SCRI-SREP Project CRIS Report
Biodegradable Mulches for Specialty Crops Produced Under Protective Covers
No Cost Extension Period, September 1, 2012 – August 31, 2013

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CONTRACT/GRANT/AGREEMENT NO: 2009-51181-05897
PROPOSAL NO: 2009-02484
START: 01 SEP 2009 TERM: 31 AUG 2013 GRANT YR: 2012-2013 GRANT AMT: $1,999,002

OUTPUTS

Activities: Numerous presentations and publications, delivered and completed.

One undergraduate independent study at UTK on "Identification of Native East Tennessee Micro-organisms Capable of Utilizing Biodegradable Mulches as a Carbon Energy Source," and two undergraduate engineering design projects on improving structural design of high tunnels (UTK and WSU), finished.

At Western Washington University, 12 undergraduate students received research credits for project participation

Events: Information about biodegradable mulches (BDMs) and high tunnels delivered to local, regional, national and international audiences via (i) classroom settings; (ii) extension presentations, field tours and workshops; and,(iii) scientific abstracts, meetings, seminars, and invited presentations.

The Project Director invited and gave presentation at SCRI Project Director's Workshop at ASHS Annual meeting at Palm Desert, CA on July 22.

Services: Six graduate students trained (3 Ph.D. and 3 M.S. graduated); 25 undergraduate students trained by project personnel.

Products: A public website http://mountvernon.wsu.edu/hightunnels on high tunnels and crops mulches maintained specifically for Pacific Northwest, High Plains, and Southeast regional audiences. In addition, the co-PD coordinated the revision of the national website www.hightunnels.org to further disseminate new project information.

A soil quality index calculated with Soil Management Assessment Framework Model (for microbial biomass C, beta glucosidase activity, soil pH, total C, and EC) showed that the index was reduced only 1-

4 units after a single incorporation of mulches across the three field study locations (Knoxville, TN, Lubbock, TX, Mount Vernon, WA).

An experimental mulch prepared from the biopolymeric blend of PLA and PHA using meltblown nonwovens textiles technology underwent degradation in the presence of an active soil microbiological community and under simulated weathering, suggesting potential utility as a biodegradable agricultural mulch in the future.

An experimental mulch containing carbon black coloring and prepared from the biopolymer PLA using spunbond nonwovens textiles technology performed similarly to commercial plastic mulch for weed prevention, possessed superior resistance to tearing, and did not undergo appreciable deterioration during Knoxville, Lubbock, and Mount Vernon growing seasons; or, in 30 week greenhouse soil burial studies at UTK; or, during simulated weathering at WSU Pullman laboratory, suggesting utility for long-term sustainable agriculture.

An intermediary survey, "Biodegradable Plastic Mulches: Experiences and Opinions of Intermediaries," done across the project's target regions (published recently in Renewable Agriculture and Food Systems) will help guide research and education directions for the future.

An optimal threshold, or 'decision rule' was developed for growers', balancing decisions between the use of conventional plastic mulches and alternative biodegradable plastic mulches; the threshold, applied empirically to tomato production and Washington State used primary data were from SCRI field experiments and focus group sessions, and secondary data from USDA, WSDA, and other sources.

Production budgets were constructed for high tunnel lettuce, tomato and strawberry crops, and field grown lettuce and tomato crops in Washington; the budgets include the application and disposal costs for mulches, and provide important financial guidance governing grower's profitability (primary data obtained from SCRI field experiments and focus group sessions; secondary data from USDA, WSDA, and other sources).

Methods for isolation of potential biodegradable mulch-degrading fungal strains from native soils, as well as methods for verifying mulch degradation by fungi in pure culture, developed and published.

Native soil fungi isolated from buried mulches, evaluated for their potential to grow in pure culture with biodegradable mulches as a sole carbon source, and identified using 18S and ITS ribosomal RNA. 18S sequences were deposited into GenBank. Selected cultures are being deposited into the American Type Culture Collection.

Pyrosequencing used to assess the effects of biodegradable mulches on soil microbial communities. No effects on community structure were attributed to biodegradable mulches. The resultant sequence database deposited into GenBank.

OUTCOMES/IMPACTS

Knowledge:

A comprehensive data set now exists regarding stakeholders' experiences with and perceptions about biodegradable plastic mulches in the three study regions. Barriers to adoption include insufficient knowledge, high cost, and unpredictable breakdown; bridges to adoption include reduced waste, environmental benefits, and interest in further learning. A majority of surveyed growers are interested in working directly with scientists and extension agents in the future on mulch design, development, and dissemination while intermediaries (those who make production recommendations to growers) prefer to receive information via printed materials, field days, and farm tours (rather than one-to-one consultations, courses, large group meetings, and social media).

A total of 56 fungi and 28 bacterial isolates colonized four biodegradable mulches buried in field soil at the three study locations; some of the fungi physically degraded the mulches to some extent, even under

anaerobic and pure culture (no other carbon source) conditions. Most fungi that degraded the biodegradable mulches are oligotrophic, and some were potential producers of mycotoxins. There were no discernible effects of biodegradable mulches on soil fungal or bacterial communities after 6 months burial, however.

