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## RESEARCH AND EXTENSION PRIORITIES TO ENSURE ADAPTATION OF HIGH TUNNELS AND BIODEGRADABLE PLASTIC MULCH IN THE UNITED STATES

C. Miles<sup>1</sup>, C. Beus, A. Corbin, R. Wallace, A. Wszelaki, H. Saez, T. Walters, K. Leonas, M. Brodhagen, D. Hayes and D. Inglis

<sup>1</sup>Department of Horticulture and Landscape Architecture, Washington State University, WSU Mount Vernon NWREC, 16650 State Route 536, Mount Vernon, WA 98273

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### **Abstract**:

High tunnels and plastic mulch are successfully used throughout the world to increase productivity of high-value specialty vegetable and fruit crops. Currently these technologies are not widely used in the Pacific Northwest (PNW), Mid-South and Southeast regions of the United States. In order to better understand the current status of grower knowledge and use of high tunnels, plastic mulch and biodegradable mulch, a key informant survey was conducted in Washington, Tennessee and Texas. Of the 34 farmer respondents, 38% used high tunnels to produce 27 crops, primarily tomatoes, lettuce/salad greens, and peppers. All farmers who used high tunnels were either satisfied or very satisfied with them; however, wind damage and humidity/condensation were main concerns. Most farmers (79%) wanted to learn more about high tunnels, especially the specific crop production practices and structures best suited to their needs. Three quarters of the farmers surveyed had used plastic mulch, primarily for weed control for tomatoes, strawberries, peppers, and cucurbits, and most (64%) were very satisfied with the results. However, plastic mulch removal and disposal were a primary concern. One quarter of the farmers had used biodegradable plastic mulch, primarily for tomatoes and cucurbit crops, but they were not satisfied due to unpredictable and incomplete biodegradation. Most farmers lacked knowledge and needed more information about biodegradable mulch products and their availability and cost. This information is being used to guide a multi-state specialty crops team investigating the adaptation and economic feasibility of high-value specialty vegetable and fruit production with biodegradable mulches and high tunnels.

### **Introduction**

High tunnels and plastic mulch are successfully used throughout the world to increase productivity of high-value specialty vegetable and fruit crops. There is an estimated 586,000 acres worldwide under high tunnel cultivation; China leads with 350,000 acres, while the U.S. has an estimated 5,000 acres (Lamont, 2009). Data for the U.S. regarding the actual area under high tunnel production and the number and priority of crops in high tunnel cultivation is currently insufficient. In a recent survey of

extension specialists in 46 states (Carey *et al.*, 2009), there was a significant variation in the definition of high tunnels from state to state, thereby complicating the ability to access production statistics. According to Lamont (2009), tomatoes, peppers, cucumbers, melons, lettuce, summer squash and eggplant are the primary vegetable crops grown worldwide in high tunnels, with cut flowers, small fruit, and tree fruit also of importance. Tomatoes and cut flowers are the primary high tunnel crops in the U.S. (Carey *et al.*, 2009).

Most high tunnel systems use plastic mulch (Lamont, 2009). Plastic mulch was introduced in the 1950's and has since become an important method of weed control for many growers, contributing significantly to the economic viability of farmers worldwide (Hill *et al.*, 1982; Shogren, 2000; Takakura and Fang, 2001). By 2006 it was estimated that approximately 400,000 acres were covered with plastic mulch in the United States, including 1,800 acres in Washington (Bergholtz, 2006; Miles *et al.*, 2007). The economic and environmental costs of plastic mulch removal and disposal are major disadvantages (Schonbeck, 1995; Olsen and Gounder, 2001). Biodegradable plastic mulch may alleviate these concerns if it can be made more affordable, have a low overall environmental impact, be produced from renewable, natural and sustainable raw products, and retain durability for a targeted duration.

