Research Reports

Farmer Perceptions of Tunnels for Berry Production: Management and Marketing Implications

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Summary. **Strawberry (*Fragaria ×ananassa*) and caneberries (*Rubus* sp.) are popular crops that can bring revenue to farms and may improve farm profitability. High and low tunnels can bring a number of benefits to growers, including season extension and improved berry yield and quality, as well as management challenges. Few studies in the literature report directly on grower experiences using tunnels. We report the results of interviews of 10 independent growers who use tunnels to produce strawberries and caneberries. The results echo previous studies finding improved yield and quality, and highlight benefits and challenges around pest, weed, and nutrient management. One novel finding is the role of season extension in creating marketing opportunities. Interviewed growers caution of a learning curve and the need to start on a small scale and grow gradually. Future focus for research should include improved ventilation and mechanization.**

Strawberry and caneberries are popular crops that can bring revenue to farms and may improve farm profitability. Protected culture provides potential benefits to berry growers. For red raspberry (*Rubus idaeus*), tunnel production has been or is being adopted in many regions of the United States (Demchak and Hanson, 2013), including the United States' major raspberry production regions in California (Tourte et al., 2016). Protected culture is used for strawberry production to a lesser extent in the United States (Demchak and Hanson, 2013).

Strawberries and raspberries are in relatively high demand, with a combined value of production (fresh and processing) of about $3.8 billion in 2017 (U.S. Department of Agriculture, 2018d). Strawberries and raspberries were grown on 23,104 acres and 67,467 acres in the United States, respectively, according to 2012 Census of Agriculture data (U.S. Department of Agriculture, 2012). In the states represented by the sample for the current study, there are 1656 acres of raspberry and 4071 acres of strawberry (U.S. Department of Agriculture , 2012). In a 2011 survey that included 72 growers currently growing berries in high tunnels across the United States, primocane-fruiting varieties of red raspberry was the berry crop grown most commonly, with 49% of current high-tunnel berry growers growing them, followed by day-neutral varieties of strawberries at 40% (K. Demchak, K. Kelley, and E. Hanson, unpublished data).

Per-capita consumption of fresh strawberries increased to an all-time high of 8.34 lb/person in 2017 (U.S. Department of Agriculture, 2018a), up 15% since 2010 (U.S. Department of Agriculture, 2018c). Per-capita use of raspberries increased from 0.20 lb in 2010 to 0.86 lb in 2016—a 330% increase (U.S. Department of Agriculture, 2018b). Demand for local produce in general has increased recently, improving opportunities for growers to market high-value crops such as berries directly to consumers. However, in highly populated areas of the Northeast and Midwest United States, berry producers within each state still only produce a limited amount of the berries purchased there. Consumers cited a short period of availability as an important factor limiting fresh berry purchases (K. Kelley, K. Demchak, and E. Hanson, unpublished data).

Many growers in populated states have turned to protected culture such as high tunnels (passive solar greenhouses) or low tunnels (rowcover suspended by wire hoops) to maximize yields on limited acreage and/or to increase the length of the growing season (Demchak, 2009; Wells, 1996), frequently using programs such as the U.S. Department of Agriculture Natural Resources

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.0929	ft^2	m^2	10.7639
0.4536	lb	kg	2.2046

Conservation Service High Tunnel Initiative to defray the cost of a tunnel (Foust-Meyer and O'Rourke, 2015). Potential benefits of protected berry culture include season extension, increased yield, and decreased pest pressure. For example, using high tunnels can increase raspberry yield (including a greater percentage of marketable berries) per area, prices received, fruit quality, and berry size, as well as offer an extended production and picking season (Demchak, 2009; Demchak and Hanson, 2013; Hanson et al., 2011; Pritts et al., 2017; Rowley et al., 2010). Tunnels increase plant survival, make production in colder northern climates more viable (Yao and Rosen, 2011), and offer protection from extreme weather in any climate. Tunnels may provide some pest management benefits as well, such as less disease overall, especially for gray mold [*Botrytis cinerea* (Demchak, 2009; Pritts et al., 2017)]. Growing strawberry in high tunnels brings similar benefits, including protection from extreme weather, season extension, greater yields, sweeter and larger fruit, precocity, and suppressed runner production (Jett, 2006; Kadir et al., 2006).

