Growing Safer Produce

- Inside the Food Safety Modernization Act
- Is Greenhouse Produce Safer?

Page 10

January 2014

PAGE 14
IT'S GE, NOT GMO The real story behind genetic engineering

PAGE 20
FROM CONCRETE TO GREEN Local Garden expands the perception of urban ag

PAGE 34
GROWING LETTUCE HYDROPONICALLY Tips for growing this gourmet food
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And with greenhouse vegetable production continuing to be one of the fastest-growing sectors of the greater greenhouse industry, it’s time to bring another issue of *Inside Grower* from your email inbox to print. You’ll find this *Inside Grower* edition takes you deeper into the topics that matter most in the business of growing edible crops in controlled environments.

Bringing all this information and inspiration to print is an impressive lineup of well-known researchers, academics and technical writers—all well-versed in various aspects of controlled environment agriculture.

The safety of the food we grow, sell and feed to our own families is a critical topic for the fresh produce industry. In fact, we think it’s so important that it’s our cover story. Foodborne illness outbreaks are an unfortunate reality when growing and distributing fresh food, and in addition to being a major public health issue, bringing a contaminated product to market can have severe economic consequences for the grower. As an industry insider and an expectant mother taking the safety of my own food options very seriously, I take a look at how the new Food Safety Modernization Act will affect greenhouse growers and other farmers, and how growing in controlled greenhouse environments can help alleviate some food safety concerns (starting page 10).

Perhaps an even more contentious topic than food safety regulations—at least in the mainstream media and among consumers—is the GMO debate. Jennifer Duffield White tackles the real story behind genetic engineering and the debate that has, at times, crippled itself (page 14).

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David Kuack brings us more tips for hydroponic success on page 24, discussing how to get vegetable seedlings off to a good start by selecting an appropriate growing medium and providing optimum germination conditions. Delving deeper into the propagation and production of hydroponic lettuce specifically, Dr. Vijay Rapaka discusses how to optimize this popular gourmet crop on page 34.

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We hope you enjoy this publication of *Inside Grower* and find its content useful to your growing endeavors. As always, we welcome your questions and feedback.

**From Your Editor**

I recently hit the send button on the 50th issue of *Inside Grower*. For more than two years, I’ve been devoted to keeping you inspired by—and connected to—this relatively new industry in the U.S., providing up-to-date information about growing methods, new products, market trends and a whole lot more.

And with greenhouse vegetable production continuing to be one of the fastest-growing sectors of the greater greenhouse industry, it’s time to bring another issue of *Inside Grower* from your email inbox to print. You’ll find this *Inside Grower* edition takes you deeper into the topics that matter most in the business of growing edible crops in controlled environments.

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**Annie White**
MANAGING EDITOR
feedback: awhite@ballpublishing.com
A Friend Remembered
G. Victor Ball, Editor from 1949–1997

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ON THE COVER
The safety of the food we grow, sell and feed to our families is a critical topic for the fresh produce industry, so we run down the latest regulations and standards for growing veggies and greens, starting on page 10.

Photo by Mark Widhalm

FEATURES

10 | Growing Safer Produce | by Annie S. White
A farm-to-fork look at current food safety issues in the produce industry and how greenhouse growers can grow even safer produce.

14 | The Real Story Behind Genetic Engineering | by Jennifer Duffield White
The GMO debate that has, at times, crippled itself.

16 | A Recipe for Hydroponic Success | by Neil S. Mattson & Cari Peters
Providing all of the essential elements in the right quantity and the right proportion to each other can seem like a daunting task to even the most mathematically gifted growers.

20 | Expanding the Perception of Sustainable Farming | by Anne-Marie Hardie
A young go-getter finds a way to cultivate his passion for green development with a new way to grow food in the city.

24 | Best Beginnings | by David Kuack
Regardless of the growing medium selected, growers should provide optimum germination conditions to ensure seedlings get off to a good start.

26 | Battling Botrytis with Peroxygen Compounds | by Dr. Vijay Chopplakatla
Thanks to advances in field/greenhouse/high-tunnel production, tomatoes are available all year long, but this doesn’t come without some fungal disease problems.

30 | Controlling Whiteflies | by Dr. Raymond A. Cloyd
Identify, prevent and control this tomato-destroying scourge.

32 | Fighting the Rise of Basil Downy Mildew | by Dr. Robert L. Wick & M. Bess Wicklow
This disease isn’t new to the world, but it is relatively new here in the States and looks like it’s here to stay. There are few fungicides to combat it, so prevention is key.

34 | Propagation & Production of Hydroponic Lettuce | by Dr. Vijay Rapaka
Although hydroponic lettuce production is much smaller compared to field production, it’s considered a high-quality gourmet product.
A Look Back at the Genetically Engineered Flavr Savr Tomato

The recent debates over new GMO labeling laws are causing quite a stir among both critics and supporters of genetically engineered food. No matter what your personal opinions are on this contemporary matter, taking a historic look back at the first genetically engineered food—the Flavr Savr tomato—is quite fascinating.

Retro Report, a nonprofit online video project that takes a long-term look at some of the biggest news headlines, made a short film on the genetically engineered Flavr Savr tomato from the company Calgene. (Calgene was later bought by Monsanto.) At the time that the Flavr Savr tomato was introduced to consumers, genetically engineered food was a much less contentious topic, perhaps because of Calgene’s transparency.

“What’s fascinating is that genetic engineering was a kind of selling point for this fruit,” says Retro Report. “...The efforts of big agrochemical companies like Monsanto to obscure the origins of genetically engineered plants creates a kind of void where we imagine the worst. But for the Flavr Savr, transparency was an advantage and discussions about how the genes of the plant were manipulated also communicated its benefit to the consumer,” added the filmmakers.

The video can be seen at http://vimeo.com/68929952. Read more about GMOs starting on page 14.

New App for Plant Pest & Disease Diagnosis

Submitting a plant pest or disease identification question to a diagnostic laboratory has never been easier. The Plant Diagnostic Sample Submission app is a joint effort with eight universities to provide a way to easily submit digital images of plant problems or pests on-the-go.

This app allows farmers, gardeners, landscapers, arborists, agricultural specialists and others to submit digital photo samples to a university plant diagnostic lab for diagnosis or identification.

The app contains sample submission forms for plants ranging from small houseplants to large-scale agronomic crops. The user completes each form by responding to simple, customized questions. After entering a description of the problem and attaching corresponding photos, the sample submission is sent to the selected diagnostic laboratory.

The following labs are accepting submissions on this app:

- Alabama Cooperative Extension System
- University of Connecticut Plant Diagnostic Laboratory
- University of Illinois Extension
- University of Kentucky Plant Disease Diagnostic Laboratory
- Michigan State University Diagnostic Services Laboratory
- University of New Hampshire Cooperative Extension Plant Diagnostic Lab
- Ohio State University C. Wayne Ellet Plant and Pest Diagnostic Clinic
- Purdue University Plant & Pest Diagnostic Laboratory

As a brand new app, there are several caveats to keep in mind. The app is currently available only for iPhone or iPad users. Submissions are sent through your iPhone or iPad’s Mail app, which requires an email account on your device. Kentucky and New Hampshire labs will only receive samples from certified agents or specialists who have a proper passcode. International submissions are not accepted.

Search the iTunes App Store to find the plant diagnostic app.

Basics of Growing Microgreens

Microgreens, those tiny edible seedlings that are perking up fresh dishes from coast to coast, continue to grow in popularity. The little flavor-packed greens are showing up at restaurants, farmers’ markets and even some grocery stores. In addition to flavor, microgreens offer a refreshing crunch, a beautiful assortment of colors and are packed with nutrients.

“This fast-growing market has become tremendously popular with both growers and chefs. For growers, microgreens have a low start-up cost for year-round production; are relatively easy to grow and most can be harvested within two to three weeks,” explains Johnny’s Selected Seeds, a Maine-based supplier of vegetable seeds, including microgreens. “For chefs, they allow for interesting colors, flavors and textures to be creatively combined to enhance any dish,” adds Johnny’s.

Although microgreens are relatively easy to grow, Johnny’s advises that they’re not entirely foolproof. Careful planning and seed selection is needed, followed by informed sowing methods, production methods and harvesting strategies. Johnny’s is making it easy for growers to explore new opportunities in microgreen production. The company offers a microgreen production guide on their website, which covers all of these topics in detail. They also provide information about packing and marketing your microgreens. A PDF version of the production guide is available at www.johnnyseeds.com/Assets/Information/MicroGreensTechSheet.pdf.

Johnny’s Selected Seeds first listed microgreens in their seed catalog in 2001, and since then, through their trialing efforts, the number of varieties selected for microgreens has continued to increase. In a recent newsletter, Johnny’s offered advice for choosing the best varieties for getting started with microgreens.

If you’re just getting started with microgreens and want to keep things simple, Johnny’s recommends trying a couple of pre-mixed microgreen blends.

A micro mix consists of many different kinds of vegetables, including amaranth, arugula, beets, broccoli, cabbage, kale, mizuna, mustards, pac choi and radishes. Micro mixes may also contain annual herbs such as basil, fennel and cutting celery.

Johnny’s two favorite blends are their mild micro mix, which combines sweet, mild-tasting brassicas, and the spicy micro mix, featuring sharper-tasting varieties.

If you’re interested in growing individual varieties and customizing your own mixes, Johnny’s offers their top five picks.

“We’ve selected the following five microgreens because, in our experience, they reliably produce dense, uniform stands that are easy to harvest. They also offer a pleasing diversity of flavors, from mild to spicy, and an attractive range of colors, shapes and textures.”

**Scarlet Frills Mustard:** Spicy flavored; ruffled red and dark-green leaves.

**Hong Vit Radish:** Spicy-flavored; attractive pink stems and green leaves; radishes are lofty and add weight and volume to micro mixes.

**Yellow Beet:** Mild beet flavor; light green leaves with yellow mid-vein and stems.

**Cressida Cress:** Spicy pepper flavor; fancy three-lobed leaves.

**Red Russian Kale:** Mild-flavored; dark bluish-green, pink-outlined, serrated leaves.

View a comprehensive list of all Johnny’s Micro Greens at www.johnnyseeds.com.
Portland, Oregon, is well-known for its small-scale farming and local food scene, but one Portland-based company is planning to take local food production to a large scale. Fresh Air Farms is an ambitious start-up aiming to provide a local, commercial-scale supply of select fruits and vegetables to the Portland area.

The company plans to grow produce year-round in sustainable, high-technology, environmentally controlled greenhouses. They plan to grow cucumbers, lettuces, peppers, tomatoes, leafy greens, strawberries, herbs and spices.

Fresh Air says that at this stage, they’ve built their team, established customer contacts and have begun the site selection process. The first greenhouse farm will provide a total of 2 million sq. ft. of greenhouse space, spread among 100 greenhouses that are 20,000 sq. ft. each. The facility is predicted to produce over 300,000 pounds of fresh fruits and vegetables daily while providing over 275 jobs and adding $40 million in sales per year to the local economy. The company plans to begin growing and shipping produce in 2014.

Fresh Air Farms plans to spend the first five years growing the site in Portland and then hopes to build duplicate sites near other cities every two years thereafter. By year 20, they aim to have nine sites, employ over 2,000 workers, and have sales around $275 million.

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**Boot Camp Farms Employs Veterans to Battle Food Deserts**

Plans are quickly moving forward for a new urban agriculture center in the Northeast. Boot Camp Farms has developed an innovative agricultural solution for a community in transition, blighted by environmentally degraded brownfields.