Degradable plastics were introduced in the 1980's, but rather than degrade, those products disintegrated, that is, they broke apart into smaller pieces of plastic (Riggle, 1998). To be considered biodegradable, agricultural plastics are expected to biodegrade (fully mineralize) at a specified rate in the field or through composting (as according to ASTM Methods D5988 and D5338). There remain many questions regarding the efficacy, biodegradability, and potential residues of biodegradable plastic mulches (Shogren, 2000; Hochmuth, 2001; Geer and Dole, 2003).

In order to obtain a better understanding of the current status of grower knowledge and use of high tunnels, plastic mulch, and biodegradable plastic mulches in areas where these technologies have not been widely adopted, a key informant survey was conducted in Washington, Tennessee and Texas. Key informant surveys target respondents who are considered to be most knowledgeable about the topic in question, and have the goal of identifying successes and issues from the perspective of individuals who are most likely to experiment with or adopt new information/technology (Marshall, 1996).

Key informant surveys tend to be low-cost and efficient as they include a low number of respondents who are contacted before hand, and only individuals who indicate they will participate are sent a survey (Pal *et al.*, 1998; Belansky *et al.*, 2009). Individuals are more likely to participate because they have been contacted beforehand, they feel their opinion is valued and is being sought out for a reason, and if needed they are reminded to complete and return the survey (Eyler *et al.*, 1999). An added benefit of a key informant survey is that researchers are able to ask more questions in more detailed ways with a high level of response (Johnson *et al.*, 2007).

### **Methods**

Team members designed a key informant survey with 31 questions that characterized each respondent farmer in terms of the number of acres farmed, total farm receipts, total years farmed, primary crops

produced, primary marketing outlets, and use or perception of high tunnels, plastic mulch and biodegradable plastic mulch. Most of the questions in the survey were Likert items designed to assess respondents' agreement or disagreement with various statements related to high tunnels, plastic mulches, etc (Likert, 1932). Respondents were asked to 'circle the best response' regarding level of importance (very important, important, somewhat important, not important, don't know), level of agreement (strongly agree, agree, unsure, disagree, strongly disagree, n/a), and perceived problems (serious problem, moderate problem, minor problem, not a problem, don't know) regarding high tunnels, plastic mulch, and biodegradable mulch. In addition, respondents were asked to provide short descriptive answers to several questions such as primary crops grown, and the primary positive and negative aspects of using high tunnels, plastic mulch and biodegradable mulch.

In each state, Washington, Tennessee and Texas, 10 to 15 key farmers were identified by SCRI team members based on their role as leaders in utilizing or experimenting with innovative agricultural technology including high tunnels and plastic mulch. Farmers were contacted personally, via telephone or email in November/December 2008 and asked to participate in the survey, and were of the length and details concerning the survey. Only farmers who agreed to participate were mailed or handed a survey questionnaire. Farmers were asked to complete and return the survey promptly (within 10 days) and were emailed or telephoned as a reminder prior to and immediately following the deadline. The survey provided key definitions for terms including biodegradable plastic mulch and high tunnels and directed respondents to use these terms when answering the questions. Biodegradable plastic mulch was defined as a manufactured alternative to plastic mulch that ideally provides the same benefits as plastic mulch (weed control, soil moisture conservation, etc.) and provides the added benefit of being 100% biodegradable, either in the field or through composting. A high tunnel was defined as a tall (enough for a person to stand up inside) temporary structure covered with single or double layer plastic used to protect the crop from rain, increase daytime temperatures, and to enable off-season crop production. Furthermore, in high tunnels crops are almost always grown in-ground, and they do not include automated heating or venting. High tunnels can be 3-season (spring, summer, fall) or 4-season (spring, summer, fall, winter).

### **Results and Conclusions**

The response rate for the key informant survey was 83% (n=41). Of the 34 respondents, 14 were from Washington, 11 from Texas and 9 from Tennessee. The number of acres farmed ranged from 1-5 acres (7 respondents) to greater than 1000 acres (2 respondents), and the average number of acres per farm was 146. Total farm receipts (2008) ranged from less than \$10,000 (4 respondents) to more than \$500,000 (10 respondents). The average number of years farmed by respondents was 24 years.