High tunnels may present challenges and drawbacks as well. Some diseases and insects, especially powdery mildew (*Podosphaera aphanis*), two-spotted spider mite (*Tetranychus urticae*), whiteflies (*Aleyrodidae*), and thrips (*Thripidaea*), may be exacerbated by tunnels (Demchak, 2009). Ventilation is often needed and, if not automated, may be time-consuming (Pritts et al., 2017; Wells, 1996). Most concerning, the cost of the tunnel may not pay for itself in increased revenue, especially for crops such as June-bearing strawberries, which have a short harvest season (Rowley et al., 2010).

The aforementioned studies largely rely on data derived from university-based research. Previous studies have looked at the experience of farmers using high tunnels for vegetable production and discovered numerous benefits and challenges that emerged from on-farm use, including a steep learning curve, extended-season produce attracting customers, and the importance of management to profitability (Conner et al., 2009, 2011; Waldman et al., 2012).

Because adoption of protected culture for berry culture has occurred relatively recently in the United States, there is little published information that discusses grower usage. This study used interviews of independent growers who have adopted high tunnels or low tunnels to grow strawberry or caneberries as part of diversified production for local markets. The objective of this study was to explore farmers' experiences using this technology. The interviews provided insight into farmers' motivations for tunnel adoption as well as the perceived benefits and challenges to production and marketing. Specifically, we address the following research questions: What are farmers' experiences growing berries in tunnels regarding production, marketing, and management? What are the perceived benefits and challenges? Results may be used to inform adoption decisions as well as future research and outreach efforts.

Materials and methods

To address our research questions, we used a set of semistructured interviews of growers who currently use high or low tunnels for berry production. Growers were restricted to those who are independent (i.e., those who develop their own markets rather than growing under contracts); these growers who have autonomy in their selection of tools, management, and marketing. Subjects were chosen by one of three methods: those known to the authors through past or ongoing research and outreach, a request through the High Tunnels listserv (Kansas State University Extension, n.d.), and asking interviewees for suggestions of other growers who use tunnels (i.e., snowball sampling) (Babbie, 2010). Interviews took place by telephone in Feb. and Mar. 2018.

Standard qualitative research methods were used (Babbie, 2010). Each semistructured interview took place by phone and lasted between 25 and 55 min. Questions focused on farmer experiences, including those regarding production, labor, inputs, pest and weed management, risk, marketing, and lessons learned (see Supplemental Appendix 1). Research protocols were approved by the University of Vermont's Institutional Review Board. A total of 10 interviews were conducted; they were concluded when no new significant information emerged. Interviews were analyzed for common themes and trends using HyperRESEARCH (Researchware, Randolph, MA), a qualitative software analysis program. In a process called open coding, the researchers read the interview notes and grouped responses by common themes. These themes were highlighted with HyperRESEARCH Version 4.0.0 and labeled with a descriptive title and an open code (Babbie, 2010). Fifteen open codes were developed (Table 1). Grower responses for the open codes were categorized as a benefit or challenge (or both). A description of these benefits and challenges with supporting quotations are presented.

Results

Sample description. The sample lived in eight states: Michigan, Arkansas, New York, Kansas, Arizona, West Virginia, Minnesota, and Wisconsin. Two were women; the rest were men. Area in tunnel cultivation ranged from a single tunnel of 1600 to 14,000 ft^2 under multiple bays. All but one farmer (the one with the largest area under tunnels) had important local markets, including farmers markets, u-pick, and sales to local grocery stores (direct wholesale). Of those with local markets, sales ranged from 10% to 100% direct to consumer. Table 1 highlights farmer descriptions and responses.

Many growers commented on the increased yield, size, and quality of the berries. One grower described fewer culls, fewer soft spots, and overall the "best berries I have ever eaten." Another described his reaction as "gee whiz" as he saw the "fantastic" berries. Many others noted the greater quality of the berries grown under tunnels, and one stated that this improved quality made the berries more desirable to wholesale buyers.

Tunnels can act as a valuable risk management tool. One grower stated that tunnels serve as "self-insurance against a big loss." Several farmers in the northern states said raspberry production would not be possible without tunnels. Tunnels were credited with protecting against cold as well as many extreme or unusual weather events such as hail, wind, torrential rain, and unexpected cold snaps. They also were found to permit shading from extreme sun, and prevented deer damage. Overall, as one grower said, "protected culture is the way to go."