Experimental PLA mulches prepared using nonwovens textile technology underwent only the initial stages of biodegradation after burial in field soil for less than 1 year; during this time the supramolecular structure "opened up", as evidenced by a loss of tensile strength and elongation, the occurrence of macroscopic deterioration (e.g., rips and tears), the breakage of microfibers, and by a small (10-20%) decrease in the average molecular weight.

In situ degradation of commercially available starch-based biodegradable mulches after 2 yr incubation was variable across the three field study locations, and ranged from 2% at Lubbock to 49% at Knoxville, and over 89% of the original mulch area remaining at Mount Vernon. Experimental Spunbond-PLA-10 mulch degraded the least ($\leq$10%) across all three locations and its durability may have application for perennial and urban plant systems.

In general, starch-based mulches degraded more at Lubbock which differed from Knoxville and Mount Vernon by a higher maximum soil temperature and soil diurnal temperature range, alkaline soil pH, and a microbial community composed of a high relative abundance of saprophytic fungi.

No visible pieces of cellulose-based mulch were found after six months soil incorporation at Lubbock and Mount Vernon, or after 12 months at Knoxville (ie., 0% remaining at end of 2 yr study period).

Shifts in soil microbial community structure were affected less by the presence of buried mulch pieces than by geo-climate differences across the three study locations. After 6-mo field incubation of selected mulch treatments, pyrosequencing for bacterial and fungal assemblages differentiated mainly by geographic location. Bacterial assemblages that distinguished Lubbock from Knoxville and Mount Vernon, included *Rubrobacteraceae, Rubrobacter,* and members of the order Rhodospirillales and family *Flammeovirgaceae.* Compared to Lubbock and Knoxville, Mount Vernon had low relative abundance of *Nectriaceae, Fusarium,* and *Chaetomiaceae humicola* but high relative abundance of Ascomycota and unidentified fugal taxa.

Actions: High tunnels evaluated as a form of risk management (Economics WG); investments in high tunnels compared to traditional crop insurance provided similar protection against adverse risk (primary data obtained from SCRI field experiments and focus group sessions; secondary data from USDA, WSDA, and other sources).

Two team members (Hayes and Miles) invited to participate in ASTM International working group on developing a new standard for plastic biodegradability in soil.

Change in Conditions:

For Agricultural Norms – Fall planting of strawberries in high tunnels now provides a niche market in Tennessee and Texas where winter strawberry harvest would not otherwise be possible.

For Community – Sociological research findings can be used to guide the activities of those involved in the design, development, and promotion of biodegradable plastic mulches for specialty crop production systems. A few growers in WA planning to test biodegradable mulches on their farms as a result of Sociology focus group sessions. Tomato growers in western Washington can manage late blight organically for the first time by using open-ended high tunnels.

For Economics - High tunnels can produce higher tomato, lettuce and strawberry yields, relative to the open field, in the three field study regions. Higher crop yield can translate to increases in profitability

depending on the crop's production costs and market price. High tunnels also provide a mechanism by which small-scale farmers can utilize space more effectively to maximize profits without the use of government payments. High tunnels can provide a means of control for some plant diseases, but not all.

For Environment – Team research on adoption barriers and bridges to biodegradable mulches will be useful, given the inclusion of 'biodegradable bio-based mulch films' in U.S. National Organic Program Standards, now under consideration.

PUBLICATIONS

Abstracts and Proceedings (published or in press):

Cowan, J., C. Miles, K. Leonas, H. Liu, A. Saxton and D. Inglis. 2013. Evaluating visual assessments of mulch deterioration to predict changes in mulch mechanical properties. HortScience 48(9):S224.

Cowan, J., C. Miles and D. Inglis. 2013. Deterioration of three biodegradable plastic mulches before and after soil incorporation in a broccoli production system. HortScience 48(9):S223.

Galinato, S.P., C.A. Miles, and D.A. Inglis. 2013. Economic profitability of growing lettuce and tomato in western Washington under high tunnel and open field production systems. HortScience 48(9):S331.

Ji, X. Miles, C.A., Martin, J.T., Wallace, R.W., Wszelaki, A.L., Moore-Kucera, J., Inglis, D.A., and Lee, J. 2013. Effect of biodegradable mulches on environmental data collected from high tunnel and open field settings. HortScience 48(9):S335-336.

Martin, J.T. and Wszelaki, A.L. 2013. Assessment of degradable alternatives for plastic mulch for organic tomato production in the Southeast. HortScience 48(9):S126.

Powell, M., Gundersen, B., Miles, C.A., Cowan, J.S., and Inglis, D.A. 2013. The effect of an open-ended high tunnel production system on late blight of tomato in western Washington. Phytopathology 103(S3):15.