Respondents were asked to list the top five crops they produced overall. Table 1 shows the five most common crops grown by respondents, with tomatoes being number one (56%). Other crops grown by 10% or more of respondents were: blueberries, carrots, cucumbers, onions, peaches, peas, peppers, potatoes, raspberries, and sweet corn.

**Table 1.** Most common crops grown on 34 respondents' farms in general, or in high tunnels (13 farmers), or using plastic mulch (26 farmers), or using biodegradable mulch (10 farmers).

System	Rank	Crop	Percent of Respondents	System	Rank	Crop	Percent of Respondents
In General	1	Tomatoes	56%	Plastic Mulch	1	Tomatoes	77%
	2	Squash	35%		2	Strawberries	42%
	3	Lettuce/salad greens	26%		3	Peppers	35%
	4	Strawberries	24%		4	Cucumbers	31%
	5	Pumpkins	21%		5	Squash	27%
High Tunnel	1	Tomatoes	77%	Biodegradable	1	Tomatoes	70%
	2	Lettuce/salad greens	54%	Plastic Mulch	2	Cantaloupe	20%
	3	Peppers	31%		3	Peppers	10%
	4	Basil	31%		4	Watermelon	10%

**Growing Under High Tunnels.** Of the total survey respondents, 38% indicated they used high tunnels for crop production, compared with 44% growing in unheated greenhouses and 59% using heated greenhouses (n=34). When respondents who used high tunnels were asked to list the top five crops they grew in high tunnels, they indicated a total of 27 crops (n=13). Table 1 shows the four most common crops grown by respondents in high tunnels, with tomatoes being the number one crop (77%). Of the respondents who used high tunnels, 69% were very satisfied with the production results, while 15% were satisfied and 15% were somewhat satisfied. Respondents who used high tunnels liked the structures best due to extended growing season (85%) and weather protection and environmental control (54%). Some respondents also listed crop diversity, working conditions (e.g., warm, out of the rain, etc.), and having fewer disease issues (23% for each issue) as beneficial aspects of growing crops under high tunnels. The most common issues that respondents indicated as needing improvement while growing under high tunnels were wind damage (39%) and humidity and condensation (23%). Other difficulties identified by respondents were plant disease problems, insects, temperature control, fertility management, drainage, planting dates/succession, snow loads, rodent control, replacing wood that contacts soil, obtaining structure permits, poor plant quality, weeds, and slugs.

Of the total survey respondents, 79% wanted to know more about farming under high tunnels and 66% were interested in extending the cropping season (n=34). Most respondents felt crop yield would be increased under high tunnels (65%), that high tunnels would work well for the crops they currently grow (73%), that crop quality would be increased by high tunnels (62%), and that high tunnels would result in increased farm income (62%). Notably, 82% of respondents did not think there was sufficient available information regarding crop production under high tunnels. While just over half the respondents were aware of sources of high tunnels, 76% felt they did not know which structure would best fit their needs.

**Growing with Plastic Mulches.** Of the total survey respondents, 76% had used plastic mulch on their farm (n=34). When asked to indicate the top five crops they grew using plastic mulch, respondents indicated a total of 28 crops (n=26). The top five crops grown by respondents using plastic mulch are given in Table 1, with tomatoes being number one (77%). Other crops grown by at least 10% of those

respondents who had used plastic mulches were: basil, beans, cantaloupe, corn, eggplant, melons, onions, and sweet potatoes. Respondents who used plastic mulch were very satisfied (29%), satisfied (35%) or somewhat satisfied (9%), however 27% were not at all satisfied or unsure. When asked to describe what went well and what they liked best about using plastic mulch, the majority of respondents listed weed control (92%), whereas some respondents listed water conservation and ease of irrigating (31%), longer season due to increased soil heat (27%), moisture control (23%), and earlier harvest (19%). When respondents were asked to describe what problems they had experienced or what needs to be improved regarding the use of plastic mulch, the most common issues were clean up and disposal (62%) and cost (23%).

