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Major challenges facing the commercial horticulture

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Horticulture contributes significantly to society in terms of provision of healthy foods, vitamins and minerals, and recreational activities. Commercial horticulture is very diverse, in terms of crops grown, available cultivars, propagation of planting material, growing media and feed, production systems, crop protection, and post-harvest management and processing; and demands intensive labor input. Increasing labor and land cost has resulted in a decline in horticultural production in many developed countries around the world, shifting the production to countries where the cost of production is competitive. Conversely, availability of affordable technology and sufficient work force with required knowledge is a key challenge facing horticulture in developing economies. Although key challenges facing commercial horticulture are the same globally, the relative importance of these challenges depends greatly on the local economy and climatic conditions.

Consumer demands for an affordable, year-round supply of horticultural produce, in addition to an increased variety and novelty of produce, are expanding. There has been a concerted effort to increase consumption of fresh vegetable and fruit within low-income regions where the consumption is well below the recommended levels. The diverse nature of commercial horticulture necessitates continuing innovation to meet these increasing demands. As demand for edible and ornamental horticultural products increases, the sustainability of horticultural production will be challenged. Some of these challenges are beyond the scope of Frontiers in Horticulture, such as immigration policy, trade protectionism, resilience in post-farm gate supply chain, land use, skill training and recruitment, and promotion of health benefits.

Sustainable production practices

Resource use efficiency

Changing environmental conditions are impacting horticultural production, particularly the availability of necessary resources. A key issue facing horticulture in almost all areas of the world is water availability. Research is urgently needed to address issues such as development of drought tolerant crops and water use efficiency practices, dealing with increased salinity, and using low quality water. Soil is acknowledged as a limited resource with its fertility and health being crucial to ensuring short- and long-term crop productivity and providing a wide range of ecosystem services. Plants possess several adaptive mechanisms to cope with abiotic stresses leading to changes at morphological, physiological, biochemical, and molecular levels. A comprehensive understanding of these adaptive responses is required to improve resource use efficiency. Significant challenges include:

- developing and optimizing management practices to promote soil C-sequestration and reduce GHG emissions in both intensive annual and perennial production systems;
- maintaining or even increasing production and sustainability with reduced input of water and nutrients;
- developing sustainable growing media as alternative to peat;
- exploiting soil microbiome and specific beneficial microbes to increase crop resilience against abiotic and biotic stresses.

Integrated pest and disease management

Emerging pests and pathogens and increasing pesticide resistance continue to pose significant challenges to horticulture. Superficial damage to fresh vegetable and fruit produce is unacceptable to consumers, but this is coupled with a desire for no pesticide residues in food. Increased global trading in planting material as well as fresh produce has increased the risk of introduction and establishment of alien pests and pathogens into new environments. At the same time, growers have fewer "conventional" pesticides available to manage pests and diseases due to increasingly stricter regulations. Innovative methods are needed to combat new and existing pests and diseases. Responsible use of pesticides, such as more targeted use, is essential to protect the environment at the same time as producing quality fresh vegetables and fruit. We need to develop new effective pesticide compounds that have less persistence in the environment as well as a lower toxicity to non-target organisms. New innovative semiochemical control methods are under development for subsistence farming, such as push-pull strategies for pest management. The next challenge is to expand similar approaches into mechanized farming systems. There is a growing interest in using beneficial microbes and/or manipulating phytobiome for crop protection in terms of managing specific pathogens or improving plant general resistance/tolerance. There remain, a number of challenges in developing and adopting this phytobiome-based approach for crop protection:

- we need tools with better resolutions to understand the assembly and persistence of phytobiome at specific host tissues/organs and the functions of specific microbial taxa groups;
- to optimize the use of beneficial microbes, we need the ability to predict their environmental fate post-application under the influence of external factors, such as environmental conditions, resident microbiomes and crop husbandry practices (pesticides, fertilizers etc.);
- we need to work with growers and help them to deal with often inconsistent benefits resulting from beneficial microbes due to their nature as living organisms.

Post-harvest management

In recent times, there has been a shift toward the consumption of fresh rather than frozen produce. The challenge is, therefore, to develop and refine storage methods to maintain produce premium quality. Understanding and predicting produce respiration, and hence produce quality, in relation to post-harvest treatment (e.g., hot water and microbial treatment), storage conditions (e.g., temperature, atmosphere) and duration is prerequisite for developing and optimizing post-harvest management strategies. Furthermore, pre-harvest management can also impact produce post-harvest storage potential and quality. For example, a "managed" transient water stress pre-harvest can improve produce quality as well as its storage potential, which is often species and genotypic specific. Detailed knowledge underpinning such physiological interactions as well as tools for precision quantification and imposition of "transient" plant physiological stress is required before growers can implement such pre-harvest management practice effectively. Another key challenge in post-harvest technology is to minimize energy usage whilst not compromising produce quality, which is a more engineering issue than biological one.

