

insideGROWER

October 2016

CONTROLLED ENVIRONMENT AGRICULTURE

Hydroponic Superhero

“Farmer Tyler” Baras
educates and inspires
at all levels, p. 8



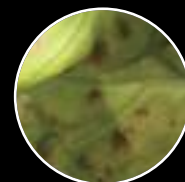
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Time Marches On

There are times when I wish I could stop time like a camera click. Or at least delay it like a slow-motion video speed. As I write this on a muggy August morning, my two kids are back in school, ready for another year of education. I, however, am wondering just how I got to 40 this fast with two kids in school—surely time jumped ahead somewhere?

But alas, time waits for no man (or woman) and we are where we are today. As greenhouse and indoor growers, it may seem like there was a rift somewhere in the space-time continuum (sorry, Star Trek fan here), and our technology started jumping ahead, as well. It can be tough to keep up with the changing times, particularly when we're often used to saying, "Well, that's the way we've always done it."

I get it, it's tough to break out of that mold. That's why in this issue we explore a couple of new options for indoor growers, as well as focus on a new name in the industry who's working to help growers figure out new and better growing methods without taking huge risks in the process. His name is Tyler Baras. At 27, he goes by the nickname "Farmer Tyler" and is working at all levels of the hydroponic industry to help educate everyone from kids to professionals on new techniques for growing food.

My interview with Tyler showed him to be a thoughtful, funny and laid back journeyman who

truly enjoys the science of hydroponics. He sort of embodies the Millennial ideal of work and fun mixed together, while spreading his passion for growing to the masses. I enjoyed our conversation, and hopefully you do, too. It starts on page 8.

Something that seems to be growing in popularity is growing in small spaces, like shipping containers and truck trailers. It's a unique niche of the industry, to be sure, but there might be something we all can learn from these systems. Read more about it on page 16.

In the immortal words of the '80s rock band Whitesnake, I don't know where I'm going, but I sure know where I've been. To look at the future, it's best to start with the past, and I found Vic Turkot's look back at Indiana hothouses from the 1950s to be a fascinating study in how indoor growing used to be. I never knew, for instance, that Indianapolis was only second in the nation in hothouse growing to my current hometown of Cleveland (that's also home to the NBA champion Cleveland Cavaliers, in case you forgot). Find out what else you didn't know about Indianapolis' hotbed of hothouses on page 22.

So what's the future of indoor growing? If you ask some, it's cannabis. In our story on page 10, GGS President Leigh Coulter writes the cannabis business is projected to outstrip health care as the country's largest industry by 2020, a mere four years and counting. Is it for everyone? No, not at all. But is it worth considering? It could be and Leigh walks us through what a business needs to know if they're considering it.

The future of indoor growing is changing and the good news is there are more tools out there than ever to navigate those challenges and opportunities. And we'll continue to be here to help you where we can!

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A Friend Remembered
G. Victor Ball, Editor from 1949–1997

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ON THE COVER

"Farmer Tyler" Baras, 27, works to bring the science and art of hydroponic growing to the masses, from school-aged kids to adult hobbyists and even the professionals. Read about his journey of becoming an ambassador for hydroponics on page 8.

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UNH Tomato Research Grant

The University of New Hampshire just received a three-year grant for nearly \$250,000 that will expand research on improving nutrient and pest management in high tunnel tomato production. Researchers there plan to identify soil tests that would show critical levels for nitrogen and potassium, and calibrate common soil tests under high tunnel conditions to determine appropriate methods for predicting nutrient availability for different varieties of tomatoes, demonstrate the benefit of plants to increase biodiversity and reduce pest problems.

"This research is critical in improving our understanding of the interaction between fertilizer applications, soil testing and crop yields in high tunnel tomatoes, one of the most important crops for New Hampshire's local food industry," says Connor Eaton, a graduate student in plant biology who's working on the research alongside NH Agricultural Experiment Station researcher Becky Sideman. "Our work aims to improve yields, increasing our local food supply and increasing gains for farmers."

