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Soy Containers: Growing Promise, Growing Plants

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There are several potential benefits of using biocontainers in greenhouse crop production. The most apparent of these benefits are that biocontainers are biorenewable and have the potential to degrade when buried in soil or composted, reducing contributions to landfills and improving sustainability. Additionally, a recent study showed that consumers are attracted to biocontainers and are willing to pay more for a premium product that's produced sustainably and has a perceived environmental benefit. These are all excellent benefits that provide growers with opportunities to market and retail sustainable crops grown in biocontainers. But what if biocontainers provided even more benefits—additional practical functions not provided by conventional petroleum-plastic containers?

Pictured: Rutgers tomato grown in petroleum-plastic (left) or soy-PLA (right) containers. Note that, when compared to the tomato grown in a traditional plastic container, the tomato grown in the soy-PLA container has improved shoot growth (top row) and a more fibrous root system with fewer encircling roots (bottom row).

In the last issue of *GrowerTalks*, we described our progress with bioplastic container prototypes that are suitable for commercial greenhouse production and how several of these prototypes can end their life cycle by degrading in soil or compost. In this article, we'll highlight the added function of soy-based bioplastic containers that provide a fertilizer effect during crop production and we'll discuss strategies growers can employ when these new containers become available.

In 2010, research at Iowa State University revealed that bioplastic containers made from corn protein (zein) could provide a "fertilizer effect" during plant culture. In greenhouse trials, the zein containers released nitrogen at excessive rates, but in forms that could be utilized by plants. In 2011, our team began a five-year project funded in part by the USDA Specialty Crops Research Initiative (SCRI) to develop new and improved biocontainers for use in ornamental greenhouse and nursery production. Early in the project, it became apparent that using soy-protein polymer in containers provided several advantages over zein. Soy is much more affordable, it’s more easily adapted for use in containers and the nitrogen that provides the fertilizer effect comes from a highly sustainable, biological source (the natural biological nitrogen fixation of soybean).

Improving container design and function

In some of the early studies with containers made from 100% soy plastic, we observed two challenges associated with the containers. First, the 100% soy plastic containers would lose structural integrity during the early stages of production. Secondly, the release of nutrients from the containers was excessive and reduced the growth and quality of plants. As a result of these early trials, our primary goals with soy materials were: 1) increasing the structural stability of containers made from soy products, and 2) slowing the rate of nutrient release to acceptable levels for quality plant growth. To achieve this, we evaluated the effects of dip coating 100% soy-plastic containers with other, more-stable bioplastic materials, and we evaluated injection-molded containers made with a new blended composite material of 50% soy plastic and 50% polylactic acid (PLA).

Dip-coating the 100% soy-plastic containers failed to improve durability or slow fertilizer release to an acceptable level. However, injection molding the soy-PLA composite material resulted in a container that reduced the fertilizer effect and degradation to levels acceptable for commercial greenhouse crop production. Additionally, the root systems of plants growing in soy-PLA containers were dense and fibrous with no root circling, unlike plants grown in traditional petroleum-plastic containers.

Adapting fertilization practices

With the improved soy-PLA containers, we discovered that providing a standard rate of water-soluble fertilizer (WSF) for the entire crop-production cycle was excessive, while providing no fertilizer resulted in plants that were anemic early in production. To better understand the dynamic fertilization effects of the soy-PLA containers, we grew Rutgers tomato in soy-PLA containers and traditional plastic containers, and provided plants with one of three fertilizer treatments: 1) a low rate of complete WSF for the entire production cycle, 2) a low rate of complete WSF for only the first two weeks of production or 3) a low rate of WSF without nitrogen for the entire production cycle. The use of solution containing the low rate of complete WSF, either for the entire production cycle or for the first two weeks, was sufficient in meeting the nutritional demands of plants in only the soy-PLA composite containers. Plants growing in traditional petroleum-plastic containers were anemic and showed signs of phosphorus deficiency even with the complete WSF applied at a low rate. These results indicate that the fertilizer effect of soy-PLA containers provides more than just nitrogen, but that nutrient release takes a short time to develop and is not sufficient during the early stages of plant production.

There are a few ways that growers can provide the fertilizer required during the early stages of crop production. A complete WSF could be applied during the first few weeks after transplanting or growers could use a substrate that contains a “starter charge” to provide nutrients for the early stages of production. We evaluated both of these strategies for producing plants in soy-PLA containers. When we used a substrate with a starter charge and no additional WSF applications to grow Rutgers tomato, the fertilizer from the starter charge was sufficient for sustaining early stages of growth, after which the slowly degrading soy-PLA containers provided ample nutrition for the remainder of production.

To further evaluate the use of WSF early in production and to compare containers made of other blends of soy-protein composites, we grew Honeycomb marigolds and Rutgers tomato in containers made of five types of materials: soy-PLA blended 50/50, soy-PLA blended 33/67, a protein-PLA formulation from Aspen Research Inc. (www.aspenresearch.com), soy blended 33/67 with polyhydroxyalkanoate (PHA) and a standard petroleum-plastic control. Plants were either fertilized with 50, 100 or 200 ppm N once a week throughout production or provided with 100 ppm N for only the first two weeks, after which fertilization was discontinued. The best plant growth and health was observed in containers made of 50/50 soy-PLA and containers made from the protein-PLA formulation provided by Aspen Research. At each fertilizer level, plants produced in these container types were healthier and of better quality than plants grown in petroleum plastic containers. Comparing among all treatment combinations, we determined that containers made of 50/50 soy-PLA material and the Aspen protein-PLA formulation required much less fertilizer to produce plants of equal quality and size as that of the petroleum-plastic control. In this trial, the fertilizer effect of these two container types allowed an 87% reduction in synthetic fertilizer needed to produce marigold and a 44% reduction in synthetic fertilizer needed to produce tomato.

Future directions

There's always a learning curve associated with adopting new technologies. The development of new protein-based biopolymer containers for greenhouse crop production will require a change in fertilization strategies for growers who adopt these new containers. The slow degradation of soy-PLA containers during production releases mineral nutrients that can provide the bulk of fertilizer required to finish a 6- to 8-week greenhouse crop. However, fertilization early in crop production is required. The use of a substrate with a starter charge can provide the mineral nutrients needed for the first two weeks. For growers who prefer not to use substrates containing a starter charge, fertilizing with 50 to 100 ppm N from a WSF for the first two weeks can also provide the necessary fertilizer for crops grown in soy-PLA containers. **GT**

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