Locals used to call the blighted brownfields in the East End of Bridgeport, Connecticut, “Mt. Trash More;” but Boot Camp Farms has much greener plans for the area. Working with Bridgeport city officials, the state of Connecticut and the EPA, Boot Camp Farms is remediating and revitalizing the site. In September, the company officially broke ground on their flagship farm, which will include 8,000 sq. ft. of controlled environment greenhouses.

Boot Camp Farms chose Nexus greenhouse systems for the project. Jeff Warschauer from Nexus explained that Boot Camp Farm’s urban agriculture center will be home to state-of-the-art Nexus Glass Vail Atrium greenhouses with hot water heating, state-of-the-art cooling systems, energy curtains, automated controls and hydroponic growing systems.

Currently, the future farm site is being graded and the project is in the final stages of permitting and financing. The first phase of the project will include 38,000 sq. ft. of greenhouse space and then the second phase will add 40,000 sq. ft. across the street.

When fully built, the greenhouses will be capable of producing 800,000 pounds of fresh produce per year. Some of the produce will be sold to Bridgeport residents at subsidized prices in an adjacent retail center, helping to alleviate Bridgeport’s urban food desert.

You may be wondering what inspired the name, Boot Camp Farms. Well, Boot Camp Farms Founder and CEO, Antonio St. Lorenzo, has long been devoted to helping our veterans and his devotion didn’t stop with this latest agricultural venture. The company wants to train and employ veterans, in partnership with the University of Connecticut’s College of Agriculture, to work in the greenhouses. They expect to create about 40 full-time green collar jobs for the community.

For more information on Boot Camp Farms visit www.bootcampfarms.com.

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**Greenhouse Permitting To Be Simplified**

Greenhouses will now be defined in the International Energy Conservation Code (IECC), which is “huge,” according to the code consultants hired by National Greenhouse Manufacturers Association—NGMA—to aid in the battle to get “greenhouses” included, defined and, where appropriate, exempted from certain codes they just can’t meet—such as energy conservation.

That’s the latest battle the NGMA has just fought and won on your behalf. We spoke with Craig Humphrey of Nexus Greenhouse Systems to learn more. He and Matt Stuppy, president of Stuppy Greenhouse Manufacturing (and current president of NGMA) tag-teamed our industry’s cause before the code committee.

The IECC sets the standard, which buildings have to meet, and writes the rules your local code official interprets. The rules for energy conservation are getting more and more strict, yet there’s no provision for greenhouses, which as we all know can’t meet the same “thermal blanket” standards as your average office building, thanks to our glass or poly glazing. NGMA successfully lobbied IECC to include a definition of greenhouse in the code—the first time we’ve ever been defined.

What’s it mean to you? Simplified permitting, says Craig. “Because now a code official can go in and say: ‘Oh, it’s a greenhouse. There’s a definition. Here’s what you have to do.’ Instead of having to educate every code official as to what you’re trying to do and how he should apply the code. It’s spelled out in black and white for him.” Although when Craig says “now,” he means 2015 and beyond, as that’s when the new code will go into effect.

The next battle will be ASHRAE—the American Society of Heating, Refrigerating and Air-Conditioning Engineers. Their energy code is adopted by some states rather than IECC, says Craig, and is the leader in energy standards, so it’s important to get them to recognize a greenhouse’s unique energy consumption qualities before they update their standards.

As for IECC, Craig says now that that definition is in the code, NGMA can go after some other proposals that will benefit greenhouse owners.
Microgreens Yield More with Vermicompost Amendments

TerraVesco, a Sonoma, California-based company that produces horticultural-grade vermicompost and vermiextract, recently conducted research trials in cooperation with Rocket Farms in Half Moon Bay, California, to look at the potential of increasing microgreen yields through the use of Vermicompost and Vermicompost Extract.

What's Vermicompost, anyway? According to TerraVesco, vermicompost is produced by thermophilic composting of organic material, which is then fed to worms to digest for further breakdown in a tightly controlled process.

“The resulting product is 100 percent natural, organic compost, rich in beneficial microbes, that closely resembles high-quality peat in appearance and is applied by amending your existing media,” says Jim Snyder, a senior consultant at the company.

For the research trial, micro mix mild and micro mix spicy supplied by Johnny's Seeds were sown in 10/20 flats filled with peat-lite mix supplied by Pinstrup, amended with 5% TerraVesco horticultural grade vermicompost. The flats were watered in with clear water containing 2% (1.50) TerraVesco vermiextract. Control flats were seeded with the same varieties in the peat-lite mix without TerraVesco horticultural grade vermicompost and watered in with clear water only.

Conclusions: Although TerraVesco reported some varietal response differences, they say it appears that fresh weight yields of micro greens can be improved by amending the media with horticultural grade vermicompost and application of an aqueous solution of vermiextract.

The company believes these positive results may be transferable to the production of other edible crops including fruits, vegetables and herbs.TerraVesco horticultural grade vermicompost and extract are OMRI and CDFA listed, so the benefits of increased yields can be enjoyed by both conventional and certified organic producers.

For more information about horticultural grade vermicompost and vermiextract, visit terravesco.com.

Certified Greenhouse Farmers Continues to Increase Members

Certified Greenhouse Farmers (CGF), a member organization that aims to define and enforce the integrity of greenhouse-grown produce, continues to add new members and expand the association’s base throughout North America.

Most recently, CGF announced the approval of six new members from British Columbia, Canada. The new CGF members include BJ Farms of Abbotsford, Canadian Valley Growers of Aldergrove, Delta View Farms of Delta, Peppertree Farms of Abbotsford, Sunnybay Greenhouse of Delta, and Millennium Pacific of Delta.

Last month CGF approved their first four growers from Mexico, including Horticola Cimarron in Guanajuato; and Finca Ahuehuetes, High Tech Gardens and Solar Garden in Queretaro.

With these new members and those companies currently pending membership certification, CGF will grow to more than 50 greenhouse operations in Canada, Mexico and the United States this year.

“Our growth continues as we work to distinguish vegetable greenhouse production from other systems by clearly defining growing standards and practices for this innovative industry,” says Ed Beckman, CGF president.

To become a member of CGF, producers must meet the strict definition for controlled-environment greenhouses as well as undergo a rigorous, third-party audit against the association’s standards. These standards include structural and environmental controls, food safety, water resource management, integrated pest management procedures, ecosystem management and integrated waste management. Once approved, members can place a CGF seal on their products and packaging.

Learn more about Certified Greenhouse Farmers on their website www.certifiedgreenhouse.com.
You’re not in the business of growing diseases.

Use Actinovate® SP Biofungicide for protection against powdery mildew, Botrytis, Pythium, Phytophthora, Fusarium and other common plant diseases in your greenhouse. Apply Actinovate® SP on your vegetables, herbs, annuals, perennials, shrubs and more. Actinovate® SP is safe for workers and beneficial insects.
Growing Safer Produce

A farm-to-fork look at current food safety issues in the produce industry and how greenhouse growers can grow even safer produce.

BY ANNIE S. WHITE
The safety of the food we grow, sell and feed to our own families is a critical topic for the fresh produce industry. Foodborne illness outbreaks are an unfortunate reality when growing and distributing fresh food, and in addition to being a major public health issue, brings a contaminated product to market can have severe economic consequences for the grower and everyone involved in the supply chain—from the farm to the fork. Nobody wants to be responsible for the next round of tainted produce that makes people sick—or worse—kills them. Most of us can recall a time or two in our lives when we were personally affected by a foodborne illness. According to recent data from the U.S. Centers for Disease Control and Prevention (CDC), about 1 in 6 Americans (that’s 48 million people) get sick each year from foodborne diseases. Of the millions sickened, about 128,000 people end up hospitalized and 3,000 die.

While most contamination occurs late in the food production chain, 14,350 of the illnesses, 1,382 of the hospitalizations and 34 of the deaths can be attributed to contamination that likely happened early in the production chain—that is, during growing, harvesting, manufacturing, processing, packing, holding or transportation. And according to the FDA, “this is a significant public health burden that is largely preventable.”

What’s making us so sick? According to CDC data, the biggest culprit is leafy greens. They found that 46% of all food illness cases between 1998 and 2008 were attributed to leafy vegetables such as spinach, lettuce mixes and cabbage. Most were caused by the norovirus, which spreads to produce from water contaminated by fecal matter. While meat and poultry contaminated with listeria and salmonella cause fewer illnesses, they are linked to more deaths.

Produce and the Food Safety Modernization Act

Issues concerning food safety, food recalls and food illness outbreaks are routine stories in the national media. The fear of being affected by an outbreak has some consumers looking for smarter food choices and growers, packers and distributors implementing more rigorous food safety measures—some by choice and some mandated.

The Food Safety Modernization Act (FSMA), signed into law by President Obama on January 4, 2013, is the first major update of federal food safety laws since 1938. FSMA gives the Food and Drug Administration (FDA) broad new powers to prevent food safety problems; detect and respond to food safety issues; and improve the safety of imported foods.

FSMA authorizes new regulations at the farm level for producers and certain facilities. Specifically, FSMA mandates the establishment of new standards for produce production (a.k.a. The Produce Rule) and new food safety measures for facilities that process food for human consumption (a.k.a. The Preventive Controls Rule). FSMA does not change food safety regulations for meat, poultry and egg products, which fall under the jurisdiction of the U.S. Department of Agriculture.

Many produce growers have already adopted rigorous food safety measures, either voluntarily or through the request of their customers. A large number of wholesale buyers and major retailers have employed independent verification programs to certify that the fresh produce they purchase is safe.

Good Agricultural Practices (GAP) and Hazard Analysis and Critical Control Points (HACCP) are two commonly employed food safety programs that address many agricultural issues with respect to food safety. Growers may find that they already meet most of the new FSMA regulations if they’re following GAP or HACCP programs.

The nitty-gritty of the Produce Rule

FSMA requires FDA to write new regulations that establish standards for produce safety. In the proposed produce rule, FDA has detailed new standards for the growing, harvesting, packing and holding of produce for human consumption. Specifically, the rule establishes standards for:

Agricultural Water: Farmers would have to ensure that water that’s intended, or likely to contact, produce or food-contact surfaces is safe and of adequate sanitary quality, with inspection and periodic testing requirements.

Biological Soil Amendments of Animal Origin: The proposed rule specifies types of treatment, methods of application and time intervals between application of certain soil amendments—including manure and composted manure—and crop harvest.

Health and Hygiene: Farm personnel would have to follow hygienic practices, including hand washing, not working when sick and maintaining personal cleanliness.

Domesticated and Wild Animals: With respect to domesticated animals, the proposed rule would require certain measures, such as waiting periods between grazing and crop harvest, if there’s a reasonable probability of contamination. With respect to wild animals, farmers must monitor for wildlife intrusion and not harvest produce visibly contaminated with animal feces.

Equipment, Tools and Buildings: The proposed rule sets requirements for equipment and tools that come into contact with produce, as well as for buildings and other facilities.

Training: The proposed rule requires training for supervisors and farm personnel who handle produce covered by the rule.

Sprouts: The proposed rule establishes separate standards for sprout production, including treatment of seed before sprouting and testing of spent irrigation water for pathogens.

Do these standards apply to me?

If you operate a business that grows, harvests, packs or stores fresh fruits and vegetables, then you may be affected by the produce rule. If you process, manufacture, pack or store human food, then you may be affected by the preventive controls rule. Many businesses will be affected by both rules.

There are a handful of exemptions to the produce rule, which benefit growers of crops not typically associated with foodborne illnesses, as well as small-scale producers. Produce that’s rarely consumed raw (e.g. potatoes or winter squash) and produce that receives additional processing that would be subject to the preventive controls rule are exempt from the produce rule. Produce is exempt if it’s grown for personal or on-farm consumption only. Entire farms are exempt if the average annual monetary value of the food they sold during the previous three-year period is less than $25,000.

