. In phase 1, detailed studies will be conducted at the Organic Unit at the Horticultural Research Farm in Fayetteville, AR in high tunnel units as described above. In phase 2, the best management practices resulting from phase 1 will be implemented in on-farm trials by organic producers in Elkins and Greenland, AR.

- phase 1: Two approaches will be taken; the first will study advanced production by using high tunnels in the spring, and the second will study extended production in fall by applying tunnels to crops in October. Data collected will be similar to that described for blueberry.

- phase 2: Trials similar to those described above will be established on two organic producer sites in Arkansas. Janet Bachmann, and Bill and Michele Morgan were selected since they are experienced producers in the Fayetteville area.

PROGRESS

2006/07 TO 2009/07 OUTPUTS: Activities: Studies with blueberries in high tunnels were conducted in Georgia, while studies on high tunnel production of raspberries and blackberries were conducted in Arkansas. All data collected from the blueberry trials have been analyzed, while the final data on blackberries are still being collected at this time. Information from these studies was used to develop interactive production budgets for organic high tunnel blackberry and raspberry production. Teaching activities that were part of the project includes mentoring of two MS students, and the involvement of undergraduate students in this research. The high tunnels at the University of Georgia were also used as part of the new organic agriculture teaching program. These high tunnels have become an integral part of this teaching program. Four graduate students in horticulture and plant biology used the blueberry planting as part of a class research project. The aim was to quantify the effect of high tunnels on diurnal changes in soil, air, leaf, and flower bud temperatures.

Events: An open house, focusing on organic production in high tunnels was held at the University of Georgia's horticulture farm with approximately 60 growers attending. Presentations about this research were given at grower and scientific meetings. Products resulting from this research include two students who received their MS degrees while working on this project (B. Haywood at the University of Arkansas worked on production budgets for blackberries and raspberries in high tunnels, while A. Ogden at the University of Georgia studies blueberry production in high tunnels. A website with information regarding high tunnels and organic production was developed as part of the open house in Georgia (<http://www.hortphys.uga.edu/hightunnel.html>). The website contains all presentation from the open house, which can be downloaded in PDF format. The project goals and opportunities for high tunnel alternate season production of blackberries were presented at talks at the Arkansas-Oklahoma Horticulture Industries Meeting and Trade Show (January, 2007), and at a blackberry production workshop (June, 2007). Two Excel spreadsheets were developed to allow growers to do an economic analysis of the organic production of blackberries and raspberries in high tunnels.

PARTICIPANTS: Nothing significant to report during this reporting period.

TARGET AUDIENCES: The target audience for this project consisted of organic growers in the Southeast, and specifically owners of small farms who would benefit from an extended harvest season to spread out cash flow over a longer period. These growers were actively engaged through open houses or workshops in Arkansas and Georgia.

PROJECT MODIFICATIONS: Project modifications were minimal. Collaboration with students in an ecophysiology class at the University of Georgia allowed for more extensive measurements of plant, air, and soil

temperatures than initially planned. An economic analysis of blueberry production in high tunnels was not possible, because field-grown plants never yielded. The cultivars used in this study flowered early, exposing the field-grown flowers and young fruits to freezes. Therefore economic comparisons between high tunnel and field production were not possible. The main benefit for high tunnel production of blueberries appears to be risk management (protection from adverse weather), but quantifying this would require long-term studies.

2007/07/15 TO 2008/07/14 OUTPUTS: Results of this project have disseminated to diverse audiences in presentations and publications, as well as field tours of the trial planting. Presentations were made at a regional producer conference, the Oklahoma-Arkansas Horticulture Industries show. Presentations were made at the Southern Region of the American Society for Horticultural Science (published abstract), and at a national horticultural science meeting, the 2008 Annual Meeting of the American Society of Horticultural Science (three published abstracts), and an International Controlled Environment Agriculture meeting (published abstract). A presentation was made at the International Society for Horticultural Science Symposium on Organic Fruit Production in conjunction with the World Congress of the International Federation of Organic Agriculture Movements in Modena, Italy, with a report of preliminary observations published. A field day for regional producers was held in Arkansas in November 2007, with a field tour of the plot. The Arkansas research plot was toured by the Student Organic Farm Project - GroGreen, of the University of Arkansas. Three different academic classes have toured the Arkansas research trial. The University of Georgia research plots have been toured by students in the organic certificate program and the Horticulture Graduate Student Association Master Gardeners have toured the plantings in both Arkansas and Georgia, and assisted with data collection. PARTICIPANTS: Hector German Rodriguez and Brittany Haywood have joined the team at the University of Arkansas. Mr. Rodriguez is a PhD student and Ms. Haywood is an MS student in the Department of Agricultural Economics and Agribusiness of the University of Arkansas. They will assist in the economic assessment of small fruit production in high tunnels. At the University of Georgia, graduate students Carrie Eaton, Jongyun Kim, and Anna Sugiyama cooperated with the team members to study leaf, flower, and soil temperature fluctuations in detail. TARGET AUDIENCES: Nothing significant to report during this reporting period. PROJECT MODIFICATIONS: Two project modifications have been made in Arkansas during this reporting period. The floricanne fruiting blackberry cultivar Apache did not establish well, and in the time since the proposal of this project, has lost commercial favor. It has been replaced with Ouachita and those plots are 1 year behind other cultivars in development. The second modification is in the primocane fruiting studies. In an effort to delay flowering and fruiting, and to create harvest synchrony, primocane fruiting genotype plots have been subdivided for pruning studies used to delay flowering and fruiting.