There are more than 2,000 growers in northern New England and surrounding states that produce tomatoes in-ground in high tunnels, according to USDA statistics. The grant came from Sustainable Agriculture Research and Education (SARE). [IG](#)



Ohio State's New Greenhouse Tech Program

The Ohio State University's Agriculture Technical Institute in Wooster, Ohio (about an hour and a half northeast of Columbus) recently approved a new greenhouse engineering technology specialization in its greenhouse and nursery management major. The program is a unique engineering approach to hort technology education and is the only two-year program in the U.S. for greenhouse engineering technology.

The new specialization prepares students to manage modern greenhouses equipped with advanced technologies. Students will learn about electro-mechanical equipment such as fans, pumps and motors, as well as automated irrigation systems, pesticide application equipment and material handling equipment, like seeding and transplanting equipment. The modules were developed by OSU, Rutgers University, The State University of New Jersey and The University of Arizona with support from the National Institute of Food and Agriculture (part of the USDA). Students also will have internship opportunities available to them through commercial production greenhouses, institution research/teaching greenhouses and equipment suppliers. [IG](#)

Changing Light Recipes with Philips LED

Philips Lighting is launching a new production module called GreenPower Dynamic LED. The LED lights and software are designed for growers and researchers looking for precision and adjustability. The new module allows them to switch between light recipes specifically designed for nurturing different crops. It made its debut in June at GreenTech 2016 in Amsterdam and will be available this fall.

"Now, growers and researchers can grow a variety of crops with dynamic LED lighting spectra and intensities with just one LED system," says Udo van Slooten, business leader for Philips Lighting Horticulture LED Solutions. "This means they can work with dynamic light recipes to meet the different growth needs of specific crops, flowers and plants."

The new GreenPower Dynamic LED allows adjustment for the LED colors in the spectrum (far red, red, white and blue), as well as individual light intensities. According to the company, this is in contrast to previous horticulture LED lights, most of which have a predefined color spectrum that can't be altered.

Find more information about light recipes at www.philips.com/horti. [IG](#)



GMO Labeling Bill

It's official. On July 29, President Obama signed into law the GMO labeling legislation that had rapidly passed through Congress in July.

Remember, this legislation was pushed through quickly, before Congress took their recess, partly because it would (and now does) preempt a Vermont law that went into effect July 1 requiring the labeling of genetically engineered (GE) (often referred to, somewhat inaccurately, in layman's terms as GMO) ingredients.

But don't think that suddenly you'll be seeing GMO labels on everything. The bill doesn't actually detail how the federal labeling law would work; instead, it gives the USDA two years to develop rules. The bill does propose that disclosing the presence of a genetically engineered ingredient could be via text, a symbol, or an electronic or digital link. Advocates for stringent labeling feel that it doesn't go far enough (possibly, consumers might need to scan a code with their smartphone to find out if the product contained any GE ingredients). Meanwhile, many feel that this compromise legislation is a better solution than a patchwork of state laws with varying requirements.

According to an NPR story, the Organic Trade Association opted to support the compromise because "the law includes some special benefits for the organic industry. It includes, for instance, a provision that allows organic food companies to label their products as non-GMO." [IG](#)



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She (He) Who Shops, Cooks

The USDA's Economic Research Service recently released a report about the eating habits of the average American. There aren't too many surprises—we drink a lot of soda and snack while we work and watch TV. But one aspect of the research that's interesting is the ratio of shopping to cooking. It's not surprising, but it's nice to see numbers behind the fact that more women than men do the grocery shopping, and regardless of sex, whoever did the shopping spent more time in meal preparation than the others.

The numbers indicate grocery shopping and meal prep go hand in hand.

The research also looked at where people were doing their grocery shopping and why—about 67% said they went to a grocery store and 25% said a supercenter like Walmart Supercenter or Super Target. The "why" is also interesting: the primary reason for shopping at a grocery store was location, while for a supercenter it was price. Only 16% shopped a grocery store for quality and that number went down to 5% for a supercenter. In both instances, price and location were the two largest factors for shoppers. [IG](#)



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An Ambassador for Hydroponics

“Farmer Tyler” Baras works in all levels of the industry to educate and inspire.

by JENNIFER POLANZ

Tyler Baras' journey into hydroponic vegetable growing is similar to a highway, but less straight-shot U.S. 70 highway and more Route 66-style winding road. At age 27, and going by the nickname “Farmer Tyler,” he’s an ambassador for the science and the art of hydroponics at all levels, educating kids and adult hobbyists with the help of a sponsorship from HydroFarm, as well as working with commercial hydroponic supplier Hort Americas, to inform on the professional level.