What’s our industry saying about the new rules?

United Fresh Produce Association, a leading trade association in the industry, supports adherence to common food safety standards by all produce suppliers to help ensure a consistently high food safety standard for all fresh produce sold to U.S. consumers, but with the release of the draft rule for imported foods, the organization has stated its concern about the exemption for small farms.

“Like I’ve said before at industry conferences and in dialogue with FDA officials, pathogens don’t know what size operation they’re on,” remarked David Combas on behalf of United Fresh.

The National Sustainable Agriculture Coalition (NSAC) is also advocating for some significant changes to the proposed rule. The problem areas identified by NSAC are:

- Added regulatory costs that could cut profits in half for...
Is greenhouse produce safer?

In all the current debate and discussion about food safety measures for fresh produce, little to no distinction is made between field-grown produce and greenhouse-grown produce.

According to Perishables Group using A.C. Nielsen scanner data, more than 50% of tomatoes sold in U.S. supermarkets in 2012 were labeled as greenhouse-grown and demand for field-grown tomatoes continues to decline. But is produce grown in greenhouses less susceptible to pathogens that cause foodborne illnesses?

While there’s a lack of science-based research comparing greenhouse-grown produce to field-grown produce, the controlled environment of greenhouses leads many to believe that yes, greenhouse produce is probably on a whole, less susceptible to contamination than field-grown produce. At least until it leaves the greenhouse.

Certified Greenhouse Farmers (CGF), an organization comprised of greenhouse vegetable growers in North America, says that food safety is their number one priority. To become a certified member, a grower must adhere to the strict food safety measures.

“Our food safety program begins with a Hazard Analysis Critical Control Points (HACCP) risk analysis—from seed through transport and identifying what steps can be taken to control those risks so that safety is not compromised. It’s a systematic approach to food safety that is focused on preventive practices,” says the organization.

CGF also requires its members to not only undertake a Global Food Safety Initiative (GFSI) benchmarked audit, but to also apply commodity specific guidance, when applicable, such as in the production of tomatoes.

“Because greenhouse vegetables are grown without soil and in a controlled environment, there are fewer critical control points where contamination may occur than are found in the field or under shade cloth or other forms of protected culture,” explains CGF.

Many greenhouse produce growers actively educate consumers about the cleanliness of their controlled growing environments and promote the safety of their products.

“We adhere to the highest levels of food safety in all aspects of our operation,” explains California-based greenhouse tomato grower (and certified greenhouse farmer), Windset Farms. “Like you, we want only the most natural produce available. Growing plants in the controlled environment of the greenhouse helps us to do that.”

Village Farms, a large producer of greenhouse tomatoes, peppers and cucumbers with greenhouses in both the U.S. and Canada (and also a certified greenhouse farmer), says that growing in controlled environments greatly lessens the possibility of sickness. The company explains that by growing plants hydroponically in a sterile medium, plants can’t absorb toxins and bacteria found in soil.

Village Farms stresses the significance of their fresh produce not using or being exposed to animal waste fertilizers, such as manure composts. Growing plants hydroponically in a protected greenhouse eliminates the risk of coming in contact with field runoff from animals. Runoff from animal wastes can introduce dangerous bacteria like E. coli.

While the greenhouse produce industry makes a strong case for why concerned consumers should feel safer feeding greenhouse-grown produce to their families, there’s still a lack of published scientific research to support their position. We’ll be looking towards universities and other research labs to fill these research needs in the near future.

Meanwhile, greenhouse farmers will be required to share FSMA rules with field growers and both will strive to bring safer fresh produce from their farms to the plates of their consumers.
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GMOs

The Real Story Behind Genetic Engineering

The GMO debate that has, at times, crippled itself.

by JENNIFER DUFFIELD WHITE

Genetically engineered (GE) plants have now been around for 30 years, and yet, in many ways, the debates over how, where, why and if we should use them still seem to be picking up steam. Some call it an important battle. Others call it a marketing failure.

The European Union (EU) elected to adopt a stringent regulatory framework for GE crops, and in the U.S., various groups are still fighting—spending great sums of money—over how to regulate and label GE crops. The public nature of the debate, at once full of emotion, assumptions, politics and science, comes with its fair share of confusion.

So what’s the real story behind GMOs, er, GE?

It’s GE, not GMO

Before we continue, let’s get precise. Everyone uses the term GMO (genetically modified organism). This is inaccurate. Genetic modification refers to any sort of genetic modification—traditional plant breeding as well as biotech methods. Anytime you create a hybrid, select for various traits, that’s genetic modification. Genetic engineering (GE)—or transgenics—however, means using biotechnology to manipulate an organism’s genome.

The Research

As always, there are things science does not yet know, or perhaps does not have comprehensive ways of quantifying yet, and some of the research methods have been questioned on both sides. However, there’s a lot that we do know.

We used a literature review from Critical Reviews in Biotechnology, published in 2013, called “An overview of the last 10 years of genetically engineered crop safety research.” They analyzed and categorized 1,783 scientific records, published from 2002 to 2012, on GE issues. Their overall conclusion: “We can conclude that the scientific research conducted so far has not detected any significant hazard directly connected with the use of GM crops.”

Biodiversity. According to “Impact of GM crops on biodiversity” (GM Crops & Food; Vol. 2, Issue 1, 2011), the effects of GE crops on the biodiversity of non-target species shows little or no evidence of negative effects, although there are two papers that reported negative impacts on arthropods. Obviously, crops engineered to resist pests or withstand herbicide applications will reduce the biodiversity of certain weeds and pests in the field, as is the case with any sort of pest or weed management.

Resistance. Researchers have reported both glyphosate-resistant weeds and Bt-resistant pests in fields with these GE crops. Resistance and corresponding chemical usage does have implications, but again, this is also the case in non-GE crops.

Spreading genes. What if these transgenes end up in the wild or spreading to other crops? In the wild, you can get a hybrid between a GE crop and a wild relative. Some strategies, such as delayed flowering and male sterility, can be used to reduce the chance of GE hybrids. However, an article on transgene introgression in Trends in Biotechnology (Vol. 29, Issue 6, 2011), reminds us that gene flow between cultivated and wild species existed long before GE crops, and natural mutations can also have conse-

The World Stage

The EU and the U.S. have taken different approaches to regulation, and worldwide, regulations seem to fall in one camp or the other. In the EU, crops are regulated by the process of how the crop was genetically engineered and also adhere to a precautionary principle; labeling is required. Such restrictions have slowed the development and research of GE crops worldwide and have made it difficult for farmers to grow GE crops in Europe. In the U.S., crop approval focuses on evaluating the product itself; labeling, so far, is not required.

Controlled Environment Agriculture—A few major points to consider for our industry:

1. Most GE crops are in the field, not the greenhouse. And most of those are commodity crops. In fact, there are no GE tomatoes on the market in North America or Europe. (Though, fact: the Flavr Savr tomato was the first commercial GE crop in the U.S., introduced in 1994, but it didn’t have a long run.) According to the GMO Compass database, GE peppers have undergone field trials for virus resistance and delayed maturity, but are, to date, only rumored to be on the market in China. While GE strawberries and cucumbers have been tested in research, the database says that a commercial use of either is unlikely right now. What’s on the market? The most popular GE crops are soybeans, corn, cotton and canola. In 2012, there were about 170 million hectares of GE crops around the world; most of those were in just five countries—U.S., Brazil, Argentina, Canada and India.

2. It’s not corn with an octopus gene. Right now, most commercial GE crops fall into the following categories: 1) tolerant to glyphosate (Roundup) or 2) production of insecticidal proteins derived from Bacillus thuringiensis, a microbial insecticide, which occurs naturally in the soil and is also approved for use in organic production.

GE crops typically contain bacteria or virus genes from tissue culture, not the genes of other organisms, although, it does occur. In one recent case, J.R. Simplot in Idaho has lobbied the USDA to remove regulations on its genetically engineered potatoes because they don’t contain any non-potato genes. In other words, each variety presents its own unique scenario.
quences, such as developing herbicide resistance. The authors also conclude that, “there is no evidence of negative effects of transgene introgression so far.” Gene flow from GE crops to commercial non-GE crops is perhaps the bigger issue, with multiple social and economic impacts. In order for various types of crops and ag systems to coexist, containment and traceability become key.

The other gene transfer issue is the ability of bacteria to acquire genetic material from other organisms (they’re worried about bacterial antibiotic resistance genes) through horizontal gene transfer. So far, results point to soil bacteria being able to uptake exogenous DNA in laboratory experiments, at a low rate. However, they haven’t found evidence of that gene transfer in field experiments, and improvements in genetic engineering are trying to prevent the possibility of unwanted horizontal gene transfer.

Our health
While the topic is debated—heatedly—one thing everyone seems to agree upon is to begin by evaluating GE crops based on how equivalent they are to the non-GE version; this is called “substantial equivalence assessment.” Some would like evaluation to go further, to include more compounds analyzed via other approaches, which have resulted in more differences between the two; however, an article analyzing these newer techniques in Plant Physiology (Vol. 155, No. 4, 2011) says that the interpretation of the results is difficult and doesn’t yet provide manageable information.

So, if we ingest transgenic DNA, then what? In 2010, the European Commission concluded that transgenic DNA does not differ from any other DNA present in food, nor does ingesting it carry a higher risk.

Allergy and toxicity effects of transgenic proteins are another concern. According to the literature review, there is no scientific evidence of toxic or allergenic effects, though there’s a potential allergy issue of the brazil-nut storing protein in a soybean—some-thing that’s not on the market. Transgenic proteins do go through an evaluation process to test for toxicity, stability, in-vitro issues, allergies and so on.

On the other hand, critics of biotechnology stress that we don’t have long-term studies assessing many of these issues and that there are still many unknowns.

The Labeling Battle
The question of whether or not to require GE labeling has become more of a pro-GE, or anti-GE (GMO), battle and has, perhaps, been the thing to shape public opinion more than anything else. As a result, more and more agriculture industry members are wondering if transparency would benefit everyone involved.

According to one organization, Label GMOs, 61 countries worldwide require some sort of GMO labeling.

In the U.S., products can voluntarily label and they usually label in the “does not contain GMOs’ sense. They can also get certified as non-GE (again, they call it non-GMO); and if they are USDA certified organic, it means they follow USDA organic rules, which do not allow for the use of GE products.

In 2012, a California ballot initiative for mandatory labeling failed to pass. In November 2013, voters in the state of Washington voted against a ballot initiative that would have required GMO labeling. In both instances, it was an intense fight, with millions being spent. Those in favor of labeling in Washington raised $7.7 million, according to MapLight, a nonpartisan research organization that tracks campaign finance data. Top contributors included Dr. Bronner’s Magic Soaps ($1.8 million), Center for Food Safety Action Fund ($455,000) and Mercola.com ($300,000). Those who opposed labeling raised $22.0 million to oppose the Washington ballot initiative, with the top three contributors being Monsanto ($5.3 million), Dupont Pioneer ($3.8 million) and PepsiCo ($2.3 million) with Dow, Bayer and BASF also ranking among the top 10 contributors.

Has Ag Killed GE’s reputation?
Genetic engineering once harbored an applause of optimism. When the GE Flavr Savr tomato was introduced in 1994, its biotech roots were celebrated. Now, companies spend millions to make sure they don’t have to identify a product as GE. They argue the technology is safe, and thus labeling would assign a negative connotation. But some say, the resistance to label implies they have something to hide.

The EU’s strict regulatory environment has made the development, growing and selling of GE crops more difficult. Furthermore, the label debate has riled up consumers around the globe, and in North America, we’re seeing growers who don’t even have an option of growing a GE tomato getting non-GMO certified. They’re doing it because their customers aren’t informed enough to know it’s a moot point right now. Plus, it may help sales.