2006/07/15 TO 2007/07/14 OUTPUTS: The focus of our activities during year 1 has been on construction of the high tunnels in Georgia and Arkansas and on getting the small fruit crops established in the high tunnels and control plots. Six high tunnels and two control plots with two cultivars of blueberries were established on the University of Georgia Horticulture farm. Blueberries were planted in the fall of 2006, allowing for small yields in the spring of 2007. A 2/3 acre high tunnel with blueberries was established at Horner Farms in Homerville, GA, almost 2 years ahead of schedule. Here the high tunnel was erected over an existing bearing blueberry crop, allowing for significant yield in the spring of 2007. However, this 2/3 acre tunnel was not finished until early February, too late to see maximum effects of high tunnels on achieving early yields. However, we were able to collect valuable data on the use of high tunnels for freeze protection. Flower development and yield data were collected at both sites. Three high tunnels with three floricanne and three primocane cultivars of both blackberries and raspberries were constructed at the University of Arkansas and yield and berry size were determined in the fall of 2006. Plant survival was poor in the summer of 2006 due to uncharacteristically hot weather and some of the plants had to be replaced in March 2007. In both Arkansas and Georgia, the effects of high tunnels on environmental conditions were studied. An additional objective of this project is to do economic analyses of these high tunnel production systems, but we do not have sufficient data yet to do so. The project goals and opportunities for high tunnel alternate season production of blackberries were presented at talks at the Arkansas-Oklahoma Horticulture Industries Meeting and Trade Show (January, 2007), and at a blackberry production workshop (June, 2007). PARTICIPANTS: Andrew Ogden, a MS graduate student, has worked on the blueberry project in Georgia. Greg Cousins, an undergraduate student, has helped as well. This has provided valuable research experience for both.

IMPACT

2006/07 TO 2009/07 Important new knowledge generated as part of this project includes a better understanding of how high tunnels modify the microclimate. The perception has been that high tunnels heat up during the day and retain that heat at night, providing freeze protection to the crops inside the tunnels. We found that high tunnels heat up quickly during sunny days, but the heat is not retained at night. The minimum temperatures inside high tunnels may actually be lower than outside, especially on clear nights. Radiative heat loss and the small air volume of high tunnels combine to produce rapid cooling of the air in high tunnels. Our finding that tunnels do not provide freeze protection is important, because many potential crops for high tunnel production are susceptible to freeze damage. The use of propane heat can be an effective, but expensive method to warm high tunnels at night. Additional study of freeze protection and supplemental heating in high tunnels is necessary. High tunnels were found to speed up vegetative and reproductive development of blueberries. Tunnels were effective at advancing the spring harvest of highbush blueberries and the summer harvest of florican blackberries and raspberries. Tunnels also extended the season of autumn-producing primocane blackberries and raspberries. Overall, tunnels advanced spring production and extended fall production of blackberries and raspberries, increasing total harvest and berry size. Without supplemental heat, spring production was advanced 2.5 weeks. The plants required supplemental heat to prevent crop damage. When ambient temperatures dropped below -5 C the heating system did not protect the crop. Economic analyses demonstrated greater investments and costs for tunnel production, the increased marketing season, spreading and reducing seasonal risk, and managing labor force, the opportunities for tunnel berry production appear. The best approach may be for some production tunnel and field production of spring/summer florican genotypes with a portion of autumn tunnel production. Selection of genotypes specifically for advanced spring production and extended autumn production of blueberries, blackberries, and raspberries is needed. Horner farms, a commercial organic blueberry grower cooperating on this project, has learned how to use high tunnels for the protection of their crop. They have been able to protect their crop from freezes by using propane heaters inside the tunnels, while the high tunnels also have been valuable in protecting the crop from hail. In tow of the three years of this research, field-grown blueberries were severely damaged by adverse weather conditions, while the high tunnels provided protection to the plant grown in them. This project has improved the infrastructure at the University of Georgia and the University of Arkansas. Upon completion of the research, the high tunnels in Georgia became an integral part of the organic teaching program, assuring that these students will get hands-on experience with high tunnels. The tunnels in Arkansas will be used for future research into high tunnel production of small fruits. **PUBLICATIONS (not previously reported):**