Extension Publications (published or in press):

Corbin, A., Miles, C., Cowan, J., Hayes, D., Inglis, D., and Dorgan, J. 2013. Biodegradable plastics as agricultural mulch. Washington State University Extension Fact Sheet: FS103E. 6 pages at https://pubs.wsu.edu/ItemDetail.aspx?ProductID=15552&SeriesCode=&CategoryID=&Keyword=mulch

Corbin, A.T., Miles, C., Cowan, J., Hayes, D., Moore-Kucera, J., and Inglis, D. 2013. Current and future prospects for biodegradable plastic mulch in certified organic production systems eOrganic: Available online May 2, 2013 at http://www.extension.org/pages/67951

Wallace, R.W. and Webb, C.J. 2013. High tunnels for crop production in Texas. Texas A&M AgriLife Extension Service Pub. No. HT-016. 12 p.

Wallace, R., Masabni, J., Gu, M., Porter, P., Nesbitt, M., and Palma, M. 2013. Crops for high tunnel production in Texas. Texas A&M AgriLife Extension Service Pub. No. EHT-029. 13 p.

Wszelaki, A., C. Miles, R. Wallace and E. Belasco. 2013. A Case Study on the Uses (and Abuses) of High Tunnels for Fruit and Vegetable Production. Proceedings of the 6th National Small Farm Conference, Memphis, TN. p. 43-46.

Wszelaki, A., Lockwood, D., and Martin, J. 2013. High tunnel strawberry production in Tennessee. University of Tennessee Extension Publication SP 754-A. 3 p.

Graduate Student Dissertations and Theses:

Cowan, Jeremy. 2013. The use of biodegradable mulch for tomato and broccoli production: Crop yield and quality, mulch deterioration, and growers' perceptions. Ph.D. Dissertation (Major advisor, C. Miles). Washington State University, Department of Horticulture. 204 p.

Dharmalingam, Sathishkumar. 201x. Fabrication of biodegradable agricultural mulches (Major advisor, D. Hayes). University of Tennessee at Knoxville. Biosystems Engineering. X p. (*awaiting publication*).

Jiang, Jingze. 2013. Economics of environmental and sustainable choices: Plastics and biodegradable products. Ph.D. Dissertation (Major advisor, T. Marsh). Washington State University, School of Economic Sciences. 165 p.

Li, C. 2013. *In situ* degradation of potentially biodegradable mulches under tomato production and impacts on soil health. M.S. Thesis (Major advisor, J. Moore-Kucera), Department of Plant and Soil Science, Texas Tech University, Department of Plant and Soil Science. 146 p.

Martin, J. 2013. The influence of organically managed high tunnel and open field production systems on strawberry (*Fragaria x ananassa*) quality and yield, tomato (*Solanum lycopersicum*) yield, and evaluation of plastic mulch alternatives. M.S. Thesis (Major advisor, A. Wszelaki). University of Tennessee, Plant Sciences Department. 128 p.

Powell, Marianne. 2013. Assessment of tomato and lettuce diseases in organically managed high tunnel cropping systems in western Washington and isolation of soil microbes potentially capable of biodegrading agricultural mulches. M.S. Thesis (Major advisor, D. A. Inglis). Washington State University, Department of Plant Pathology. 181 p.

Refereed Journal Articles (published or in press):

Bailes, G., Lind, M., Ely, A., Powell, M., Moore-Kucera, J., Miles, C., Inglis, D., and Brodhagen, M. 2013. Isolation of native soil microorganisms with potential for breaking down biodegradable plastic mulch films used in agriculture. Journal Visualized Experiments (75), e50373; available online doi:10.3791/50373.

Belasco, E., Galinato, S., Marsh, T., Miles, C., Wallace, R. D. 2013. High tunnels are my crop insurance: An assessment of risk management tools for small-scale specialty crop producers. Agricultural and Resource Economics Review 42/2, 403-418.

Cowan, J. S., Miles, C.A., Andrews, P.K., and Inglis, D.A. 2013. Biodegradable mulch performed comparable to polyethylene in high tunnel tomato (Solanum lycopersicum L.) production. Journal of the Science of Food and Agriculture: (*accepted November 22, 2013*).

Cowan, J.S., Miles, C., and Inglis, D. 2013. Deterioration of three potentially biodegradable plastic mulches before and after soil incorporation in a broccoli field production system in northwestern Washington. HortTechnology 23(6): (*in press for December edition*).

Galinato, S.P, and Miles, C. A. 2013. Economic profitability of tomato and lettuce in western Washington under open field and high tunnel production systems. HortTechnology 23(4): 453-461.

Goldberger, J.R., Jones, R.E., Miles, C., Wallace, R., and Inglis, D.A. 2013. Barriers and bridges to the adoption of biodegradable plastic mulches for US specialty crop production. Renewable Agriculture and Food Systems, 11 p; available online at doi:10.1017/S1742170513000276.