As an industry intimate with new variety introductions, we know that each new plant has good attributes and not-so-desirable attributes. It’s the job of the breeder, the researcher, the grower and the consumer to consider each one distinctly, for what it has to offer—risks and benefits. The great challenge, however, may be in deciding where to place your rhetoric and how to educate your buyers.

CASE STUDY:
The Flavr Savr Study
Successful breeding, but a failed variety

In 1994, the first genetically engineered crop hit the stores. It was the Flavr Savr tomato, engineered by Calgene so that it could ripen on the vine and handle the post-harvest distribution chain, and still look and taste like a homegrown fruit in the hands of consumers. Calgene’s researchers did not use genes from other species; they inserted a gene from one tomato into another.

By many accounts, it was a successful introduction. And interestingly, it was perhaps the most transparent introduction of a vegetable, ever. The new attributes of the Flavr Savr were all about consumer satisfaction, which helped. Calgene sought FDA approval even though regulations were not yet in place for such a product. They were upfront with consumers and the media about the tomato’s genetic engineering, going so far as to provide pamphlets and 800 numbers at the point of sale. Every tomato was labeled. Consumers dug it. The media helped spread the word. While genetic engineering had some outspoken critics questioning how much was actually known about the safety and implications of GE crops, it seems that public opinion was not affected.

But today, the Flavr Savr is nowhere to be found. Most commercial GE crops benefit the grower first and foremost. And while researchers continue to look at developing GE tomatoes, they are not currently on the market.

“We were really a bunch of gene jockeys, you know, not tomato farmers,” Belinda Martineau, former principal scientist for Calgene, told The New York Times in a Retro Report interview in which former Calgene employees examined the failure. They pointed out that they failed at variety selection for different growing regions, at understanding distribution and the vegetable business. As a result, they didn’t corner the market as they’d hoped. Instead, they sold to Monsanto, who was likely interested in their technology patents. Monsanto shelved the Flavr Savr.

Nutrition

A Recipe for Hydroponic Success

Providing all of the essential elements in the right quantity and the right proportion to each other can seem like a daunting task to even the most mathematically gifted growers.

by NEIL S. MATTSON & CARI PETERS

Among the more challenging questions for growers beginning hydroponic production is how to design the crop’s fertilizer program. Plants require 14 essential elements in the root zone; including the macronutrients (needed in relatively large quantities) of nitrogen, phosphorus, potassium, sulfur, calcium and magnesium; and the micronutrients (needed in relatively small quantities) of iron, manganese, zinc, boron, copper, molybdenum, chloride and nickel. All of these nutrients must be supplied by the hydroponic nutrient solution, although chloride and nickel aren’t included in most recipes as they’re available in sufficient quantities as impurities with the fertilizer.

Fortunately, plants have adapted to growing at a wide range of nutrient concentrations. From a practical standpoint, this means that many different nutrient solution recipes can be used successfully to grow a hydroponic crop. With so many different recipes to choose from, where do you begin and how should you make changes and improvements from there?

Key factors when selecting fertilizers

In hydroponics, it’s absolutely essential to begin with a laboratory analysis of your water. The three main things to note are the alkalinity, the electrical conductivity (EC) and the concentration specific elements.

Alkalinity is a measure of water’s ability to neutralize acid. Alkalinity is usually reported in terms of ppm of calcium carbonate equivalents (CaCO₃). Alkalinity values may range from near 0 (in very pure or reverse osmosis-treated water) to more than 300 ppm CaCO₃. The greater your water’s alkalinity, the more the pH will tend to rise in your nutrient solution.

Water source alkalinity is a much more important number to look at than its pH. The pH is simply a one-time snapshot of how acidic or basic your water is; alkalinity is a measure of its long-lasting pH effect. Once you know your water alkalinity, you can work with your local extension educator, fertilizer supplier or testing laboratory to select an appropriate fertilizer strategy. Depending on your alkalinity, you may need to either choose a formulation with a greater proportion of acidic nitrogen forms (ammonium or urea) or add acid to neutralize the alkalinity and counter the pH rise.

Next, consider the EC of your water source. EC is a measure of the total dissolved salts, including both essential elements and unwanted contaminants (such as sodium). Therefore, EC is a rough measure of water source purity. Unfortunately, EC gets reported using several different related units, however, it’s easy to convert between them: 1 mS/cm = 1 mhos/cm = 1000 µmhos/cm = 1000 µS/cm. Knowing water source EC will help you determine whether to use an open or closed irrigation system. In closed hydroponic systems, the irrigation water is captured and reused, whereas in open systems, it’s not. EC should ideally be less than 0.25 mS/cm for closed systems.

Many hydroponic growers have found it necessary to filter source water, often using reverse osmosis, so that it’s pure enough for closed hydroponic systems. The only way to counter salt build-up in closed systems is to “bleed” the reservoir—that is, purposely drain off some fraction of the nutrient solution and replace this with fresh water. In open systems, the build-up of salts can be managed by applying excess water to leach out soluble salts. Therefore, source water EC can be higher than in closed systems—ideally less than 1.0 dS/cm.

The laboratory water analysis will also tell you which specific essential elements and contaminants are in your water. The concentration of essential elements should be taken into account when preparing your fertilizer recipe. Often linked with your water alkalinity are considerable levels of Ca, Mg and S in the water. Be sure to look and see if your water contains these important secondary nutrients and at what concentration, then be prepared to supply these nutrients through your fertilizer program if not available in sufficient quantities for your crop’s recipe.

Sodium and chloride are common contaminants in some waters; ideally these should be less than 50 and 70 ppm, respectively. This can help you determine the need to purify your water, leach or bleed more frequently, as well as to avoid these contaminants in the fertilizer.

Once you know your water source quality you can begin to plan a fertilizer strategy specific to your crop. Plant fertilizer concentration needs vary depending on the crop grown, the crop growth stage and environmental conditions. However, for a new grower, a good starting point is to simply develop one recipe that works decently well for a range of crop growth stages and conditions. Later, you can work on honing the recipe, optimizing it for different growth stages or based on your current growing conditions.

Recipes for lettuce, herbs and leafy greens

For vegetative crops, most nutrient-solution recipes don’t adjust the ratio of nutrients while they grow; whereas, in fruiting crops the ratio may be adjusted to alter the shift between vegetative and reproductive growth. At Cornell’s Controlled Environment Agriculture group, for many years we’ve successfully used a modified Sonneveld’s recipe for growing lettuce.

The modified Sonneveld’s recipe for lettuce:

Table 1. Three hydroponic nutrient solution recipes to prepare 100 gal. of fertilizer suitable for hydroponic production of lettuce, herbs and leafy greens. If preparing to dilute in a 100-gal. reservoir, all the components within a recipe can be mixed into the water. If using stock tanks (i.e., a 100X concentration), then the calculations represent the amount to use per 1 gal. of stock. Where indicated, the Tank A and Tank B components MUST be prepared separately so a precipitate does not occur. If using stocks, dilute using 1:100 injector(s) (two injectors connected in series for Tank A and Tank B mixes). This will make 100 gal. of dilute fertilizer.

<table>
<thead>
<tr>
<th>Tank A</th>
<th>Tank B</th>
</tr>
</thead>
<tbody>
<tr>
<td>284 g Calcium nitrate (15-0-0)</td>
<td>284 g 5-12-26</td>
</tr>
</tbody>
</table>

**Jack’s Hydro-FeEd (16-4-17)**

This is a 1-bag solution; use 355 g in 100 gal. water (dilute) or for each 1 gal. in a stock tank (using a 1:100 injector)

<table>
<thead>
<tr>
<th>Tank A</th>
<th>Tank B</th>
</tr>
</thead>
<tbody>
<tr>
<td>184.0 g Ca(NO₃)₂·3H₂O</td>
<td>51.5 g K₂HPO₄</td>
</tr>
<tr>
<td>14.4 g NH₄NO₃</td>
<td>93.1 g MgSO₄·7H₂O</td>
</tr>
<tr>
<td>1673 g KNO₃</td>
<td>*0.290g MnSO₄·H₂O</td>
</tr>
<tr>
<td>*3.8 g 10% Iron-DTPA</td>
<td>*0.352g H₂BO₃</td>
</tr>
<tr>
<td>Sprink 330 or Sequestrene 330</td>
<td>*0.023g Na₂MoO₄·2H₂O</td>
</tr>
<tr>
<td>*0.217g ZnSO₄·7H₂O</td>
<td>*0.035g CuSO₄·5H₂O</td>
</tr>
</tbody>
</table>

*A precise scale is needed to weigh the micronutrients*
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and other leafy greens (spinach, pak-choi) (Table 1). You will notice that this is a made-from-scratch recipe that requires mixing of several individual compounds. Large commercial operations often follow the made-from-scratch method because of the ability to adjust individual compounds and because it can be more cost effective to purchase the individual compounds in bulk.

This is a good time to point out that most hydroponic recipes call for the use of two or three stock tanks (Figure 1). This is necessary to avoid a nasty precipitate or sludge that will occur when specific nutrients are mixed in concentrated stock solution. The more cost effective to purchase the individual compounds in bulk.

This is where it’s very important to pick quality nutrients that are very pure and 100% water-soluble.

The made-from-scratch method can be difficult for new or smaller hydroponic growers to manage. One commonly used alternative is a two-bag approach using Jack’s Hydroponic (5-12-26) and calcium nitrate (Table 2). In this method, Tank B contains 5-12-26 pre-blended formula mixed at a rate to deliver approximately 50 to 100 ppm N. Tank A contains calcium nitrate at 100 to 150 ppm N and can also be used to add in some useful crop-specific boosters, such as potassium nitrate or individual micronutrient chelates such as iron-EDTA, DTPA or EDDHA. If acid is required to neutralize source water alkalinity, this may be added to Tank B (the tank without Calcium nitrate) or some operations use a separate tank for acid.

A relatively new one-bag alternative is Jack’s Hydro-FeED (16-4-17). This formula is specifically designed to be used as a one-bag formula to deliver a complete nutrient solution to hydroponic and aeroponically grown crops. It was developed specifically for leafy green and herb growers, but has also been used to make a hydroponic formula for tomato, cucumber and pepper crops. What’s unique about this formula is its potentially neutral effect on solution pH, as well as its buffered micronutrient package that also includes the essential blend of iron chelates from EDTA, EDDHA and DPTA. This formula works well for water types with an alkalinity in the range of 40 ppm to 200 ppm N.