“I was never really passionate about plants all through high school,” notes the affable and easy-going Tyler about how he got started. “I got to college and I was an engineering major. I was really discouraged ... I took a sabbatical, left school for a few months and went to work for the National Parks Service building trails.”

He was inspired by the outdoors and went back to school at the University of Florida in search of something that would let him continue working in nature. After trying environmental engineering (“I eventually realized environmental engineers don’t get to work outside all that often”), he switched to horticulture, where he got hooked on the science of plants. “I took a plant physiology class with Dr. [Rebecca] Darnell, who has a great way of explaining the physiology,” he says. “The science was amazing—that’s what got me hooked. When I was able to see the story behind what the plant was showing ... what the plant does, that’s what got me hooked.”

Educating the Masses

Now it’s his turn to hook others, as well as help the pros figure out better ways to grow their crops. His practical experience comes from multiple places, including 3 Boys Farm, a certified organic hydroponic farm in Florida; the GrowHaus, a nonprofit indoor farm in Denver; and overseas studies of indoor farming in Spain and China. He also expanded his knowledge creating fun and informative videos under the Farmer Tyler nickname on his website www.farmertyler.com and YouTube.

It’s never been a better time to hook the masses, too, as interest in hydroponic growing at the hobbyist level and the professional level is skyrocketing. According to a 2015 global hydroponic report from firm Research & Markets, the industry is predicted to grow nearly \$8.5 billion worldwide by 2020, and North America will be the fastest-growing region for hydroponics. While there are no statistics for hobbyist interest, Tyler says he’s continually amazed by the amount of response he receives when he does local television spots about indoor growing, which he does regularly thanks in part to a sponsorship from HydroFarm to help educate consumers on the company’s products and the science of hydroponics in general.

“I really enjoy working in both worlds because you see the overlap,” he says of the commercial and hobbyist realms. “It’s really fun to be in that mix.” What’s just as much fun, if not more, is his interaction with elementary-age students when he visits classrooms to talk about hydroponic growing. An example is when he brought some equipment to a first-grade classroom at Preston Hollow Elementary in Dallas and then checked in by Skype to keep up with the progress of the gardens. After four weeks of growing, the class harvested their lettuce. “I wasn’t expecting the response,” he says, laughing. “They were hugging me, doing lettuce dances. The best part of it is still seeing them get excited about vegetables they grew themselves.”

The Commercial Side

If it sounds like Tyler has quite a few irons in the fire, well, we’re just getting started. He signed on last November to help Hort Americas design and run a demonstration hydroponic greenhouse in Dallas, Texas. The facility is a 12,000 sq. ft. greenhouse that sits behind a Ruibal’s Plants of Texas garden center/grocery store and Tyler has been working with Hort Americas to retrofit it with a variety of systems and products supplied by the company while making sure they can produce viable crops for sale under a separate entity called Dallas Grown for Ruibal’s and other potential buyers. And, in true journeyman fashion, Tyler’s living in an RV parked next to the greenhouse during his contracted time.

“The real goal of the site is to demo Hort Americas’ products being used in a variety of systems,” Tyler notes. “Our customers are coming from so many different areas and coming from different systems.” He’ll be gathering information on

“Farmer Tyler” Baras shoots videos explaining the science behind hydroponic growing.





First-grade students from Preston Hollow Elementary in Dallas show their enthusiasm for hydroponic lettuce growing with Tyler Baras.



The Demo Facility

The 12,000 sq. ft. demonstration facility in Dallas, Texas, won't be a showcase of the fanciest, most expensive technology out there; instead, it will highlight systems and products for practical applications for all sizes of hydroponic growers. Of the space, 3,000 sq. ft. will be used for hydroponic trials, 2,500 sq. ft. will be for 4-in. potted herbs, 2,500 for succulents and 3,000 sq. ft. is rented by HydroFarm for retail demonstrations and video.

