

# Soilless substrate science: a North American needs assessment to steer soilless substrate research into the future

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## **Abstract**

There is an increasing interest in transitioning conventionally soil-grown specialty crops (i.e. fruit, vegetables, ornamentals) to soilless culture. However, growers are often not fully aware of the opportunities, challenges, or measures to define success in adapting specialty crops to soilless systems. A North American needs assessment for soilless substrate science was conducted. The assessment consisted of three individual phases: 1) a North American grower survey with over 290 responses, 2) two online listening-sessions with 12 growers representing the diversity of North American specialty crops, and 3) one-on-one interviews with 12 substrate suppliers, processors, and distributors. The goal of this project was to develop a holistic understanding of grower and supplier needs with projections of increased substrate use in the coming years. The respondents were from a broad scope of growers, with 41% of respondents growing vegetables, 40% small fruit, 35% ornamentals, 30% tree fruit and nut, and 12% medicinal crops. It was determined that many high value crops (small fruits in particular) are transitioning into soilless culture, primarily as a means of disease control, have crops yield or finish earlier, and improving crop quality. Knowledge of the efficient use of resources, particularly in regard to water and fertilizer, and economic return on investment were identified by the participants as boundaries to adoption. Supplier interviews indicated that a transfer of trusted knowledge is imperative, and growers need support and evidence to initiate major changes. Suppliers believe that we must identify localized materials that are consistent, sustainable, cost-effective, and recyclable to support growers. North American specialty crop production is facing a transition period, as an influx of crops begin to transition to soilless culture. Connecting researchers, suppliers, and growers together to a new level can support all industries as we rise to the challenge of combating climate change and ensuring global food security.

**Keywords:** education, fruit crops, grower survey, ornamentals, production methods, quality control, specialty crops, substrate uniformity, vegetables

## **INTRODUCTION**

Sustainable production of specialty crops (i.e. fruit, vegetables, ornamentals, etc.) is becoming an essential component to feed and provide ecosystem services to the world's population (Raviv, 2017), and soilless culture can support that need. Many growers are beginning to transition many crops from in-field production practices to soilless culture (Minuto et al., 2010). This is in part due to diminishing availability of fumigants, reduced availability of viable production land, increasing pest pressure, and the need for more efficient and flexible options (Raviv, 2017; Gonnella and Renna, 2021). Soilless culture provides an easy-to-manage, forgiving, and interchangeable system for production within conventional systems, especially where soil is degraded and water is limited (Sambo et al., 2019). Perhaps the most strategic benefit to soilless systems is the ability to engineer the substrate physiochemical attributes to fit specific circumstances and yield targeted outcomes (Barrett et al., 2016). There are also political and humanitarian forces pushing for more food



production in urban areas to meet the nutritional needs of economically stressed neighborhoods and fight the expanding food deserts in those areas. Production of crops in soilless systems is often the only option in urban areas where healthy and productive soils are lacking or completely absent (Gomez et al., 2019). Additionally, recent research has predicted the global demand for soilless substrates to double in the next 20 years, with growing demand, new crops, and emerging markets around the world (Block et al., 2021).

The challenge of preparing, supplying, and implementing superior substrates for the future where an increasing world population will require greater food availability, plants for ecosystem services, and reduced reliance upon natural resources (i.e. water and mineral nutrients) for crop production, all while utilizing less land with a minimal carbon footprint (Gruda, 2019; Benke and Tomkins, 2017) must be addressed by substrate suppliers and specialty crop growers together. This will require a reimagining of soilless culture for the future, including the components utilized, engineering of material blends, and substrates are managed within specific production settings to meet needs over time with resource- and cost-efficiency. Additionally, end-users will require multifunctional substrates that not only optimize growth and yield, but are engineered to reduce consumptive water use, deliver mineral nutrients, and remediate agrochemicals while remaining economical.

New issues are likely to arise as existing specialty crop sectors evolve and new sectors begin to transition to soilless substrates. Stakeholders associated with newer container production sectors will likely have different research and outreach needs when comparing to experienced soilless growers. As such, the objective of this research was to develop a North American needs assessment for soilless substrate research over the next 10+ years to support current and future users of soilless substrates and the suppliers that will support those users. Growers across all major specialty crop sectors were surveyed through an online poll, with select representatives of various specialty crop sectors participating in focus groups. This grower survey was then used to inform key interviews with substrate and allied suppliers in an effort to develop a holistic needs assessment for soilless substrate researchers to best support the soilless community.