As you grow your skills mixing fertilizers and observing impacts on plant growth, you may be ready to begin adjusting your fertilizer program. For example, you may take into account the slightly lower fertilizer needs during propagation or the specific fertilizer needs of different

### Table 2. Comparison of the nutrients (in ppm) supplied by the three different recipes for lettuce, herbs and leafy greens.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Jack’s Hydro-FeED (16-4-17)</th>
<th>Jack’s Hydroponic (5-12-26) + Calcium nitrate</th>
<th>Modified Sonneveld’s solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>16</td>
<td>39</td>
<td>31</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>132</td>
<td>162</td>
<td>210</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>38</td>
<td>139</td>
<td>90</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>44</td>
<td>47</td>
<td>24</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>2.1</td>
<td>2.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>0.47</td>
<td>0.38</td>
<td>0.25</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>0.49</td>
<td>0.11</td>
<td>0.13</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>0.21</td>
<td>0.38</td>
<td>0.16</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>0.131</td>
<td>0.113</td>
<td>0.023</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>0.075</td>
<td>0.075</td>
<td>0.024</td>
</tr>
</tbody>
</table>

### Table 4. Two hydroponic nutrient solution recipes to prepare 100 gal. of fertilizer suitable for hydroponic production of tomatoes, cucumbers and peppers.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Jack’s Hydroponic (5-12-26) + Calcium nitrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank A</td>
<td>Tank B</td>
</tr>
<tr>
<td>Nitrogen (N)</td>
<td>347.8 g Ca(NO₃)₂·3H₂O</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>152.5 g KNO₃</td>
</tr>
<tr>
<td>*78 g 10% Iron-DTPA</td>
<td></td>
</tr>
<tr>
<td>Sprint 330 or Sequestrene 330</td>
<td></td>
</tr>
<tr>
<td></td>
<td>*0.048g Na₂MoO₄·2H₂O</td>
</tr>
<tr>
<td></td>
<td>*0.549g ZnSO₄·7H₂O</td>
</tr>
</tbody>
</table>

* A precise scale is needed to weigh the micronutrients

### Table 5. Comparison of the nutrients (in ppm) supplied by the three different recipes for lettuce, herbs and leafy greens.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Jack’s Hydroponic (5-12-26) + Calcium nitrate</th>
<th>UA CEAC Recipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>190</td>
<td>189</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>50</td>
<td>39</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>205</td>
<td>341</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>176</td>
<td>170</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>60</td>
<td>48</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>2.85</td>
<td>2.00</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>0.48</td>
<td>0.55</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>0.14</td>
<td>0.33</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>0.48</td>
<td>0.28</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>0.14</td>
<td>0.05</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>0.10</td>
<td>0.05</td>
</tr>
</tbody>
</table>

* Adapted from data collected at J.R.Peters Laboratory and Smithers Oasis Inc. 2012-2013
crops. For example, a target of 150 ppm N works well for head and leaf lettuce during the main production stage; whereas a target of 175 to 200 ppm N is more appropriate for kale, Swiss chard and mustard greens, which tend to be slightly heavier feeders (Table 3). During the seedling propagation stage a somewhat lower fertilizer target of 125 ppm N works well for both these categories.

**Recipes for tomato and other fruiting crops**

Fruiting crops tend to have higher nutrient demands than leafy greens. Besides simply bumping up the nitrogen, it’s important to increase the potassium, calcium and magnesium as well. A single fertilizer recipe has worked well for growing tomatoes, cucumbers and peppers at the University of Arizona Controlled Agriculture Center greenhouse (Table 4). A similar recipe following the two-bag approach and a nutrient comparison is noted in Tables 4 and 5.

For tomatoes, commercial operations often adjust the nutrient solution recipe according to the crop growth stage. The strategy is typically to supply more nitrogen, calcium and magnesium at first to promote good plant structure and vegetative growth (Table 6). Then about six weeks after transplanting the tomato seedling, nitrogen is reduced, but potassium is increased, to promote the transition between vegetative growth and flowering and fruit set. Finally, the recipe may be adjusted again to balance vegetative and reproductive growth as the plant continues to grow and set fruit.

**Honing your fertilizer recipe**

Whether you’re a beginner or an old pro, it’s important to continually monitor your nutrient solution. Daily in-house testing of the nutrient solution pH and EC followed up by periodic full nutrient testing in a laboratory will give you a good peace of mind that you’re providing nutrients in the correct quantity for the plant and the proper pH. Establishing a baseline concentration of nutrients in your reservoir through consistent testing of the solution will greatly help you determine how to make changes in the future.

To further hone your fertilizer recipes, periodic tissue sampling is a must. This lets you determine the exact nutritional status of your plant, allowing you to determine how the nutrients you apply are absorbed into, stored and redistributed in the plant. Monitoring the change in nutrient concentration over time with periodic sampling is one of the best methods of evaluating if you’re providing the right nutrients to your plant, matching its growth stage and growing conditions.

Understanding nutrient mobility relationships within a plant will greatly enhance how you interpret and use the data generated by a tissue analysis. Young leaves tend to show higher levels of the mobile nutrients (nitrogen and potassium) and lower levels of immobile nutrients (calcium, iron and manganese). Therefore, samples taken from young leaves can be most useful to diagnose calcium or micronutrient deficiencies. If no particular problem is suspected, testing laboratories typically recommend taking samples from recently matured leaves as a decent representation of what’s happening to both new and old growth. Take time to evaluate your records of fertilizer inputs, light and temperature conditions, and EC/pH balance. This may allow you to come to a better understanding of why and how your actions can influence the nutrient balance in solution and in the plant’s leaves.

Preparing hydroponic fertilizer solutions doesn’t have to be a daunting task. Start with one recipe that makes sense for your crop. Monitor early, monitor often and as your comfort level grows, you may begin to modify the recipe to optimize crop growth. Who knows—you might find that preparing fertilizer recipes becomes as enjoyable to you as following grandma’s chocolate chip cookie recipe.

**Table 6.** Recipe for tomatoes in winter according to crop growth stage (units are ppm).

<table>
<thead>
<tr>
<th></th>
<th>Weeks 0-6 Higher N, Ca and Mg for vegetative growth</th>
<th>Weeks 6-12 Lower N, higher K for reproductive growth</th>
<th>Week 12+ Maintain balance of vegetative / reproductive growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>224</td>
<td>189</td>
<td>189</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>47</td>
<td>47</td>
<td>39</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>281</td>
<td>351</td>
<td>341</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>212</td>
<td>190</td>
<td>170</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>65</td>
<td>60</td>
<td>48</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>0.33</td>
<td>0.33</td>
<td>0.33</td>
</tr>
<tr>
<td>Boron (B)</td>
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<tr>
<td>Copper (Cu)</td>
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<tr>
<td>Molydenu (Mo)</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Source: Sunco, Ltd., and University of Arizona, Controlled Environment Agriculture Center, http://tinyurl.com/lj785/

NEIL MATTSON is Associate professor and greenhouse extension specialist, Cornell University, Department of Horticulture. He can be reached at (607) 255-0621 or nsm47@cornell.edu. CARI PETERS is Vice President at J.R. Peters Laboratory in Allentown, Pennsylvania.
Expanding the Perception of Sustainable Farming

A young go-getter finds a way to cultivate his passion for green development with a new way to grow food in the city.

by ANNE-MARIE HARDIE

Imagine you could convert the roof of an unused parking space into a lush area that could produce enough food to feed a city. Imagine if, in a small portion of this space (just a 10 by 100 sq. ft. area), you could produce as much food as a 13-acre farm, while using 90% less water and no chemical pesticides. In Vancouver, this vision has transformed into a reality when Institute B member Donovan Woolard became the Strategic Advisor for Alterrus in Vancouver, British Columbia.

At Institute B (a consulting firm for entrepreneurs), Donovan is fondly nicknamed “Green Thumb” and there’s no wonder. Passionate about sustainable projects, Donovan was seeking out a venture that would best match his managerial skill set with his love for green development. Donovan shares that, when the opportunity to become involved in the Alterrus project arose, he jumped on it.

From concrete to green

In 2009, Time magazine called Alterrus’ (formally known as Valcent) VertiCrop system one of the top innovations of that year. Geared towards growing leafy greens in urban environments, Donovan shares that the VertiCrop system (essentially a vertical growing system) is a sustainable solution that meets the varied needs of our global food production.

A publicly traded company, Alterrus Systems, Inc. is based in Vancouver. When developing their VertiCrop system, their vision was simple: to create a sustainable urban farming system in every major city. In January 2013, Alterrus launched their inaugural vertical farm—called Local Garden—in Vancouver, which was chosen as the host location for a variety of reasons, but one of the main ones was the city’s aspiration to become the greenest city in the world by 2020.

“When talking to the city, they made it clear to us that they had a number of parking garages (parkades) that used to be quite profitable for them. But with changes in the urban demographic… revenues from their parking has gone down,” said Donovan. “They were looking for ways to repurpose these big empty slabs of concrete and it seemed an attractive place for us to put in our first installation.”

The end result was that Alterrus took over the roof level of a garage in downtown Vancouver and installed a 6,000 sq. ft. vertical greenhouse structure. Today, this growing space is producing enough local greens for 12 to 13 grocery stores and a similar amount of restaurants while employing seven people.

The urban growing system

The standard VertiCrop system is a 4,000 sq. ft. commercial scale system equipped with 3,000 grow-
Specialist in vegetable greenhouses since 1965!

Harnois is a leading manufacturer of quality vegetable greenhouses. We offer our customers unique and fully integrated growing solutions. From structures, water and climate management to construction assistance and agronomic support, we enable growers to achieve efficient and successful vegetable production. Harnois is THE reference in vegetable growing solutions.
ing trays, each stacked 12 high on a continually moving conveyor. Moving the crop serves several purposes: from saving the energy on lighting (crop rotation ensures that each crop has an equal exposure to the light) to reducing the infrastructure for irrigation. With a rotating crop, the harvesting process has also become extremely simple. Alterrus’ VertiCrop system eliminates the needs for cultivators, as the moving conveyor brings the harvest directly to the picker. In the Vancouver installation, the harvest area is a mere 200 sq. ft., allocating the remaining space for growing leafy produce.

“The VertiCrop system is designed essentially for leafy greens. Most of the leafy greens that we eat in Canada come from about 2,000 to 3,000 kilometers away,” said Donovan. “In addition to the freshness, taste and quality issue, there is a significant environmental and climate impact involved with the transportation of these crops.”

Not only is there significant energy savings in transportation, Donovan estimates that the VertiCrop system uses 10 times less water than in equivalent fields.

“Other than evaporation or transpiration, water only leaves our facility through the plants,” said Donovan.

The reason for this is that the irrigation system is fully contained. The irrigation takes place from the top and then funnels down to the bottom. Each tray has a lid with 40 slots: 39 of these slots contain growing plugs while the fortieth acts as a funnel. Water comes down into the funnel and fills the trays from the inside. The overflow cascades into the funnel in the tray below it. As the water flows into the last tray, it’s captured in a recirculation trough that travels into the purification pump and then is pumped up into the day tank.
Moving the urban farming movement

It's been more than 10 months since the grand opening of Vancouver's Local Garden and the city's response has been extremely positive. The Local Garden's leafy produce is in most of the major Vancouver grocery stores while also serving 12 local restaurants. The concern that the Local Garden faces is lack of supply rather than lack of demand.

As of October 2013, Alterrus now has a second VertiCrop structure in operation at Epcot Center's "Living with the Land" exhibit in Orlando, Florida. Donovan’s hope is that this installation will expand the conversation of what sustainable, local farming is.

“If you want to feed 9 billion people, we need to maintain all of our existing farmland and augment with other types of land, such as existing car parkades,” said Donovan.

After the success of Vancouver, Alterrus is looking for areas to expand and ideally develop local partnerships with those involved in the farming industry. The minimum requirement for the growing area is 4,000 sq. ft., although Donovan recommends 8,000 to 10,000 ft. is probably a more realistic estimate if the company is planning on doing both propagation and packaging on site.

The Vancouver installation is housed in a Vanderhoven greenhouse using the F-clean material, a thin, very strong poly.

“There are a number of reasons for us to use this. First of all, because it’s very lightweight, which is key when building on top of an existing structure,” said Donovan. “It has a better fire rating than glass and it has an inflated dual layer, offering insulation while heating. In addition, if we need to melt off snow, we can actually deflate the walls and roof and the melting occurs very quickly.”

One of the other advantages of this VertiCrop system, is it has a fairly quick installation process. The timeline to install a VertiCrop system is approximately three to four months from pouring the first concrete to the final installation. The challenge for some cities, says Donovan, may be in obtaining a permit for this unique structure. In particular, if the installation is occurring in a city that doesn’t have a farm code. In Vancouver, Donovan had to work with the city from scratch, as the city hadn’t had a farm code in decades. The fact that Vancouver had a highly supportive council and senior leadership helped accelerate the process to install the system.