Of the total respondents, 61% felt the cost of plastic mulch was a serious or moderate problem, 73% felt plastic mulch was a serious or moderate problem to remove from the field, 82% felt the cost and time of disposal was a serious or moderate problem, and 64% indicated plastic was not recyclable in their areas (n=34). Most respondents (82%) felt plastic mulch worked well for the crops they grew. Adequate equipment and labor to lay plastic mulch in the field was considered a problem by 36% of the respondents whereas 58% did not feel these were issues for them.

**Biodegradable Plastic Mulch.** Of the total survey respondents, 29% had used biodegradable plastic mulch on their farm (n=34). When asked to indicate the top five crops they grew using biodegradable plastic mulch, respondents indicated a total of 8 crops (n=10). The top four crops grown using biodegradable plastic mulch are given in Table 1, with tomatoes being number one (70%). Of the respondents who used biodegradable plastic mulch, 60% were not at all satisfied while 20% were unsure. When asked to describe what went well and what they liked best about using biodegradable plastic mulch, respondents indicated weed control (28%), water/moisture conservation (28%), application (14%), pest prevention (14%), and establishing new starts (14%). The most common issues described as problems needing improvement were that mulches were not 100% biodegradable and they had unpredictable breakdown (100%), along with the cost of removal of un-degraded pieces (44%).

Of the total respondents, 24% felt biodegradable plastic mulch was available in their area and 32% felt it was suitable to the crops they currently grow (n=34). The high cost of biodegradable plastic mulch was considered a serious or moderate problem by 47% of respondents, while 41% indicated they did not know if this was a problem. In general, many or most respondents felt they did not know enough about biodegradable plastic mulch to provide informed responses to the questions asked in this section. For example, 47% of respondents did not know if biodegradable plastic mulch was well suited to their irrigation systems, 73% did not know if laying these products would be problematic, 67% did not know if weed control was effective throughout the season, 55% did not know if the products were totally biodegradable, 52% did not know if these products had a negative impact on soil health and quality, 40% were unsure if toxic byproducts were released upon their biodegradation, 52% did not know if they required more management than plastic mulch, and 61% did not know their impact on soil temperatures.

## **Conclusions**

The key informant survey targeted progressive farmers in each region—farmers who are generally considered leaders and innovators. Of these farmers, a third used high tunnels for a total of 27 different crops. The primary crops grown with high tunnels in Washington, Tennessee and Texas are similar to the primary crops grown in high tunnels worldwide – that is, tomatoes, lettuce/salad greens, and peppers. All farmers who used high tunnels were satisfied to very satisfied with them, primarily for the extended season and weather protection that high tunnels offer. About one third of the farmers indicated that wind damage was a primary concern for high tunnel production in their area, while humidity and condensation were also of high concern. Three quarters of the farmers wanted to know more about high tunnels, primarily for crop season extension, to improve crop quality, and to increase farm income. Although most farmers knew of sources from which to purchase high tunnels, they were not sure which structures best fit their needs and felt there was insufficient information regarding crop production practices under high tunnels.

Three quarters of the farmers had used plastic mulch, primarily for weed control in tomatoes, strawberries, peppers, and cucurbit crops, and were satisfied with the results. However, their primary concern with the use of plastic mulch was removal and disposal, because recycling was not an option for most respondents. Roughly one quarter of the farmers had used biodegradable plastic mulch, primarily for tomatoes and cucurbit crops, however they were not satisfied with the results due to their unpredictable and incomplete biodegradation.

While availability and cost of biodegradable mulches were considered obstacles by one-half of the farmers surveyed, most lacked the knowledge and necessary information about biodegradable products, their efficacy, and potential impacts on soil health and quality.

Information gained from this survey is being used to guide the investigation of high tunnels for the production of tomatoes, lettuce and strawberries in Washington, Tennessee and Texas. The manufacture and use of biodegradable plastic mulch is also being investigated for efficacy and its potential impact on soilborne microorganisms and plant health.

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