Powell, M., Cowan, J., Miles, C., and Inglis, D.A. 2013. Effect of a high tunnel, organic production system on lettuce diseases and yield in western Washington. Plant Health Progress Online. doi:10.1094/PHP-2013-0922-01-RS. http://www.plantmanagementnetwork.org/php/

~140,500 readership).

Powell, M., Gundersen, B., Miles, C., Coats, K., and Inglis, D. A. 2013. First report of Verticillium wilt on lettuce (*Lactuca sativa* L.) in Washington caused by *V. tricorpus* I. Plant Disease 97:996; available online at doi.org/10.1094/PDIS-12-12-1166-PDN.

Powell, M., Gundersen, B., Miles, C. A., Humann, J. L., Schroeder, B. K., and D. A. Inglis. 2013. First report of tomato pith necrosis (*Pseudomonas corrugata* Roberts & Scarlett) on tomato (*Solanum*

lycopersicum Mill) in Washington. Plant Dis.97(10):1381; available online at http://dx.doi.org/10.1094/PDIS-03-13-0265-PDN

Wadsworth, L,C., Hayes, D.G., Wszelaki, A.L., Washington, T.L., Martin, J., Lee, J., Raley, R., Pannell, C.T., Dharmalingam, S., Miles, C., Saxton, A., and Inglis, D.A. 2013. Evaluation of degradable spun-melt 100% polylactic acid nonwovens mulch materials in a greenhouse environment. Journal of Engineered Fibers and Fabrics 8(4): (*in press for December edition*).

Wallace, R.W, and Webb, C.J, 2013. Strawberries grown under protected cultivation on the Texas High Plains. Journal of the American Pomological Society 67(1): 7-10.

Publications Now Submitted or Under Review:

Cowan, J.S., Goldberger, J., Miles, C., and Inglis, D. 201x. Finding tactile space during an Extension field day event: The case of biodegradable plastic mulch. Agriculture and Human Values: (*in revision for resubmittal January, 2014*).

Hablot, E., Dharmalingam, S., Hayes, D.G., Wadsworth, L.C., Narayan, R., and Inglis, D.A. 201x. Effect of simulated weatherometry on physio-chemical properties and inherent biodegradation of PLA/PHA non-wovens mulches. Polymer Degradation and Stability (*submitted Oct 18, 2012*).

Jingze, J., and Marsh, T.L. 201x. Sustainable plastic mulch use and disposal decisions in agriculture. Ecological Economics (*submitted Jul 23, 2013*).

Li, C.H., Moore-Kucera, J., Lee, J., Corbin, A., Brodhagen, M., Miles, C., Inglis, D. 201x. Effects of biodegradable mulch on soil quality. Applied Soil Ecology (*submitted Nov 19*).

Li, C., Moore-Kucera, J., Miles, C., Leonas, K., Lee, J., Corbin, A., and Inglis, D. 201x. Degradation of potentially biodegradable plastic mulch films and influence of abiotic and biotic properties in the soil environment at three geographically distinct agricultural locations in the U.S. Agroecology and Sustainable Food Systems (*submitted Jul 5, 2013*).

Wszelaki, A., and Martin, J. 2013. Choosing a high tunnel in Tennessee: A comparison of high tunnel types and uses. University of Tennessee Extension Publication SP 754-B. X p. (*in review*).

Publications Nearing Submission (ie., first draft is complete):

Moore-Kucera, J., Cox, S.B., Peyron, M., Bailes, G., Kinloch, K., Karich, K., Miles, C., Inglis, D.A., and Brodhagen, M. 201x. Native soil fungi associated with compostable plastics in three contrasting agricultural settings. Applied Microbiology and Biotechnology (*completed; submitting ~Dec 1*).

Dharmalingam, Hayes (corresponding), Wadsworth, Dunlap, R.N., DeBruyn, J.M., Lee, J., and Wszelaki, A. L. 201x. Effect of soil moisture and microorganisms on physico-chemical properties and the degradation of PLA/PHA nonwovens mulches in greenhouse soil burial studies (*anticipated for Environmental Science & Technology*).

Jingze, J. 201x. Bandwagon effects on participation in voluntary environmental programs: A case of plastic bags reduction (*anticipated for Journal of Environmental Management and Economics*).

Jingze, J., Marsh, T.L. and Tozer, P.R. 201x. Volatility spillover effects from the energy and the corn market to the plastic markets (*anticipated for Energy Economics*).

Martin, J.T., Moore, J.L., and Wszelaki, A.L. 201x. Tomato cultivar comparison in organically managed high tunnel and open field production systems (*anticipated for HortTechnology*).

Powell, M., Gundersen, B., Cowan, J., Miles, C.A., and Inglis, D.A. 201x. The effect of high tunnels on late blight and physiological leaf roll of tomato in western Washington. Plant Disease: (*completed; submitting ~Dec 1*).

Publications Still in Preparation

Dharmalingam, Hayes (corresponding), Wadsworth, Miles, Inglis. 201x. On the time course of degradation of PLA/PHA-based nonwovens as agricultural mulches in soil burial studies (*anticipated for Journal of Polymer Degradation and Stability*).