Table 1. States where interviewed protected-culture berry farmers were located, tunnel type used, berry crops grown, and associated benefits and challenges related to tunnel type and crop.

No.	State[z]	Tunnel type	Berry produced	Berry quality	Direct markets	Ease and comfort of labor	Extend season	Labor automation	Labor venting	Learning	Loss leader	Nutrient management	Pests	Plant stock	Profit and price	Protection and risk	Scale	Value-added products
1	Michigan	H	C	b				c	c				b, c		c		c	
2	Arkansas	h, l	S		b		b			c		c	b	c				b
3	New York	h, l	S, C		b		b					b	b, c		b	b	b	
4	Kansas	h	C	b	b			c	c	b		c	b, c					
5	West Virginia	h	S			b		c	c	c			b, c			b		b
6	Arizona	h	S		b		b		c	c						b	c	
7	Minnesota	h, l	C, S	b		c	b	c			b		b, c		c	b		b
8	Minnesota	l	S	b	b		b	c	c				b, c				c	
9	Wisconsin	h	C				b		c				c		b			
10	Minnesota	h, l	C, S	b		b, c	b				b			c		b		

[z]State of farm location.
h = high tunnel; l = low tunnel; S = strawberry; C = caneberry; b = benefit of tunnels as described by farmers; c = challenge of tunnels as described by farmers.

Regarding pest, weed, and nutrient management, tunnels offer different challenges than managing field production. There is a consensus that tunnels have different insect pressures, especially with regard to increased mite pressure, whereas spotted-wing drosophila (*Drosophila suzukii*) remains a problem both in tunnels and in open fields. Biocontrols such as predatory mites (commonly *Phytoseiulus persimilis*, *Neoseiulus fallacis*, and *Neoseiulus californicus*, among others) were reported to be effective against two-spotted spider mite, and lacewings (*Chrysoperla*) were used to manage aphids (*Aphididae*) and other prey. There is a perceived need for more proactive scouting in tunnels as pest problems were noted to escalate quickly. Many growers felt diseases are managed more easily in tunnels, although viruses and fungi continue to be challenges for some. One grower described a tunnel as a "petri dish for pests."

Nutrient management also is subtly different in tunnels, potentially requiring both more inputs and more attention. High productivity and warmer overall temperatures imply faster cycling of nutrients. Standardized soil test regimes are not perceived to be adequate, resulting in tests typically being conducted more frequently than in field production. One grower also conducted frequent tissue nutrient analysis.

Growers did not notice a great difference in weed pressure between tunnel and field production, although one commented that a large amount of hand weeding was needed. Another remarked that tunnels are not conducive to the use of large cultivation and spraying equipment used in fields: "[W]hen you are used to fieldwork, tunnels can get in the way."

Tunnels similarly pose a series of both benefits and challenges to farm labor. Several growers mentioned how it was pleasant to work inside tunnels when inclement weather occurs outdoors. The predictable environment of tunnels can make labor management easier. One grower noted how having tunnels allowed for year-round work and revenue outside of the traditional field growing season, permitting the farm to retain a full-time manager over the winter months; this was vital for the retention of a valued employee.

One of the major labor challenges concerns ventilation, and thus maintaining temperature control in high tunnels. There is worry that excess heat can affect plant dormancy. One farmer noted: "[T]emperature management is a challenge." Several growers also noted challenges with low tunnels, describing them as fragile, time-consuming to construct and maintain, and difficult to reach inside. One was "not sure [growing in low tunnels] is worthwhile" given the labor needs.

Growing berries in tunnels impacts marketing practices and outcomes both directly and indirectly. All but one grower sells at least some of their products directly to consumers (farm stands, farmers' markets, and u-pick), and most also have small wholesale accounts (to local grocers and restaurants). The improved size, taste, and overall quality of the berries was discussed earlier. One grower remarked that the quality and consistency of the berries creates a "branded product" that people request specifically. One grower mentioned being able to sell all of the berries grown in high tunnels and "could sell 10 times more" if needed. Season extension helps bring both price premiums and can facilitate sales of other items. One grower said offering extended-season berries to wholesale accounts "opened the door" to high volume sales of other types of produce. One who operates a u-pick apple (*Malus ×domestica*) orchard said having late-season strawberries helped to differentiate their farm from similar orchards: "Late season strawberries help sell u-pick apples." Finally, many growers incorporate value-added products. One sells chocolate-dipped strawberries as part of a school fundraiser. Others freeze any excess (e.g., strawberries that ripen before farmers' market season begins) or use them in jellies and jams.