Today, Alterrus has several active conversations across the world from North America to Asia and even the Middle East.

"It is exciting because in each major city there are different motivations for installing an Alterrus system," said Donovan. "In the Middle East, an area where there is lots of space and a warm climate, what attracts people there is the water consumption. In some of the dense urban areas, where farmland is limited, the appeal lies in the flexibility of the space required."

Donovan shares that in major Asian cities, one of the key attractors is the space efficiency of the system. In these densely populated areas, the fact that you can have farm production levels in an extremely low land footprint is very appealing.

One of Donovan’s highlights of this project is watching people question their assumptions of what sustainable food production looks like.

“If we want to continue to eat local, even in the middle of winter, then a system like this is a good solution,” said Donovan. “We can do this with a small amount of land, with no chemicals, pesticides, herbicides. We deliver our entire restaurant product by cargo trike. It is an interesting conversation to have on what sustainable farming looks like.”

Anne-Marie Hardie is a freelance writer/speaker from Barrie, Ontario, and part of the third generation of the family-owned garden center/wholesale business Bradford Greenhouses in Barrie/Bradford, Ontario.
The basic function of a germination substrate is to establish uniform, vigorously growing seedlings. Vijay Rapaka, manager of grower research at Smithers-Oasis Co., said once the seedlings have true leaves and roots growing out of the substrate, they’re ready for transplant. It takes two days for the seed to germinate and the seedlings are usually ready to transplant in 10 to 16 days, depending on the season.

The seedlings take up less space, so one efficient way to use production space is to hold the seedlings longer in a nursery area. However, the seedlings shouldn’t be allowed to become overcrowded because stretching can occur. Vijay said the higher the plant density per tray, the sooner the seedlings need to be transplanted.

There are various substrate configurations available and Vijay said growers should select the ones that best meet their production needs and specifications. Once the seedlings are transplanted into a nutrient film technique (NFT) or floating raft system, the substrate simply acts as an anchoring material and the root system grows outside the substrate.

Michael Christian, CEO and president at American Hydroponics, said when a grower starts producing lettuce or greens using an NFT system, the preferred growing substrate is a root cube.

“The root cube is used basically as a seedling germination and plant support structure,” Michael said.

“The medium is actually the nutrient solution in which the roots live and derive oxygen and nutrients. The grower usually starts with a seedling tray and moves the two-week-old seedlings into a plant site in the nursery channel. After two more weeks, the plants are moved into a finishing channel. Two weeks later, the plants are harvested. This production schedule allows a grower to achieve 26 crop turns per year."

Michael said when he starts working with a new grower he usually recommends using an Oasis cube.

“For the beginning grower, we’ve found it’s easier to sow the seed into the Oasis cube,” he said."Growers
who are just starting out are doing their planting by hand and it’s easier for most to do their seed sowing with Oasis. Also, we can guide the grower through the watering cycle to make sure the Oasis cubes are not too wet and are at the right moisture level for optimum seed strike, uniformity and growth.

Vijay said that uniformity and vigorously growing seedlings are crucial to ensure successful production.

“The Oasis Horticube material is inert,” Vijay said. “The pH of the cube is about 5, but once water and the nutrient solution are applied, it changes to the pH of the nutrient solution. The cube doesn’t have any buffering capacity or cation exchange capacity, and it doesn’t contain any fertilizer. It offers growers the flexibility to change the pH and electrical conductivity to what they want.”

**Optimizing germination conditions**

Vijay said that after the initial watering, the Horticube trays should be placed in a dark room at temperatures between 66 to 68°F (18 to 20°C). Darkness isn’t required for germination, but it can help the seedlings start uniformly. The seed doesn’t need to be covered with vermiculite or any other type of material.

Vijay said the trays need to be moved from the dark room to the greenhouse after 48 hours. Leaving the trays beyond 48 hours can lead to stretching of the seedlings.

Phil Johnson, crop consultant propagation at Grodan, said depending on the climate, time of year and size of the rooting cubes, the plants are usually grown on until the stage where the leaves of the plants are touching each other.

“The plants are generally maintained for 14 to 21 days before the cubes are moved into the production area,” Phil said. “It’s cheaper to keep the plants in the propagation area because a smaller area is being heated and cooled. It’s also easier to create a good microclimate around the small plants. The bigger the plants can be grown in the propagation area without allowing them to get leggy, the less time they will spend in the production area. The benefit of this during the summer is when larger plants go out into the production area where the climate is hotter and drier, the plants are more able to deal with and manage these conditions.”

Phil said one of the advantages of sowing seed into rockwool cubes is the uniformity they provide when growing a crop.

“A grower wants plants to grow at the same speed so they are the same size,” Phil said. “When the plants are moved out into the production area, a grower doesn’t want to have to be harvesting a few plants at a time because they are growing at different rates. A lettuce grower wants to be able to bench-clear a crop just like a flowering crop. The grower wants uniformity across the crop from day one.”

“Rockwool is inert with no buffering capacity. This enables a grower to make a very precise fertilizer recipe so that the nutrient solution delivered is what is available to the plants. Rockwool is also a clean substrate and won’t clog filters or cause the irrigation system to become clogged over time.”

Michael said one of the advantages of the rockwool cube is its durability in shipping.

“When we ship long distances—for instance, large containers to other countries—we ship rockwool,” he said. “It is very durable and can withstand the rigors of shipping.”

**Organic compatible substrate**

Sylvain Helie, an agronomist and phytotechnologist at Jiffy Products of America, is working with an organic grower of lettuce, greens and microgreens who is using Jiffy 7 pellets and QSM (quick soil mix) cubes.

“Jiffy was able to supply the grower with a pellet that was made from only peat and lime. The pellet contained no conventional fertilizer charge,” Sylvain said. “We sent the ingredient list to the grower’s certification organization and it was accepted. The product did not have to be OMRI listed. Jiffy has also produced a rectangle-shaped QSM cube that the grower can use in his NFT gutter system to produce lettuce and greens.”

The grower is also using the rectangle-shaped cubes to produce microgreens. A 26- by 13-in., vacuum-formed, white germination tray holds 18 of the cubes.

“The trays are solid with no drain holes,” Sylvain said. “The employees know exactly how much water needs to be added to the tray to thoroughly wet the cubes. The microgreens seed is germinated in the cubes and, after five to eight days, the plants are ready to harvest.”

Sylvain said the grower is also using the round-shaped QSM to grow microgreens in clear plastic clamshells.

“One application of water and fertilizer is applied to one cube in each clamshell,” he said. “This expands the cube and the microgreens seed is sown. In five to eight days the microgreens are up, the clamshells can be closed and shipped to market.”


**DAVID KUACK** is a freelance technical writer in Fort Worth, Texas. He can be reached at dikuack@gmail.com.
Battling Botrytis with Peroxygencompounds

Thanks to advances in field/greenhouse/high-tunnel production, tomatoes are available all year long, but this doesn’t come without some fungal disease problems.

by VIJAY CHOPPLAKATLA

Tomatoes are one of the major greenhouse-grown crops in the United States. Production in greenhouses ensures a constant and adequate supply of quality tomatoes to the market. However, greenhouse production has its own challenges. Warm temperatures and high humidity provide apt conditions for disease development. Some of the most commonly occurring tomato diseases in greenhouse production include, but are not limited to, fungal diseases such as Botrytis Gray Mold, Leaf Mold and Powdery Mildew, and bacterial diseases such as Bacterial Canker, Bacterial Speck and Bacterial Spot.

Conventional pesticide usage in greenhouse tomato production in general is limited. Growers tend to manage disease and insect issues primarily through the use of resistant cultivars, cultural control, modifying the greenhouse environment and use of biologicals. When pesticides have to be applied, there’s a growing interest about the use of bio-rational/organic-based products that are effective, economical and safe to the environment. Peroxygencompounds [POCs; Hydrogen Peroxide (H2O2) + Peroxyacetic Acid (PAA)] are one such group of bio-rational chemistries that have potential for use in crop protection.

The breakdown on POCs

POCs are well known for their excellent biocidal properties. They’re made by mixing Hydrogen Peroxide and Acetic Acid, which produces a highly reactive product called Peroxyacetic Acid (PAA) (See Figure 1). PAA was found to be more effective as a bactericide, fungicide and sporicide compared to straight hydrogen peroxide by itself. The POC applications in the industry range from crop protection to use in food processing and handling as a sanitizer/disinfectant and from irrigation water treatment to general cleaning and sanitation. In crop protection, POCs—such as BioSafe Systems LLC’s OxiDate 2.0, a 2% Peroxyacetic Acid product, and TerraClean 5.0, a 5% Peroxyacetic Acid product—were found to be effective in the control of such important field and greenhouse diseases like Botrytis Gray Mold, Bacterial Wilt, Phytophthora Blight and Root Rot Knot Nematode.

These products are also associated with the increase in total/marketable yield of food crops and improved vigor/aesthetics of ornamental crops. In the greenhouse and nursery industry, POCs such as ZeroTo1 2.0, a 2% Peroxyacetic Acid product, and SaniDate 12.0, a 12% Peroxyacetic Acid product, were found to be effective in the control of plant pathogens that transmit through water and also on hard surfaces.

Figure 1. The Peroxyacetic Acid (PAA) molecule.

Figure 2. Effect of Treatments in Controlling Leaf Mold (Measured as % Infection) in Fresh Market Tomatoes

Ohio State University, 2008

<table>
<thead>
<tr>
<th>Treatment</th>
<th>% Leaf Mold</th>
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<tr>
<td>Untreated Control</td>
<td>16.6 a</td>
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<td>Treatment #3</td>
<td>15.3 ab</td>
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<tr>
<td>Treatment #4</td>
<td>15 ab</td>
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<td>Treatment #5</td>
<td>9.8 c</td>
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<tr>
<td>OxiDate 2.0</td>
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Figure 3. Effect of Treatments in Controlling Leaf Mold (Measured as Area Disease Progress Curve (AUDPC))

Ohio State University, 2008

<table>
<thead>
<tr>
<th>Treatment</th>
<th>AUDPC</th>
</tr>
</thead>
<tbody>
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<td>Untreated Control</td>
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<tr>
<td>Treatment #2</td>
<td>164.3 abc</td>
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<tr>
<td>Treatment #3</td>
<td>220.3 a</td>
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<td>212.3 ab</td>
</tr>
<tr>
<td>Treatment #5</td>
<td>137.8 bc</td>
</tr>
<tr>
<td>OxiDate 2.0</td>
<td>122.5 c</td>
</tr>
</tbody>
</table>
New research
In recent years, a university trial conducted at Ohio State University evaluated OxiDate 2.0, a POC-based chemistry whose active ingredients are 27.0% Hydrogen Peroxide and 2.0% Peroxyacetic Acid, and a product that works similarly to ZeroTol 2.0. OxiDate 2.0 was evaluated among other bio-rational products for the control of fungal diseases Botrytis Gray Mold (Botrytis cinerea), Leaf Mold (Fulvia fulva syn. Cladosporium fulvum) and Anthracnose (Colletotrichum coccodes) in fresh-market tomatoes grown in a high tunnel environment and treatments were compared for their performance in the presence or absence of composted dairy manure in the beds.