Cowan, J.S., H. Liu, K.K. Leonas, L.C. Wadsworth, S. Dharmalingam, R. Dunlap, D. Hayes. 201x. Accelerated laboratory weathering of agricultural mulch products. Journal of Polymers and the Environment (*anticipated to be submitted Jan 2014*).

Cowan, J.S., Inglis, D.A., and Miles, C.A. 201x. Evaluating visual assessments of mulch deterioration to predict changes in mulch mechanical properties. Journal of Polymers and the Environment (*anticipated to be submitted Jan 2014*).

Lee, J., et al. 201x. Effect of biodegradable mulches on environmental data collected from high tunnel and open field settings (*anticipated for HortScience*).

Martin, J.T., Moore, J.L., and Wszelaki, A.L. 201x. Degradable alternatives for plastic mulch for organic tomato production in high tunnels and open field systems in the Southeast (*anticipated for Agriculture, Ecosystems and Environment*).

Walters, T. et al., 201x. Strawberry production under high tunnels in western Washington (*anticipated for HortTechnology*).

Wszelaki, A., Miles, C., Wallace, R., Walters, T., Martin, J., Cowan, J., and Inglis, D. 201x. Comparison of high tunnel types and functions: A case study (*anticipated for HortTechnology*).

PRESENTATIONS – (Local, Regional, National and International Audiences)

Tennessee Senior Authors:

Martin, J. March 13, 2013. "The influence of organically managed high tunnel and open field production systems on strawberry (*Fragaria x ananassa*) quality and yield, tomato (*Solanum lycopersicum*) yield, and evaluation of plastic mulch alternatives." M.S. Thesis Seminar, Department of Plant Sciences, University of Tennessee, Plant Sciences Department, Knoxville, TN *(~20 attendees*).

Martin, J. August 19, 2013. "Organically managed high tunnel and open field strawberry, tomato and lettuce variety trial research summary." University of Tennessee Crop Production Workshop Series: Organic Vegetable Showcase: Maximizing Your Investment from Variety Selection to High Tunnel Production, Knoxville, TN (*46 attendees*).

Wszelaki, A. January 8, 2013. "Overview of the Tennessee high tunnel program." Kentucky Fruit and Vegetable Growers Conference and Trade Show, Lexington, KY *(~150 attendees*).

Wszelaki, A. January 26, 2013. "High quality strawberry production in East Tennessee." Tennessee Horticultural Exposition, Nashville, TN (30 attendees).

Wszelaki, A. February 7, 2013. "Strawberries in December: Gardening year-round in tunnels." Master Gardener Winter School, Murfreesboro, TN (*174 attendees*).

Wszelaki, A. June 19, 2013. "Overview of the University of Tennessee Organic and Sustainable Crop Production Program." University of Tennessee Board of Trustees Meeting, Knoxville, TN (*~50 attendees*).

Wszelaki, A. July 22, 2013. "Assessment of degradable alternatives for plastic mulch for organic tomato production in the Southeast." Annual Meeting American Society for Horticultural Science, Palm Desert, CA *(~40 attendees*).

Wszelaki, A. August 6, 2013. "High tunnel strawberry production." University of Tennessee Steak and Potatoes Field Day, Crossville, TN (*110 attendees*).

Texas Senior Authors:

Li, C. May 28, 2013. *In situ* degradation of potentially biodegradable mulches under tomato production and impacts on soil health. M.S. Thesis Seminar, Department of Plant and Soil Science, Texas Tech University, Lubbock, TX (*25 attendees*).

Wallace, R.W. Oct 12, 2012. "Strawberries and other fruit crop opportunities with high tunnels." Texas Fruit & Nut Orchard Conference, Bryan, TX (*125 attendees; citation not included in Yr 3 report*).

Wallace, R.W. Dec 7, 2012. "Growing strawberries in high tunnels." Texas A&M AgriLife Extension Service. High Plains Ag Conference. Lubbock, TX (*20 attendees; citation not included in Yr 3 report*).

Wallace, R.W. Dec 11, 2012. "High and low tunnels for vegetables." Texas A&M AgriLife Extension Service, West Plains Ag Conference, Levelland, TX (*20 attendees; citation not included in Yr 3 report*).

Wallace, R.W. Feb 21, 2013. "Construction of high tunnels and strawberry production." Texas A&M AgriLife Extension Grower Meeting. Weslaco, TX (*15 attendees*).

Wallace, R.W. Feb 26, 2013. "High tunnel production in Texas." East Texas Commercial Fruit & Vegetable Conference. Tyler, TX (*250 attendees*).

Wallace, R.W. Mar 21, 2013. "High and low tunnels." Hale County Master Gardener Program. Plainview, TX (*10 attendees*).

Wallace, R.W. Mar 30, 2013. "High tunnel strawberry field day." Texas A&M AgriLife Research & Extension Center, Lubbock, TX (*50 attendees*).