## **MATERIALS AND METHODS**

### **Grower survey**

A Specialty crop grower survey was developed based on the Theory of Planned Behavior (Ajzen, 1991) in an effort to determine specialty crop growers' economic perspectives, attitudes, subjective norms and perceived behavioral control associated with the adoption of substrates and potential opportunities from implementing them in specialty crop production. The survey was developed using an online instrument (Gibson et al., 2020) which was adapted to fit the context of this study. The survey was distributed to North American specialty crop producers through online promotion through the soilless substrate science website, distribution through regional grower associations and societies, industry magazines, trade shows and extension contact across the continent.

### **Grower focus groups**

Twelve growers were then invited to participate in one of two focus groups. The focus group participants were selected to best understand key points learned in the online survey. Growers representing ornamentals, vegetables, small fruit, tree fruit, and cannabis were invited, with varying levels of knowledge regarding soilless culture. Those invited were distributed between current soilless users and those considering incorporating soilless production into their operations. A moderator's guide was developed based on Diffusion of Innovation theory (Rogers, 2003) to best identify barriers and enablers of adoption and guide substrate science research in the coming decades.

### **Supplier interviews**

A series of interviews were then conducted to identify current issues and research needs from the supplier perspective. Twelve industry members, representing lead sales or

research based divisions of the major North American wholesale suppliers were selected to represent the North American substrate industry, including substrate materials harvesting/mining, processors, blenders, distributors, and allied suppliers.

To alleviate any discomfort or unwillingness to discuss weaknesses with their competitors, key informant interviews were conducted to ensure privacy of responses and assist in open dialog (Creswell et al., 2007). Staying congruent with the theoretical framework of the first objective, an interview guide was developed using the Theory of Planned Behavior. The interviews identified successes and challenges associated with substrate development, storage and distribution by asking participants about their attitudes, subjective norms, perceived behavioral and economic control.

Survey data and focus group data were analyzed independently and then integrated for results interpretation (Creswell and Creswell, 2017; Sandelowski, 2000). The qualitative results were used to corroborate and further inform the quantitative results (Bazeley, 2012). With much of the data being subjective in nature, many of the discussion points were categorized by the authors into different concepts and focus areas.

## **RESULTS AND DISCUSSION**

### **Grower survey**

A total of 290 responses were received. Nearly 75% of growers responding to the online survey reported utilizing soilless substrates in their current or previous operations, with approx. 67% of those indicating the majority of their production is in soilless systems. Of the respondents who did not currently utilize soilless substrates, over half indicated their interest or expectation in shifting portions of their production to soilless systems over the next five years. Both soilless growers and in-ground growers were included in the survey as the authors wanted to identify soilless substrate research needs holistically, including both current users and potential future users.

The most responses were from vegetable producers, followed closely by small fruit and ornamental producers. Half the respondents were from relatively small farms with less than \$100,000 in annual sales. The remaining responses were split evenly between medium (\$100,000 - \$1,000,000) and large scale (over \$1,000,000 in annual sales) operations.

The survey identified overall plant quality and disease management as the primary deciders for adoption of soilless production systems. Other highly valued decision factors included reduce substrate shrinkage, faster germination for rooting, and increased crop uniformity. While effect on crop quality and uniformity was the highest indicated area for research needs, aligning with the decision factors, fertilizer management, water management, and economics were the other highest identified areas of need for research.

### **Grower focus groups**

The grower focus groups allowed for more detail in the topics of interest identified by the online survey. Growers first discussed adoption advantages and challenges associated with soilless production. Crop quality and uniformity was highly discussed, as being to top priority from the online grower survey. Most of the growers agreed that improvement of overall crop quality and marketability was necessary for the adoption of soilless culture. With crop uniformity playing such a critical role for growers, differentiation in crop associated with soilless culture would be seen as a major challenge.

Crop and soil disease management was also identified as an important factor when considering transitions to soilless culture. Growers indicated that the loss of fumigants in recent years have been one of the primary drivers for adoption of soilless culture. Moreover, the disease and virus free initial conditions associated with soilless substrates are critical for producers.

Transportation, availability, consistency, and reliability of the soilless substrates were also regarded as highly important to growers. These growers were adamant that consistence among batches was crucial for success of their operations. Moreover, the availability, especially from regional sources was necessary to maintain consistency with reduced

shipping costs and create more appeal to consumers.

With regards to perceived research needs, two primary areas were discussed. Soilless substrate properties and water and fertility management in soilless systems. Growers were very interested in better understanding of the soilless substrates they are employing, including understanding more about physical, chemical, and biological properties, and more importantly, how to interpret and utilize the knowledge of these properties for their own systems. It seems growers are wanting more input control over the physiochemical properties of the media they use, with general interest in how custom blends can be developed to meet specific needs and fit current systems. However, many new and transitional soilless growers do not have the knowledge to develop their own soilless substrate materials or request custom blends. Therefore, it is important that researchers provide research-backed information and decision tools to support new soilless substrate users to the same level as current and expert soilless users. Moreover, growers noted that as substrates tend to shift away from defined materials (peat being specifically mentioned), they want to understand how the new materials affect the substrate properties and influence the system as a whole. Growers were very willing to acknowledge what they did not know, and want help understanding more about substrate properties.