- 2006/07 TO 2009/07 1. Aselage, J. and D.T. Johnson. 2008. Chapter 39: From IPM to organic and sustainable agriculture, pp. 489-505. In E.B. Radcliffe, W.D. Hutchison and R.E. Cancelado (eds.), *Integrated Pest Management*, Cambridge University Press.
2. Ogden, A.B. J. Kim, C.A. Radcliffe, M.W. van Iersel, L.A. Donovan, and A. Sugiyama . 2010. Leaf and bud temperatures of southern highbush blueberries (*Vaccinium corymbosum*) inside high tunnels. *Acta Hort.* (in press).
3. Ogden, A.B. and M.W van Iersel. 2009. Southern highbush blueberry production in high tunnels: environmental conditions, development, yield, and fruit quality. *HortScience* (in press).
4. Rom, C. R., M.E. Garcia, D. T. Johnson, J. Popp, H. Friedrich, and J. McAfee. 2009. Organic Production of blackberries and raspberries in high tunnels. *Acta Hort.* (in press).
5. Johnson, D, B. Lewis, C.R. Rom, H. Friedrich, R. Bryant, and Maciej Pzsczolkowski. 2009. Organic fruit production needs and pest management practices in the southeastern united states. *Acta Hort* (in press).
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2007/07/15 TO 2008/07/14 Research in Arkansas has focused on blackberry and raspberry production in high tunnels. As it takes two to three years for a newly planted blackberry and raspberry field to reach productive maturity, the full output and impact of the project is yet to be seen. The data developed from this project, and the demonstration and workshops associated with the project have led to growers planting organic blackberries and the installation of high tunnels. Growers who have recently planted organic blackberries and installed high tunnels have not yet achieved production. A one-day organic fruit production workshop and field day was held in November 2008, with a major emphasis on high tunnel bramble production. Over 100 growers and Extension agents, from Oklahoma, Missouri and Arkansas, were in attendance. Evaluation feedback was enthusiastic and attendees requested more organic workshops. Efforts in Georgia focus on blueberry production in high tunnels. As part of this research several important constraints for blueberry production in high tunnels have been identified. Early blueberry yields necessitate early flowering, and flowering in high tunnels may occur during a period when freezing temperatures are common. We have found that high tunnels by themselves provide little or no protection against freezing temperatures, but the use of high tunnels makes it feasible to use heaters in the high tunnels to prevent freezing damage. Pollination is another important issue. Because flowering may occur before there is much activity from natural pollinators or honey bees, we have used bumblebees for pollination. However in 2008, bumble bee colonies used in both North and South Georgia were not very active, resulting in poor fruit set. Thus more effective pollination methods would be beneficial. Lately, market access is a critical issue. High tunnels may be used for the early production of organic blueberries. However, packing sheds in South Georgia do not open early enough in the year to handle the earliest blueberries from high tunnels. Since most of Georgia's blueberry production is in areas of Georgia with a small local market, the lack of marketing options for early season blueberries is a serious problem.

2006/07/15 TO 2007/07/14 In Athens, GA, we studied the effect of the timing of high tunnel closure on blueberries. Tunnels were covered with plastic on December 16, January 2, or January 20 and 'Emerald' flowered January 8, 11, and 21, respectively. 'Emerald' in the outdoor plots flowered January 26. Despite earlier flowering in high tunnels that were closed earlier, blueberries in all tunnels ripened at the same time, starting in late April, with harvest continuing through May. Early yields were similar in all tunnels, irrespective of when they were closed. Throughout May, yields were higher in tunnels that were closed later, resulting in highest yields in tunnels that were closed on January 20. Due to the Easter freeze of 2007, all outdoor fruit was lost. Freeze protection in the tunnels was achieved with propane heaters. The high tunnel at the commercial farm in South Georgia was not finished until the second week in February, and its maximum effect on fruit ripening was not seen. Nonetheless, fruit ripening in the high tunnel was advanced by about one week. The data in South Georgia provided valuable information regarding the effect of high tunnels on microclimate. Without heat, the closed tunnels increased air temperature by about 2 F compared. During the 17 Feb. freeze the outside temperature dropped to 22 F and the inside temperature to 31.5 F. The high tunnel was heated with just one 155,000 BTU propane heater. The 17 Feb. freeze destroyed about 50% of the advanced flowers outdoors, but there was little damage in the high tunnel. The tunnels also were effective for preventing damage during the Easter freeze. Fruit yields were greatly increased by use of the tunnels. Outdoor 'Millenia' yield was 1.03 lbs versus a tunnel yield of 3.09 lbs per bush. Outdoor 'Star' yield was 1.41 lbs versus a tunnel yield of 2.05 lbs per bush. The objective of the research done in Arkansas was out-of-season organic blackberry and raspberry production. Although no yields were expected in the year 1, because of the growth of the primocane fruiting blackberries, yield data were collected. High tunnel yields were increased in the range of 400% ('Prime-Jim') to 77% ('Prime-Jan') with an average increase of 65% compared to outdoor plots. Part of the yield increase was due to increased berry size. High tunnels also extended the season of flower formation and harvest. While yields outdoors started decreasing in the middle of October, yields in the high tunnels did not peak until the end of October. We have found in both Arkansas and Georgia that the effect of high tunnels on the microclimate is not easy to predict. Although nighttime temperatures inside the high tunnels are generally higher than outside, on some nights the tunnels are cooler. We plan to look at the use of row covers to provide additional, and more economical, freeze protection.

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