Wallace, R.W. Apr 4, 2013. "High and low tunnels for vegetables." Texas A&M AgriLife Extension Center, Abilene, TX (*20 attendees*).

Wallace, R.W. Apr 5, 2013. "High tunnel strawberry production." Texas Fruit Growers Association. Wichita Falls, TX (25 *attendees*).

Wallace, R.W. Apr 6, 2013. "High and low tunnels for vegetable production." Texas A&M AgriLife Extension Service. Potter County Master Gardeners, Amarillo, TX (*10 attendees*).

Wallace, R.W. Apr 9, 2013. "High and low tunnels for vegetable production." Texas A&M AgriLife Extension Service. Dawson County Gardening Class, Lamesa, TX (*6 attendees*).

Wallace, R.W. Apr 16, 2013. "High and low tunnels for vegetable production." Texas A&M AgriLife Extension Service. Muleshoe Gardening Class, Muleshoe, TX (*15 attendees*).

Wallace, R.W. Apr 18, 2013. "High and low tunnels for vegetable production." Texas A&M AgriLife Extension Service. Swisher County Gardening Class, Tulia, TX (*20 attendees*).

Wallace, R.W. Apr 30, 2013. "High and low tunnels for vegetable production." Texas A&M AgriLife Extension Service. Tom Green County Master Gardeners, San Angelo, TX (*20 attendees*).

Wallace, R.W. May 18, 2013. "High and low tunnels for vegetable production." Texas A&M AgriLife Extension Service. Hemphill County Master Gardeners, Canadian, TX (*10 attendees*).

Wallace, R.W. Jun 5, 2013. "Gardening in the wind and heat." Texas A&M AgriLife Extension Service. Presentation online through Microsoft Lync (*30 viewers*).

Wallace, R.W. Jul 16, 2013. "High and low tunnels for vegetable production." Texas A&M AgriLife Extension Service. Cochran County Gardeners, Morton, TX (*5 attendees*).

Washington Senior Authors:

Brodhagen, M. Oct 7, 2013. "Biodegradable plastics and native soil fungi." Guest speaker for Vancouver Chapter Master Gardeners Association of British Columbia monthly meeting. Vancouver, BC Canada *(~100 attendees*).

Cowan, J. and Goldberger, J., October 15, 16, 19, and 22, 2012. "Biodegradable mulch demonstrations and focus groups." Washington State University NWREC, Mount Vernon, WA (*24 total attendees*).

Cowan, J. February 28, 2013. "Exploring biodegradable mulch for specialty crop production." Department of Horticulture, University of Wisconsin – Madison, Madison, WI *(~30 attendees*).

Cowan, J. April 4, 2013. "Exploring biodegradable mulch for specialty crop production." Ph.D. Dissertation Seminar, Department of Horticulture, Washington State University, Pullman, WA (*~60 attendees*).

Cowan, J. April 8, 2013. "Exploring biodegradable mulch for specialty crop production." Department of Horticulture, University of Georgia, Athens, GA *(~50 attendees*).

Cowan J.. and C. Miles. April 20, 2013. "Biodegradable mulch for crop production." Home and Garden Show. Klickitat County, WA *(~6 attendees*).

Cowan J.. and C. Miles. April 20, 2013. "High tunnel production." Home and Garden Show. Klickitat County, WA *(~8 attendees*).

Cowan, J. June 4, 2013. "Exploring biodegradable mulch for specialty crop production." Ferrum College. Ferrum, VA *(~20 attendees*).

Cowan, J. June 25, 2013. "WSU Spokane County Extension Regional Extension Horticulture: A plan for success." Spokane County Extension, Washington State University, Spokane, WA *(~20 attendees*).

Cowan, J., C. Miles, K. Leonas, H. Liu, A. Saxton and D. Inglis. July 25, 2013. "Evaluating visual assessments of mulch deterioration to predict changes in mulch mechanical properties." Annual Meeting American Society for Horticultural Science, Palm Desert, CA *(~20 attendees*).

Cowan, J., C. Miles and D. Inglis. July 25, 2013. "Deterioration of three biodegradable plastic mulches before and after soil incorporation in a broccoli production system." Annual Meeting American Society for Horticultural Science, Palm Desert, CA *(~20 attendees*).

Inglis, D.A. June 19, 2013. "The effect of an open-ended high tunnel production system on late blight of tomato in western Washington." Joint Meeting Pacific & Caribbean Divisions, American Phytopathological Society, Tucson, AZ (*~60 attendees*).

Inglis, D.A. July 18, 2013. "Achieving transdisciplinary success: Biodegradable mulches for specialty crops produced under protective covers." Brown Bag Seminar, WSU Mount Vernon NWREC (*~25 attendees*).

Inglis, D.A. July 22, 2013. "Achieving transdisciplinary success: Biodegradable mulches for specialty crops produced under protective covers." SCRI Project Director's Workshop, Annual Meeting American Society for Horticultural Science, Palm Desert, CA *(~15 attendees*).