Water management was discussed in length with regards to research needs. Water management in regards to irrigation, within the container system, and once the water leaches from the system were all found to be of high importance. They acknowledge that substrate selection and implementation changes all other cultural decisions down the line, and there was great interest in research to support matching substrates for specific irrigation systems. Within the same sentiment, growers expressed interest in more research devoted to fertility management with soilless systems. Growers focused on how soilless substrates might be developed to retain fertilizer and reduce the fertilizer requirement in crop production. A grower stated, "Managing the nutrition, I think that's something that every grower around the country is interested in, due to leaching, pollution, and runoff." Reducing the loss of luxury fertilizer consumption as well as water and fertilizer loss through leaching were considered high priorities for soilless substrate research.

In regards to research needs, growers across cropping systems believe research is often too specific and laboratory-centric, while they benefit more from comprehensive and applicable research. This led into a strong desire to develop regional and crop-specific grower-friendly substrate standards and decision-making tools to assist with designing, formulating, selecting, and deploying substrates. Growers believe that research, especially university sponsored research, needs to be more applicable and directly beneficial to producers.

### **Supplier interviews**

Suppliers tend to see two major sectors opening up for increased use of soilless substrates, berries and hemp. Every supplier in the interview discussed the expansion of soilless media into the berry market, with one supplier remarking "we expect [the berry] market to grow at a much faster rate in the coming years." It was clear that suppliers have been working with berry growers and feel this was a sector that will rapidly expand into soilless culture in North America. Hemp was the second most discussed new sector, with growers indicating that many of the growers might not have the most experience and tend to over complicate things. "Cannabis growers are used to purchasing and using soilless substrates that are more complicated and much more expensive than they need." As the cannabis market becomes more mature, we expect that growers will begin to develop more economical practices.

Suppliers also identified regulation and education as the primary limiting factors for perceived growth of the substrate industry. It is evident that suppliers consider regulations to slow most processes down and identifying will be a steering factor in future research needs. A common sentiment was "regulations slow everything down and make things more expensive." As the industry faces additional regulations, the growth of the substrate industry will be limited by support, need, and trust, especially when dealing with end-users.

Suppliers identified education as the primary research need. Both growers and

consumers need better education on soilless substrates and soilless culture. Supporting growers adapt their current practices to new ideas and options requires significant education. “The biggest thing is for growers to know about the science that already exists,” said one supplier. “As an industry, we’ve always been sitting back and making our products, selling our products, but not really doing any of the educational aspect, and teaching people what really is going on.” Many suppliers indicated reliance on academics and extension faculty to educate their growers. Suppliers went further indicating that they would “love to see growers themselves get involved with research, and educate each other.”

Raw materials were also noted as important research needs. Sustainability and cost-effectiveness in material sourcing was identified as a major research need. “Make use of local raw materials,” one supplier stated, “it is too expensive to ship this material around the world.” Identifying local materials that can be developed into regional products is of high importance to suppliers. Alternative materials, specifically peat alternatives, were stated as part of the future.

University scientific experts, trade organizations, and research conferences were identified as the primary learning sources that suppliers rely upon. Suppliers tend to rely upon a network of university researchers and specialists for much of their research needs. These resources were identified to be relied upon more often than internal research. Of all the options identified, the internet was the least relied upon source.

## CONCLUSIONS

The overall objective of this research was to identify research needs for soilless substrate science over the next ten years. Education seemed to be a common theme in this research. There is great room for research into materials, processing, and practices, but education for growers, suppliers, and consumers was the most discussed idea across all assessment methods. Growers wanted to know more about their substrate, and what they can do with their substrate. The concept of “designer” substrates or custom blends to fit a specific purpose were highly regarded. Understanding how to develop or design a substrate to suit their needs would go a long way in regards to supporting soilless producers. Similarly, suppliers found education for growers and end consumers to be of high importance.

Uniformity, both substrate and subsequently crop was also a key factor with soilless substrate success. Growers indicated the need for crop uniformity and increased quality as the primary reason to shift to soilless production or to limit the shift to soilless production. Conversely, uniformity among substrates, especially in concerns to quality control, is of the utmost importance. Minor variations in substrate composition and properties can result in major production differences. This consistency must be maintained and ensured for growers to successfully transition to soilless production.

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