Year-round supply

Consumers now expect year-round provision of safe, nutritious fruit and vegetables, and cut-flowers, which is primarily achieved through a combination of locally-produced and imported crops *via* storage and long-distance transportation. Because of the high demand for energy in transport and storage, there is a need for extending production season and expanding total controlled environment horticulture locally. The challenge is to develop specific cultivars and production systems under the controlled conditions. Concurrently, we need to understand crop physiology in order to maximize genetic potential, and minimize energy consumption as well as GHG emission in these new production systems. For instance, varying photoperiod or fertilizer regimes to change flowering and hence fruiting can be effective for some fruit crops. In addition, under such controlled production systems, automation may be easier to implement than in other production systems.

Precision tools

Automation is being seen as a key solution for solving several critical production challenges. Use of robotics, particularly for routine repetitive tasks such as planting, crop monitoring, crop protection, plant husbandry and fruit harvesting, will greatly reduce the required labor input to horticultural production, addressing labor shortages in commercial horticulture particularly in developed economies. Developing devices incorporating AI algorithms to provide crop intelligence, including phenology, and pest and disease development, at a sufficiently high spatiotemporal resolution will not only allow timely crop management intervention, but also enable precision treatments applied to those plants at specific locations only. Pre-harvest detection of asymptomatic pathogen infections in fruit can be of a great value in assisting growers making decisions about storage management and marketing. Similarly, early detection of plant physiological stresses is a prerequisite for implementing precision water and nutritional management. Accurate, continuous quantification of atmosphere in cold stores, particularly those gases related to vegetable/fruit respiration, can significantly improve post-harvest management and reduce crop waste.

One key challenge for developing and marketing automation and/or precision technology is the diverse nature of the aforementioned horticulture enterprise. Much research and development is needed to develop affordable automated solutions specific to individual crops (potentially individual cultivars) and production systems. Furthermore, such automation will need to be energy efficient as well as easy to implement. Allied to this technology drive is the need to train a new generation of farm workers and managers and equip them with the necessary skills to operate the new technology and to interpret the resulting information for decision making.

Breeding new varieties with precision techniques

Most crop production and management practices are conditioned for specific genotypes. Provision of new cultivars through rapid breeding is not only necessary to reduce crop management burdens but also to address challenges of meeting supply chain demand (e.g., production in total controlled environment conditions) as well as changing consumer preferences with regard to produce quality. For many perennial horticultural crops, the conventional breeding cycle usually takes 8–15 years; for such crops, technology tools are urgently needed to reduce the length of breeding cycles (i.e., speed breeding). Techniques for precision genetic manipulation, such as targeted gene editing, can significantly increase breeding efficiency, particularly for those characters that are genetically controlled by a few major genes, such as resistance to pathogens. However, there may be regulatory hurdles to overcome as well as consumers' resistance in accepting the use of such gene-editing tools in breeding horticultural crops. Researchers need to work with regulatory authorities and to engage with public to demonstrate the safety of these technology tools.

Many important characters, such as quality traits, are genetically controlled by many genes and can be greatly modified by environmental conditions (i.e., G × E interactions). Elucidating genetical control of these characters and the nature of G × E interactions is a challenge facing geneticists and plant breeders. Genomic prediction and selection (GPS) are proposed partially to tackle this challenge. In addition to cheap and efficient genotyping, a more important challenge for using GPS in breeding programmes is related to germplasm before GPS can be routinely used in breeding programmes. As GPS is conditioned on the initial germplasm used as training material for GPS, introducing novel germplasm into an existing breeding programme, which is a common practice, may necessitate developing new GPS algorithms, incurring additional cost and delaying breeding programme. The challenge is to extend existing GPS algorithms, incorporating new germplasms, with minimal cost and delay.

Toward net-zero horticulture

It is recognized that we need to move toward net-zero horticulture in order to mitigate climate change risks. Developing innovative methods contributing to net-zero horticulture need baseline data on the environmental footprint of individual processes in primary production and immediate post-harvest management. Given the diverse nature of crops grown and associated production system, there are yet no generally accepted assessment tools for conducting such analysis (life-cycle analysis—LCA) to obtain necessary baseline data, not to mention the baseline data. There is a urgent need to develop common LCA tools to quantify environmental footprint of individual horticultural processes before we can efficiently develop and optimize crop production innovations (as outlined above) that not only improve crop productivity but also contribute toward net-zero horticulture.

Reducing, reusing and repurposing agro-wastes is another key aspect contributing to net-zero horticulture. Currently agro-waste reduction and activities are often fragmented with limited profit margin, discouraging participation of private companies and adoption by end-users. Substrate production is critically important for high-value vegetable and fruit crops; such production systems generate one major waste—spent growing media. There are other waste materials, e.g., plastics, green biomass, and woody materials. Urgent research is needed to develop innovations that not only minimize and reuse agro-waste in horticulture but also repurpose agro-waste for crop production as well as food and non-food industrial processes, such as cosmetics, household products, packaging, mechanical, and construction applications.

Translational research and knowledge dissemination

A participatory-based approach is one of the most effective ways to develop solutions in collaboration with local horticultural producers and to promote technology adoption. Furthermore, this approach also ensures that solutions developed are fit for purpose and can be readily adopted in commercial horticulture. In developing countries, where the effective provision of knowledge from both private and public sectors may be underdeveloped, the demand for relevant information is growing as horticultural enterprises become more sophisticated. There are a number of advanced routes for disseminating and accessing information; researchers need to work with the horticulture industry to provide necessary information in a manner that can be easily used by the industry for decision-making.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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