Jiang, J. Apr 28, 2013. "Optimal plastic mulch use and disposal decisions in agriculture". Invited Seminar, Endinboro University, Endinboro, PA (*7 attendees*).

Jiang, J. May 17, 2013. "Voluntary rewards for consumers' participation in green practices: A case of plastic bags reduction." 47th Annual Pacific Northwest Regional Economic Conference Regional Competitiveness in the Global Economy, Spokane, WA (*12 attendees*).

Jiang, J. Oct.2, 2013. "Voluntary rewards for consumers' participation in green practices: A case of plastic bags reduction." International Conference On Applied Business and Economics, New York, NY (*20 attendees*).

Jiang, J. Oct. 5, 2013. "Risk spillovers in U.S. crude oil, corn and plastics markets" International Conference on Applied Business and Economics, New York, NY (*30 attendees*).

Mathes, D. Oct 7, 2013. "Biodegradable plastics." Guest speaker for Vancouver Chapter Master Gardeners Association of British Columbia monthly meeting. Vancouver, BC Canada *(~100 attendees*).

Miles, C. Oct. 7, 2012. "High tunnel vegetable production in the South Sound." Washington State University Thurston Co. Extension, Olympia, WA (*45 registrants; citation not included in Yr 3 report*).

Miles, C. Oct 29, 2012. "High tunnel vegetable production workshop." Washington State University Clark Co. Extension, Vancouver, WA (*75 registrants; citation not included in Yr 3 report*).

Miles, C.A. Jan 15, 2013. "High profits under high tunnels." Oregon Horticultural Society, Canby, OR (*150 registrants*).

Miles, C.A. Feb 15, 2013. "Biodegradable mulch for crop production." Johnson Community College, Overland Park, KS (*120 registrants*).

Miles, C.A. July 23, 2013. "Economic profitability of growing lettuce and tomato in western Washington under high tunnel and open field production systems." Annual Meeting American Society for Horticultural Science, Palm Desert, CA (*poster presentation; ~300 potential viewers*).

Miles, C.A. Jul 23, 2013. "Effect of biodegradable mulch on high tunnel and open field environments." Annual Meeting American Society for Horticultural Science, Palm Desert, CA (*poster presentation; ~300 potential viewers*).

Powell, M. November 14, 2012. "Disease outbreaks in high tunnels in western Washington, and isolation of microbes from agricultural mulches." M.S. Thesis Seminar, Washington State University, Pullman, WA (*~70 attending*).

Project Scientists (2012-2013):

Project Director and Co-Project Director: Debra Ann Inglis and Carol Miles, Washington State University (WSU) NWREC, Mount Vernon, WA.

Crops Working Group (WG): Annette Wszelaki (Leader), University of Tennessee (UTK), Knoxville, TN; Russell Wallace, Texas AgriLife Research & Extension Center, Lubbock, TX; Tom Walters, WSU Mount Vernon NWREC.

Economics WG: Tom Marsh (Leader), Suzette Galinato at WSU Pullman; Eric Belasco, Montana State University (MSU), Bozeman, MT.

Materials WG: Douglas Hayes (Leader), Larry Wadsworth at UTK; Karen Leonas at WSU Pullman.

Sociology WG: Jessica Goldberger (Leader), Department of Crop and Soil Sciences, WSU Pullman.

Soils WG: Jennifer Moore-Kucera (Leader) at Texas Tech University, Lubbock, TX; Marion Brodhagen, Western Washington University (WWU), Bellingham, WA; Andrew Corbin, WSU Snohomish County Extension; Jaehoon Lee, UTK.

Other Project Participants (2012-2013):

Ad Hoc Interest Groups: Terry Phillips, BIOgroupUSA, Inc., Palm Harbor, FL; Eric Menard, Dubois Agrinovations, Waterford (Ontario) CAN; Dick Mathes, Crown Films, Burlington, WA.
Note: not all directly involved during 2013 (no-cost extension period).

Graduate Students: Jeremy Cowan, Ph.D. (Horticulture, WSU); Sathish Dharmalingam (Ph.D. candidate, Biosystems Engineering, UTK), Jingze Jiang, Ph.D. (Economics, WSU); Chenhui Li, M.S. (Soils, TTU); Jeff Martin, M.S. (Horticulture, UTK); Marianne Powell, M.S. (Plant Pathology, WSU).

Industry Advisors: Robert Green, NatureWorks LLC, Cary, NC; Mark Williams, BioBag USA, Inc., Palm Harbor, FL. *Note: not all directly involved during 2013 (no-cost extension period).*

Scientific Advisors: John Dorgan, Colorado School of Mines; Lewis Jett, West Virginia University, Ramani Narayan, Michigan State University.
Note: not all directly involved during 2013 (no-cost extension period).

Stakeholder (grower) Advisors: George (Ben) Craft, Alm Hill Gardens, Everson, WA; Elizabeth Malayter, Farm2School, Rogersville, TN; Ashley Basinger, South Plains Food Bank, Inc., Lubbock, TX; Tom Thornton, Cloud Mountain Farm, Everson, WA.
Note: not all directly involved during 2013 (no-cost extension period).