Some of the highlights of the demo greenhouse include:

- DWC Floating Raft System
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- Vertical Tower System
- Capillary Mat System for leafy greens
- A variety of LED lights to conduct top lighting LED trials

how the systems and products interact together, as well as compare them on how they do in the brutal Texas heat.

Hort Americas General Manager Chris Higgins says Tyler was a natural for the position because of his ability to interact with the growers who'll be visiting the demo greenhouse. "One thing that's difficult to find are young people who are able to train other young people," Chris says. "He's able to educate and communicate with people his age and younger how to function in a commercial production facility.

"He has this desire and easy way about him in his personality that allows him to communicate with a wide variety of personalities. Those personalities get into what he's saying and relate to what he's saying."

Along with the products and systems, Tyler will be taking a look at the challenges in general that face hydroponic growers, including the upfront costs of getting an operation started, and the labor associated with maintaining a small to mid-scale hydroponic operation.

"At the scale of a lot of these farms, these small, 5,000 sq. ft. family farms, they can't afford to go on vacation and leave the farms," Tyler says. "There's no offseason—they go year-round and it can be really demanding on the grower when they feel like they can't leave the farm."

His findings from the year-long journey in the demonstration greenhouse will culminate in a book created by Hort Americas, tentatively called "Lettuce Greenhouse Roadmap," a complement to the already published "Tomato Greenhouse Roadmap." Tyler's contract with Hort Americas is for one year from the time the demos get underway (which were scheduled to start in early September), but Chris hopes he can continue to challenge his younger colleague as a way to keep him on board.

"He's free spirited and prone to adventure," Chris says. "He's a young person, but his knowledge about crop production makes him feel older than he is.

"This facility will keep going for years after he's done, but we have a place for Tyler for many years to come if he wants it."



Cannabis Growing for Profit

As more states begin to legalize medical and/or recreational marijuana, more and more greenhouse growers are looking into it. If you're one of those people, here's some good information.

by LEIGH COULTER

Let's get right to it and put any individual ideologies aside: the cannabis plant is the greatest profit potential any grower has seen in the history of human civilization. The cannabis potential encompasses a large consumer market with an enormous variety of market segmentation opportunities, huge upside growth potential, sizable barriers to entry and an unprecedented profit margin for early agriculture producers.

But profit potential is no guarantee, and while the opportunities are sure to catch the attention of most growers, this is not a crop for everyone. With great opportunity often comes great risk and understanding both the upside and the downside is essential for any well-thought-out business plan.

UNDERSTANDING THE MARKET SIZE

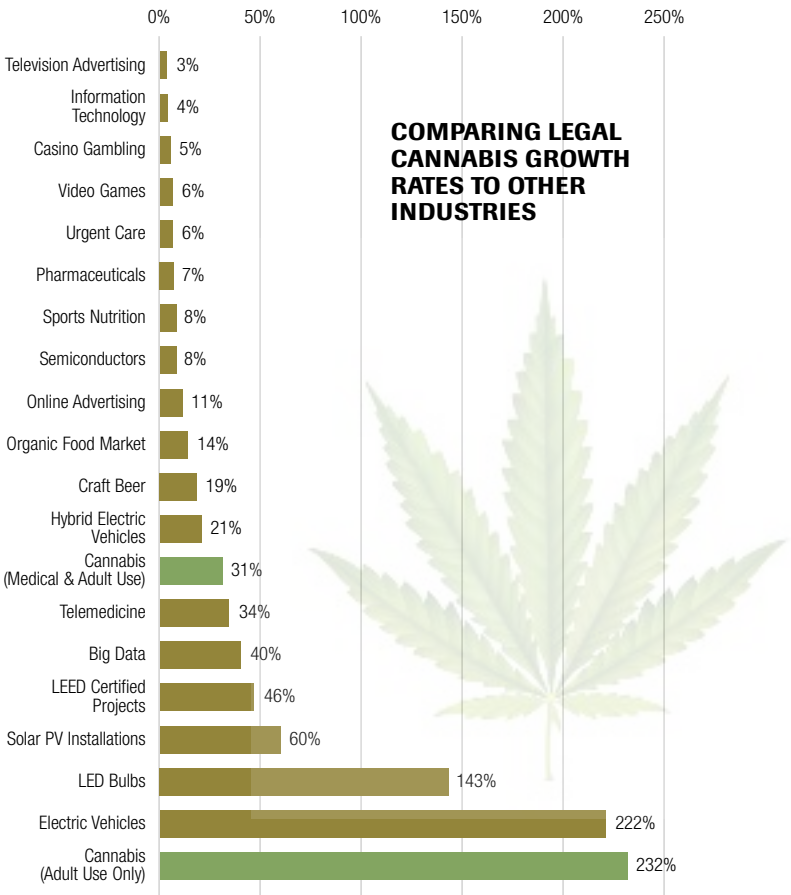
The estimated world value of marijuana is in excess of \$200 billion¹. In the U.S. alone, legal marijuana is projected to grow to \$44 billion by 2020². Not bad when you consider that *Inc. Magazine* in 2014 ranked Health Care as the largest industry in the U.S. with only \$21.8 billion in revenue.³ With 183 million people estimated to have used cannabis in 2016⁴, it's easy to see there's a vast worldwide market demand.