The experiment was conducted on Florida 47 tomato variety transplants and test plots were arranged in a randomized split block design with four replications. Each plot consisted of eight plants spaced 1.5 ft. apart with 4 ft. between rows. OxiDate 2.0 was applied at 1.0 gal. per 100 gal. of water using a backpack CO2-pressurized sprayer (40 psi, 92.4 gal/A, 0.5 mph) on a seven to 10-day schedule beginning on August 1 and ending on September 12, for a total of seven applications. The severity of leaf mold on foliage and Botrytis Gray Mold on flowers was evaluated using a scale of 0% to 100% foliage infected and by counting the number of infected flowers, respectively. Fruits were harvested multiple times and weight of marketable fruit, healthy cull fruit and fruit with Anthracnose, Botrytis, “other” rots (minor fungal and oomycete fruit rots), blossom end rot and fruit damage by insects were determined.

Results showed that plots treated with OxiDate 2.0 had significantly less Leaf Mold than the other treatments (Figures 2 and 3). Only treatment with OxiDate 2.0 significantly reduced the severity of Botrytis Gray Mold on tomato flowers (Figures 4 and 5). Tomato plants treated with OxiDate 2.0 yielded significantly higher proportions of marketable fruit than the untreated control (Figure 4). There were no significant differences among treatments including OxiDate 2.0 and the untreated control in the incidence of Anthracnose.

In another trial conducted by BioSafe Systems in 2009, StorOx, a POC-based chemistry similar to OxiDate 2.0 and ZeroTol 2.0, was evaluated for its effect in controlling Botrytis in greenhouse tomatoes at the ICMS research station in Abbotsford, British Columbia. This tomato crop was produced using commercial practices. The cultivar Tradiro, a cluster tomato that is locally grown by the greenhouse industry, was sourced from a local nursery. The trial was set up as a randomized complete block design with four replicates. Each plot consisted of two plants in one growing bag and the bags were spaced 3.9 ft. (1.2 m) apart within each row and from row to row. 

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**Figure 4**
Effect of Treatments in Controlling Botrytis Gray Mold (Measured as % Infection) in Fresh Market Tomatoes (Ohio State University, 2008)

**Figure 5**
Effect of Treatments in Controlling Botrytis Gray Mold (Measured as Area Under Disease Curve (AUDPC)) in Fresh Market Tomatoes (Ohio State University, 2008)

**Figure 6**
Effect of Treatments on % Marketable Tomatoes (Ohio State University, 2008)

**Figure 7**
% Crop Severity
- Stem
- Leaves
- Fruiting Structures

---
Multiple treatments of StorOx (listed below) were evaluated and compared against a standard chemistry. A total of four applications were made with a CO₂ backpack sprayer using four full cone D1/25 nozzles spaced at 1.6 ft. (50 cm) and at an operating pressure of 40 PSI, targeting a seven-day application interval. One day prior to the first application, the tomato plants were wounded by cutting the vine and removing the lower leaves. The trial was inoculated with a Botrytis isolate obtained from Agriculture and Agri-Food Canada.

Treatments included in the trial were:
1. Non-Inoculated Check
2. Inoculated Check
3. StorOx 165ml/100L – 1:600
4. StorOx 330ml/100L – 1:300
5. StorOx 1,000ml/100L – 1:100
6. Decree 0.75 kg a.i./ha

Crop tolerance was rated using the following scale: 0% = no injury; 100% = dead; unacceptable crop injury = greater than 10% crop injury. The control of Botrytis on the stem was assessed by measuring the length of 10 lesions per plot. The control of Botrytis on the leaves and fruiting structures was assessed using the Horsfall-Barratt scale (0 = 0% infection; 11 = 100% infection) to rate 10 leaves per plot or five fruiting clusters per plot. The severity is reported as the sum of the lesions in each plot. The incidence is reported as the percentage of subsamples that showed infection.

The greenhouse tomato Tradiro showed excellent crop tolerance to the different rates of StorOx. No injury was observed on the plant or the fruit. Throughout the trial, StorOx treatments provided comparable control of Botrytis on the stem, leaf and fruiting structures as the industry standard, Decree. (Severity ratings from final evaluation are presented in Figure 7.)

POC-based products, such as BioSafe Systems’ OxiDate 2.0 and StorOx, provide an excellent option for greenhouse tomato growers looking for sustainable disease management. Research has shown these chemistries are effective all while being approved for use in organic production. POC-based products also have a shorter half-life in the environment and are safer to use overall. Due to their unique mode of action—oxidation—the risk for pathogen resistance is minimal to none.

DR. VIJAY CHOPPLAKATLA is Technical Services Manager for BioSafe Systems based in East Hartford, Connecticut.

References:
Baldry, M.G.C. The bactericidal, fungicidal and sporidical properties of hydrogen peroxide and peracetic acid. Journal of Applied Bacteriology 54,417-423
**Svensson**

Svensson’s new enhanced XLS Ultra Firebreak curtains offer maximum energy savings potential plus superior flame retardance. They feature new diffuse, light-transmitting films that improve light distribution and enhance plant quality. The diffuse strips allow light to penetrate deeper into the crop, further stimulating growth. Ultra Firebreak’s unique structure reduces overheating while reducing shadowing. Available in 30%, 43%, 55%, 65%, 75% and 86% shade levels.  

**New Products January 2014**

**Delta T Solutions Inc.**

Create a superior growing environment and increase energy efficiency by heating both your greenhouse and irrigation water. Warm water irrigation prevents thermal shock to plants, increases rooting, promotes healthier growth and has less disease. The Delta-Temp system from Delta T Solutions saves fuel by instantly responding and heating water up to 70°F (21°C). It easily adapts to existing boilers or provides self-contained capacity.  

**Philips Lighting B.V.**

The Philips GreenPower LED production module is specifically designed for multilayer cultivation in conditioned environments. The module (50 to 250 µmol/s/m²) can replace conventional fluorescent lighting, reducing energy consumption up to 60%. Several spectrum versions are available. Philips has now released the new version with deep red, blue and far red, since they have seen that this spectrum can result in better plant growth and development.  

**Novozymes BioAg Inc.**

Met52 EC is labeled for the biological control of thrips, mites, whiteflies and black vine weevils in greenhouse ornamentals, greenhouse vegetable starts, outdoor leafy and fruiting vegetables, outdoor small fruits and berries, and onion production. *Metarhizium anisopliae* strain F52 is a contact bioinsecticide with no chemical residue and little potential for resistance.  

**Oasis Grower Solutions**

Specifically formulated for commercial hydroponic production of lettuce, herbs and vegetables, the new Oasis 16-4-17 Hydroponic Fertilizer is a one-bag solution that replaces the two-part systems traditionally used by growers. This complete nutrient system is designed to deliver all the essential nutrients for balanced root zone uptake all from a single bag. All of which helps growers simplify hydroponic operations, slice labor costs in half, better manage inventory and even reduce supply costs.  

**Growers Supply**

The Series I Aquaponics Systems produce high-quality vegetables and fish through the process of combining a hydroponic growing system with a fish-producing aquaculture tank. With seven different system sizes, growers can choose the one that works best for their needs. All systems are comprised of tanks, pumps and filters needed to support the production of natural, pesticide-free products, including lettuce, microgreens and vegetables. In addition, when used in a greenhouse setting, these systems are designed to produce year round.
Whiteflies are major insect pests of greenhouse-grown horticultural crops. The greenhouse whitefly, *Trialeurodes vaporariorum*, is one of the most destructive insect pests of greenhouse-grown vegetables, especially tomatoes. Greenhouse whiteflies are phloem-feeders with both the nymphs and adults possessing piercing-sucking mouthparts, which are used to withdraw plant fluids. The nymphs cause greater plant damage because they feed more extensively than adults. Direct feeding damage to tomatoes and other vegetable crops includes curling of leaves, leaf yellowing, chlorotic mottling, spotting of fruit, and stunting and wilting of infested plants. Nymphs may also cause indirect damage by secreting copious amounts of honeydew, a sticky clear liquid that serves as a growing medium for black sooty mold fungi, which can inhibit the plants ability to manufacture food via photosynthesis.

**Biology**

All life stages of greenhouse whitefly, including the egg, nymphs, pupa and adult, are located on the underside of tomato leaves. Greenhouse whitefly adults are winged, approximately 1/16 in. (2.0 mm) in length, and their bodies are covered with a white, powdery wax. Adults hold their wings flat and parallel to the top of the body. Adult females live up to six weeks and a single female greenhouse whitefly may lay up to 200 eggs. Approximately 20 eggs are laid in small circles on leaf undersides. The eggs are erect, spindle-shaped and attached to a short pedicel. They eventually turn gray and hatch in four days at temperatures between 65 and 75°F (18 to 24°C).

Nymphs (or crawlers) move short distances before finding a suitable place to settle and initiate feeding. The pupa (fourth instar nymph) doesn’t feed and has distinct red eyes. Greenhouse whitefly pupa possess elongated waxy filaments that encircle the outer periphery and are elevated in profile with vertical (perpendicular) sides, resembling a “cake” on the leaf surface. Development from egg to adult takes 14 to 30 days to complete; however, this depends on the host plant and ambient temperature, as warmer temperatures tend to shorten the development time.

**Management**

Scouting vegetable crops regularly using yellow sticky cards for adults and visual inspections of plants by examining leaf undersides for eggs, nymphs and pupae will avoid outbreaks of greenhouse whitefly. The number of adult whiteflies should be counted on yellow sticky cards each week and recorded. This information may be used to decide if biological control agents (e.g., parasitoids or predators) should be released or insecticide applications are required.

Clean greenhouses of debris, plants and weeds between crop cycles. Weed removal, both within and outside the greenhouse, is important, as many weed species serve as reservoirs for greenhouse whitefly populations. Be sure to place weeds and any plant debris in containers with tight-sealing lids or place into piles located “far away” from greenhouse openings. Remove heavily infested plants and avoid over-fertilizing plants, especially with nitrogen-based fertilizers, as this may make plants more attractive to greenhouse whitefly adult females for egg laying.

Contact insecticides may be used to regulate or suppress greenhouse whitefly populations; however, it’s important to obtain thorough coverage of leaf under-
sides and conduct multiple applications, as both the egg and pupa stages are not susceptible to most insecticides. Therefore, applications should be implemented frequently enough to kill both nymphs and/or adults that were previously eggs and/or pupae. Horticultural oils (e.g., petroleum-based), however, may have activity on whitefly eggs. Furthermore, develop appropriate rotation programs by using insecticides with different modes of action in order to avoid the prospect of resistance developing in greenhouse whitefly populations. Consult insecticide labels for information regarding resistance management.

When planning the use of biological control, it’s important to phase out the use of insecticides with long residual activity, which can disrupt biological control programs.

The use of biological control agents has proven to be successful against greenhouse whiteflies. The primary biological control agent is the parasitoid, Encarsia formosa. The females lay eggs inside the nymphal stages of greenhouse whiteflies. Parasitized whiteflies eventually turn black during the pupal stage. Adults emerge from these parasitized pupae. In addition to direct kill via parasitism, adults may directly kill young nymphs by feeding on them (host-feeding). Encarsia formosa performs best at temperatures between 70 and 80F (21 and 26C) and a relative humidity between 50% and 80%. This parasitoid is less effective on tomatoes that have leaves containing an abundance of hairs or trichomes because these obstructions make it difficult for the parasitoid to detect greenhouse whiteflies and inhibits the ability of adult females to lay eggs in nymphs.

Another parasitoid that may be effective against greenhouse whitefly is Eretmocerus eremicus, which also host-feeds on young nymphs. This parasitoid may be more tolerant of higher temperatures and pesticide residues than E. formosa. Before releasing any parasitoids into the greenhouse be sure to remove all yellow sticky cards, as parasitoids are attracted to yellow and may be captured; thus, reducing the effectiveness of the biological control agents. Wait three to four days before replacing yellow sticky cards. Consult with your biological control supplier to determine the frequency of release and release rate. Be sure to release parasitoids early in the production cycle. Also, control ants within the greenhouse, as they will protect whiteflies from natural enemies.