Technical Support: C. Joel Webb (TX Agri-Life); Rachel Dunlap and Galina Melnichenko (UTK);

Hang Liu (WSU Pullman); Babette Gundersen, Jacky King, Jonathan Roozen, Don Wallace (WSU Mount Vernon)

Undergraduate Students: Dillon Avans, Rob Baldus, Rachel Dunlap, Andrew Veeneman, (UTK); Ryan Faulkner, Joseph Jonathan, Sindhuja Jujhavarapu and Ryan Kelley (WSU); Graham Bailes, Alex Batson, Andrew Ely, Molly Harris, Kate Healy Kalin Karich, Briana Kinash, Kevin Kinloch, Megan Leonard, Margaret Lind, Megan Leonard, Joseph McCollum and Maria McSharry (WWU).

Professional Development: Four team members attended ASHS annual meeting. Six graduate students (3 Ph.D. and 3 M.S.) and ~25 undergraduate students trained by project personnel and students gained uncommon experience in transdisciplinary research approaches.

Targeted Audiences: Targeted audiences were local, regional, national and international, and included both conventional and organic specialty crop growers who use high tunnels and mulches, as well as high tunnel and biodegradable mulch manufacturers. Audiences reached via various publications and a public website; and, via presentations in classroom settings, at extension meetings, during workshops and field tours, by mass media and on-line articles, at seminars; and, via scientific meetings and publications. Overall, 100,000+ people directly contacted and 3M+ people potentially impacted.

Deviations: In personnel - Dr. Karen Leonas left her position at WSU Pullman to chair a department at another university; Dr. Jeremy Cowan (Miles/Leonas' former graduate student on the project) was hired to help complete the writing of Leonas' manuscript. Dr. Jaehoon Lee's graduate student at UTK left his position and other team members likely will need to take responsibility for completing the writing of a manuscript. Dr. Tom Walters, small fruit horticulturist at WSU Mount Vernon also left his position, and other team members likely will need to take responsibility for completing the writing of a manuscript. Some other manuscripts from some team members also are still forthcoming.

Unexpected Outcomes:
Congresswoman DelBene (D, WA-1) highlighted project during hearings before The House Ag Committee (May 15, 2013, C-Span, http://www.c-spanvideo.org/clip/4451442) .

EPA P3 Award (G2013-P3-Q3s) of $15,000 to Hayes, D.G., DeBruyn, J., Lee, J., and Wadsworth, L.C. for "Eco-friendly additives for biodegradation of agricultural mulches," A National Student Design for Sustainability Focusing on People, Prosperity and the Planet (Phase I).

Former graduate students were hired: One into a tenure-track teaching/research position; one into a tenure-track extension/teaching position; one into a PhD program; one into a Plant Diagnostic Clinic; one as a Volunteer Coordinator for a student internship program.

Inglis and Miles on behalf of WSU and the project team accepted 2013 NIFA Partnership award for Innovative Programs and Projects.

National Organic Standards Board (NOSB) voted in October 2012 to recommend to NOP (National Organic Program) to approve biodegradable plastic mulch in U.S. organic production; team members contributed comments on some of the language and assumptions.

National Strawberry Sustainability Initiative (funding through University of Arkansas and the WalMart Foundation) Award of $158,391 to Wallace, R. for "Revitalization of Texas strawberry industry through identification of production constraints and introduction of new technologies."

UTK Ag Research Innovation Grants Program Award of $7,840 to Hayes, D., Wszelaki, A., De Bruyn, J., and Wadswoth, L. for "Planning Meeting for a USDA-SCRI CAPS Proposal: Versatile applications and end-of-life outcomes for biodegradable plastics in specialty crop production."

WSU CSANR BIO-Ag Program of $9,538 to Koenig, R., Miles, C., Hayes, D., and Inglis, D. for "Planning for a Phase II SCRI grant proposal on "Utilization and versatility of biodegradable agricultural materials in specialty crop production."

MEDIA INTERVIEWS

Inglis and Miles interviewed for *WSU News* Press Release, Nov 18 edition, "Researchers win national award for sustainable ag".

MOSES (Midwest Organic & Sustainable Education Service), May 2013 edition, linked to Corbin et al. e-Organic article,"Current and Future Prospects For Biodegradable Plastic Mulch in Certified Organic Production Systems."

AWARDS

UTK Undergraduate Student Team (Dillon Avans, Robert Baldus and Andrew Veeneman) were American Society of Agricultural and Biological Engineers' 2013 AGCO National Student Design Competition Finalists and 2nd Place Winners for their project on "Windproofing High Tunnels" (advised by D. Hayes and R. Wallace).

Co-PDs, Inglis and Miles, on behalf of WSU and the project team, received 2013 NIFA Partnership Award for Innovative Programs and Projects. November 17, 2013. Annual Meeting Association of Public and Land-Grant Universities, Washington D.C.