Furthermore, cannabis legalization is riding an enormous trend of global popularity. The spring 2016 Quinnipiac poll found 54% of Americans outright support marijuana legalization. And cannabis legalization is popular elsewhere in the world, too. In 2013, Uruguay became the first country to federally legalize marijuana and Canadian Prime Minister Justin Trudeau was elected while campaigning on a platform supporting a federally regulated adult recreational marijuana industry similar to alcohol. Israel, Italy, Chile, Jamaica and Australia are just a few of the countries to adopt medical marijuana cultivation as a legal and viable medicine for citizens in need.

CANNABIS INDUSTRY POTENTIAL

There's growing interest from mainstream investors like tech billionaire Peter Thiel who invested \$75 million dollars in cannabis-focused Privateer Holdings. It's not hard to see why investors are interested when you look at how quickly the marijuana industry is growing compared to other sectors. Information from New Frontier shows that adult recreational use of cannabis grew by 232% in 2015.

Although cannabis is still federally illegal, states across the U.S. are rapidly changing their marijuana laws. Twenty-six states have passed laws allowing marijuana cultivation to some degree, and this November, legal recreational marijuana is on the ballot and expected to pass in California, Maine and Nevada, while medical marijuana will be voted on in Florida, Kentucky, Missouri, Nebraska, South Carolina, North Dakota and Tennessee.