Two related cross-cutting themes emerged: the need to start small and to anticipate a learning curve. One grower who is uncertain of the profitability of tunnels encourages others to start with a small area under tunnels This grower made a large upfront investment in multibay tunnels and is now looking to sell them because they do not fit his operation (mechanized) and markets (commodity). A grower who started small is very satisfied with tunnel performance. Another said it was "important to start small and gain experience." Another echoes these sentiments, saying it is "difficult to scale tunnels to wholesale" because tunnels are "not easily automated," leading to labor constraints.

Another benefit of starting small is the oft-mentioned learning curve. As discussed earlier, there are many subtle differences in field vs. tunnel production. One grower mentioned the importance of continuous learning. Growers in Kansas and Minnesota expressed satisfaction in research and outreach available from the land-grant universities and extension, whereas another grower cited a lack of resources in his state.

Discussion

This study used interviews to understand the experiences of 10 independent growers using tunnels to produce strawberry or caneberries and to sell (for the most part) to local markets. As found in previous studies (Demchak, 2009; Hanson et al., 2011; Pritts et al., 2017; Rowley et al., 2010), these growers stated the tunnels produced high yields of berries with improved quality and fewer culls. The tunnels can extend the season, improve plant survival, and help mitigate certain kinds of pests (Demchak, 2009; Yao and Rosen, 2011). The extended season brings direct benefit in terms of greater prices and also serves to attract customers who buy other items. Major challenges identified during this study include the labor required in ventilation and hand weeding—tasks that are not automated easily (Wells, 1996). Growers also identified a learning curve, difficulty in scaling up, and lack of available outreach in certain regions.

Our results suggest one profile of a grower for whom tunnels can likely contribute to profitability: small scale and relying on direct and other local markets, particularly those in geographic areas represented by this study (Northeast and Upper Midwest United States) with strong local food markets. The season extension capability and high-quality berries can translate into price premiums and attract customers who will buy other items for sale, especially for the early adopters in a given area. Growers with this profile can only supply limited quantities of berries; the differentiation value of extended season and greater quality may be eroded as more farmers adopt within a given locale. Next we posit research and outreach needs if tunnels are to maximize value to producers.

First, research and concomitant outreach are needed to address labor challenges—notably, automating ventilation and permitting efficient cultivation. Second, research and outreach can help address the learning curve for new adopters, informing good management decisions in nutrient management, pest management, and other areas in which field and tunnel production differ. Last, efforts should be made to help early adopters reinnovate if the advantages of early adoption erode.

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Supplemental Appendix 1

List of questions used to guide semistructured interviews of 10 growers using high tunnels and/or low tunnels to grow berry crops.

1. What berries do you grow in what tunnel types? (low, high, mixed)
2. How long have you done so?
3. What was your motivation for adopting this technology (growing berries in tunnels)? How has growing berries in tunnels played out? (better/worse than expected, etc.)?
4. How has this technology impacted overall farm profitability?
5. How has growing berries in tunnels impacted farm management? How has it impacted your (owner operator) time? Hired labor? Think about amount of labor, skills needed, timing (does it compete with other tasks), etc.
6. How has growing berries in tunnels impacted inputs and equipment used?
7. How has growing berries in tunnels impacted fertility, and weed and pest management? What is different from field production? How does it play out?
8. How has growing berries in tunnels impacted marketing? Are the berries easier to market? Has growing berries in tunnels created new opportunities or barriers? Has it made it easier or harder to sell other products? How has growing berries in tunnels impacted yields, quality, and prices received?
9. How has growing berries in tunnels impacted postharvest/packing, food safety, shipping, packaging, etc.?
10. If you grow more than one kind of berry or use more than one kind of tunnel, compare and contrast different crops in different tunnels (type, structure, plastic used). What is similar? What is different?
11. How does growing berries in tunnels play into risk management? Factors may include (cue for, if needed) structure collapse or damage, cold or heat, pest or weeds, food safety.
12. What do you wish you knew when starting out with growing berries in tunnels that you know now? Why?
13. Overall, what has been most successful about growing berries in tunnels?
14. What have been the biggest setbacks/challenges?
15. Anything important I missed?
16. Can you suggest other growers who use this technology who may be good interview subjects?