When dealing with greenhouse whitefly populations in greenhouse-grown vegetables, it’s important to act preventatively, whether scouting, applying insecticides or releasing biological control agents. Once greenhouse whitefly populations reach outbreak proportions, then options for management are limited, which may result in an economic loss. [13]

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Growers throughout the North-east need to be on the lookout for a downy mildew of basil, a disease that’s relatively new to this region. This disease has the potential to cause serious losses in basil throughout New England.

Downy mildew caused by *Peronospora belhapi* was first reported in Uganda in 1930. The disease didn’t attract international attention until it recently appeared in several new locations—Italy (2004), France (2005), South Africa (2006), Iran (2007), the United States in Florida (2007) and Argentina (2008). During 2008 and 2009, the disease occurred throughout the east coast in epidemic proportions both in the field and in greenhouses. Many states reported 100% infection of greenhouse and field basil, often with 100% yield loss. Considerable economic losses occurred in Massachusetts during that time and basil downy mildew will be a major disease of basil in the U.S. in the foreseeable future.

**Symptoms**

The pathogen is active in southern regions year-round and long-distance transport from Florida to Massachusetts occurs by aerial dispersal of spores. Rapid transcontinental transport probably occurred via infested seed sold internationally. Although the downy mildew pathogen has been detected in basil seed, seed transmission is probably a rare event.

In July 2011, infected transplants were observed in some large retail stores selling plants to homeowners in Massachusetts, which increases the likelihood of widespread infection. This means of dispersal will continue to threaten commercial production of basil.

Infected leaves develop diffuse yellowing on the top of the leaf, but distinctly vein-bounded patches on the bottom. When spores are produced, a characteristic gray, fuzzy growth on the underside of the leaves is evident. Symptoms of downy mildew on basil can easily be mistaken for a nutritional deficiency. The fuzzy growth of spores on the underside of the leaf looks as if soil had been splashed onto the leaf underside.

Field trials conducted in southern New Jersey in 2009 determined that commonly grown sweet basil (*Ocimum basilicum*) cultivars such as Poppy Joe and Nufar were the most susceptible to downy mildew. The least susceptible basils included the lemon and spice types such as *O. x citriodorum* and *O. americanum* cultivars Lemon Std, Lemon, Lime, Spice, Blue Spice and Blue Spice Fil.

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**Fighting the Rise of Basil Downy Mildew**

This disease isn’t new to the world, but it is relatively new here in the States and looks like it’s here to stay. There are few fungicides to combat it, so prevention is key.

by **DR. ROBERT L. WICK & M. BESS WICKLOW**
Management
The most important environmental factors favoring disease development are high humidity and extended leaf wetness.

In the greenhouse, these factors can be reduced by:
- The most important management tactic is to heat and vent the greenhouse, especially when warm days are followed by cool nights. This practice allows water-saturated air to escape and draws in less humid air that’s further dried by heating.
- Improve horizontal airflow by the use of fans.
- Reduce plant canopy density by spacing to speed leaf drying.
- Water in the morning, if practical, or sub-irrigate rather than overhead.

In the field, these factors can be reduced by:
- Plant in sites with good soil and air drainage and orient rows with the prevailing winds.
- Control weeds and space plants to enhance leaf drying.

Few fungicides are labeled for herb plants and there are differences in registrations for field-grown plants versus greenhouse plants. In the field, Quadris (azoxystrobin), Ranman (cyazofamid), Fosphite (phosphorous acid) and Armicarb (potassium bicarbonate) are registered for downy mildew on basil.

Greenhouse-registered fungicides include Ranman, Fosphite and Armicarb.

Alternative control products include MilStop (potassium bicarbonate), OxiDate (hydrogen peroxide), Actinovate (Streptomyces lydicus) and Sonata (Bacillus subtilis). Control obtained with these materials may be commercially unacceptable.

Research trials have demonstrated that a mixture of azoxystrobin plus phosphorous acid fungicides gives the best control of downy mildew. The addition of phosphorous acid fungicides to any other fungicide enhances their efficacy. It’s recommended that fungicides be tested on a small portion of the crop for adverse effects before applying to the entire crop. It’s the grower’s responsibility to read and follow label instructions. The label is the law and any recommendations made here are superseded by the label.

At the University of Massachusetts, we’re investigating methods to control this disease with biological control agents. We’re interested in collecting live, infected plants from residential gardens, greenhouses and field-grown basil. If you think your basil plants are infected, please call or email Rob Wick at (413) 545-1045 or rlwick@umass.edu.

DR. ROBERT L. WICK is a professor in the Department of Plant Soil and Insect Sciences and M. BESS DICKLOW is extension plant pathologist for the University of Massachusetts, Amherst, Massachusetts.
In the U.S., lettuce is the third most important vegetable grown hydroponically in the greenhouse after tomatoes and cucumbers. Over the past few years, hydroponic lettuce production is getting more and more attractive because of urbanization and the demand for fresh and locally grown produce. Lettuce is a short-term crop that can be grown in 45 days or less in water culture systems without suffering from oxygen deficit, unlike other long-term crops such as tomatoes, peppers and cucumbers. Because lettuce is a short-term crop and can be grown hydroponically year round, lettuce production is considered as a sustainable revenue generator throughout the year. As such, it’s become increasingly interesting for greenhouse ornamental growers who are constantly seeking profitable crop alternatives.

Starting the seed
Typically seedling production takes 12 to 18 days from sowing the seed. During hydroponic lettuce production, substrate is only used for seedling production. Propagation media can be broadly classified into stabilized media and loose-filled media. The loose-filled media includes peat, perlite and vermiculite. Loose-fill media isn’t very commonly used because it’s considered messy and not very versatile. Degrading peat can also compete for the oxygen and act as breeding ground for pathogens. The most commonly used stabilized media includes Rockwool and OASIS propagation media. Both are inert, sterile and synthetic, and are available in various configurations.

Germination
In the case of Rockwool and OASIS foam propagation media, water with a full-strength nutrient solution of 1 mS (125 ppm N) with the first watering. In the case of Rockwool, soak the media in a pH of 4.5 to lower the pockets of high pH of 7.5. With OASIS foam, use the standard pH of 5.8 to raise the pH from 5. OASIS foam is a cellular foam, and to avoid any dry spots, the foam should be float-saturated followed with overhead watering. This can be achieved by a watering conveyor system.

The lettuce seeds will germinate both under darkness and light. For uniform germination and start, place the trays in a dark condition at temperatures between 65 and 68°F (18 and 20°C). The lettuce seed will germinate in two days. Move the trays to the greenhouse under light after 48 hours, as any delay might cause stretching.

Seedling production
For seedling production, maintain the greenhouse day temperatures between 65 and 70°F (18 and 21°C) and night temperatures between 55 and 60°F (12 and 15°C). Maintain humidity between 60% to 70%. The light levels can be maintained between 500 to 600 µmol/m²/s. Consider shading during afternoon hours when the light levels get very high. Lettuce seedling growth is very receptive to Daylight Length Interval (DLI) and can tolerate much higher than 20 moles/day. In northern latitudes during winter months, supplemental lighting can be provided during cloudy days or to extend day length.

During the course of propagation, water as required, using a full-strength complete nutrient solution of 1 mS (125 ppm N). Watering can be achieved by misting, using a hose and a breaker, or an ebb-and-flood system. With misting, consider two to three times per day, depending on the time of the year. With overhead watering with a breaker or sub-irrigation by ebb and flood, consider watering once a day. It’s not required to keep the media constantly wet, as it promotes algae growth and can slow down the seedling growth. General overhead misting or watering promotes superior growth because of a higher rate of oxygen incorporation associated with these methods. With sub-irrigation by ebb and flood, consider media with bottom grooving to ensure proper drainage.

The seedlings are ready to transplant once they have two to three true leaves and roots emerging from the bottom of the propagation cube. The plug propagation density also determines the time to transplant. The lower the propagation density, the longer it can be held in the propagation area and vice versa.

Production systems
Typically production takes from 30 to 40 days, depending on the season. In southern latitudes where sunlight is abundant (day length averages between 14 to 16 hours), it’s possible to obtain 10 to 12 crops annually. In northern latitudes where sunlight is lower, eight crops turns annually is typical. However, supplemental lighting can shorten the crop cycle. For lettuce, the optimal DLI is 15 to 17 moles/day.

Although hydroponic lettuce production is much smaller compared to field production, it’s considered a high-quality gourmet product.

by DR. VIJAY RAPAKA
The two most common production systems are NFT (Nutrient Film Technique) and Raft Culture System. An NFT system uses a thin film of nutrient solution that flows through the plastic channels, which hold the roots. The root system develops partly in and partly above the shallow stream of re-circulating solution, which ensures it has access to adequate oxygen levels. The re-circulating nutrient solution is always pH and EC adjusted. The advantages with this system are the low amount of nutrient solution required and the fact it's easily heated during winter for optimal growth or cooled during hot summers. Some of the disadvantages are possible clogging and mechanical/electrical failures, which can result in crop loss.

The Raft Culture System typically consists of a large tank or shallow pond of nutrients, upon which plants float in rafts made of lightweight materials, such as polystyrene. The nutrient solution in the pond is pH and EC adjusted by direct additions to the pond and mixing, or by pumping adjustments into the mixing tanks and re-circulating back into the pond. Aeration is achieved by a pump or compressor that bubbles air into the system. The main advantage of this system is that the nutrient pool is a “frictionless conveyer belt” for planting and harvesting from the movable floats. In addition, the temperature fluctuations are typically less using this system. The disadvantages are the need for multiple transplants to effectively use the space and the fact this system is more labor intensive.

Nutrient solution

The key for optimal plant performance nutritionally is by choosing nutrient sources that are balanced and available for the plant to take up. A good balanced nutritional profile can come from one “complete” bag of fertilizer or a combination of different amendments. The result should contain all macro, secondary and micronutrients. To begin, it’s important you know what you’re starting with. Test the water source and use the results as a baseline to make the nutrient amendments. Following are the mineral nutrient targets for lettuce adapted from data collected at J.R. Peters Laboratory in Allentown, Pennsylvania.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Target Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>130 ppm (NO3: 120 ppm and NH4 10 ppm)</td>
</tr>
<tr>
<td>P2O5</td>
<td>25 to 35 ppm</td>
</tr>
<tr>
<td>K2O</td>
<td>100 ppm</td>
</tr>
<tr>
<td>Ca</td>
<td>80 ppm</td>
</tr>
<tr>
<td>Mg</td>
<td>40 ppm</td>
</tr>
<tr>
<td>S</td>
<td>100 to 300 ppm</td>
</tr>
<tr>
<td>Fe</td>
<td>1.5 to 2 ppm</td>
</tr>
<tr>
<td>Mn</td>
<td>0.75 to 1.0 ppm</td>
</tr>
<tr>
<td>B</td>
<td>0.25 ppm</td>
</tr>
<tr>
<td>Zn</td>
<td>0.25 ppm</td>
</tr>
<tr>
<td>Cu</td>
<td>0.15 ppm</td>
</tr>
<tr>
<td>Mo</td>
<td>&gt;1</td>
</tr>
</tbody>
</table>

The best way to measure the fertilizer strength is to check the EC of the nutrients solution as it’s delivered to the plants. This gives you a good idea of the consistency of the nutrients around the root zone. In addition, when timed with a pH measurement, you can ensure the nutrients you are delivering are available when the pH is maintained in the ideal range of 5.8 to 6.2.

DR. VIJAY RAPEKA is Manager of Grower Research for OASIS Grower Solutions based in Kent, Ohio.
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