CANNABIS MARKET SEGMENTATION

Medical cannabis

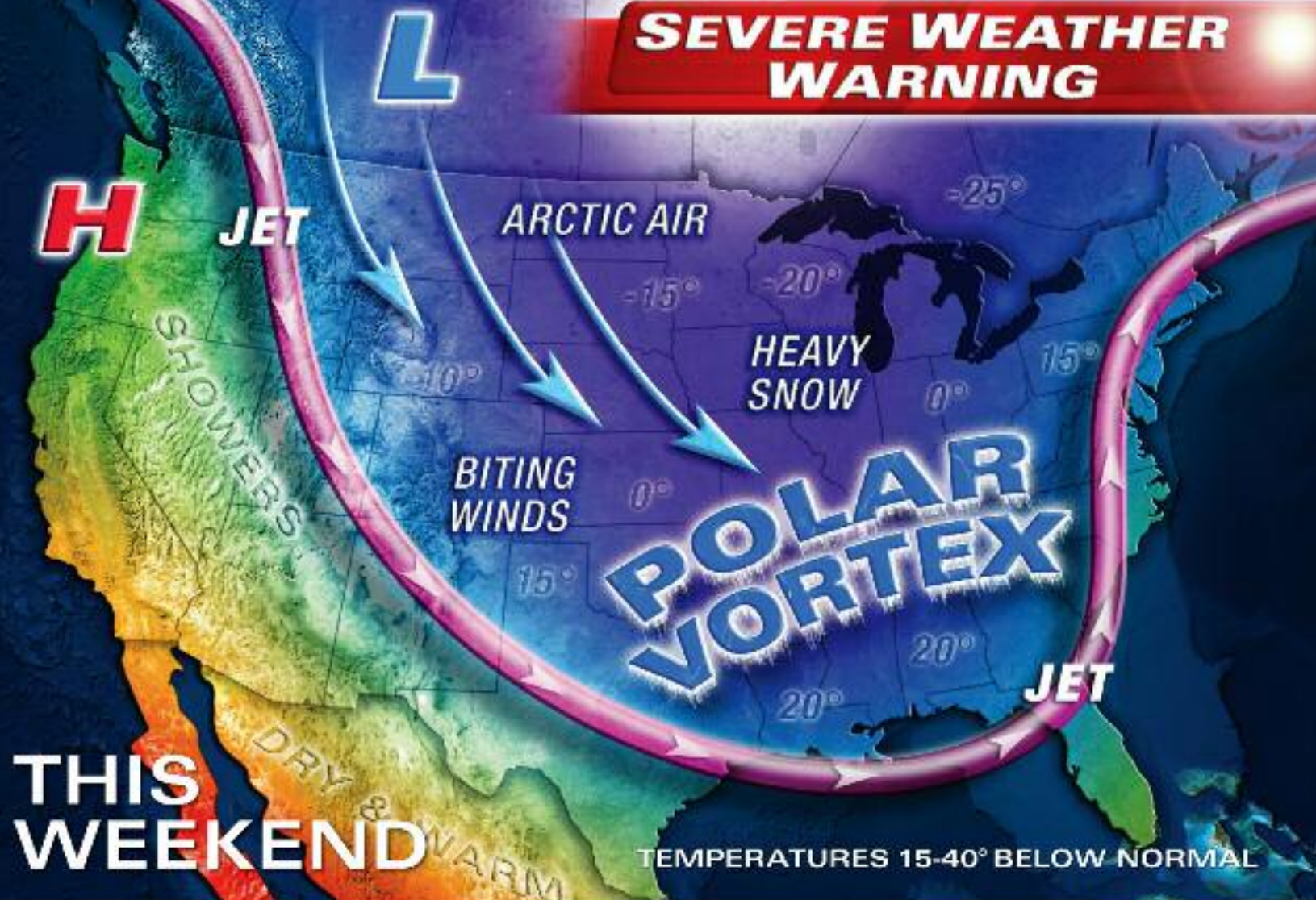
The United Patients Group lists 173 different conditions and ailments for which medical marijuana is reported to provide benefits.⁵ Among the benefits is pain relief for which cannabis is showing signs of being a safer substitute to opioids. According to the National Institute on Drug Abuse, there's a global problem of prescription opioid abuse and addiction.⁶

The Global Pharmaceutical Market is expected to pass \$1.2 trillion in 2016 and medical marijuana is poised to take its share.

Lifestyle cannabis

If you think the possibilities on the medical side are exciting, wait until you explore the different reasons people choose to enjoy cannabis for their pleasure. Cannabis as a stimulant can be a substitute for alcohol; as a relaxant it can help people sleep. Cannabis can be used as an aid for creativity or as a boost for athletes. >>>

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Other Markets

Like wine, cannabis varieties come with a wide range of smells and flavors thanks to the terpenes of the flower. Cannabis can be enjoyed alone or infused in coffee, wine and other food products.

Cannabis gardening

In Canada, medical marijuana patients are allowed to grow their own due to a Supreme Court ruling. In Washington D.C., homegrown cannabis is also legal. This opens up the future possibility of an industry supplying flats of cannabis starter plants and garden center seed bags—and perhaps specialty “Get Well Soon” cannabis arrangements.

SWOT ANALYSIS FOR EXISTING GROWERS

If the upside market potential has your interest, then you need to sit down and do a thorough analysis of your situation. There will be some dramatic differences from state to state and each grower will have different points to add, but here’s a basic rundown as it applies to existing growers considering a cannabis business.

Strengths

- Existing horticultural knowledge and experience is important. Quality growers are in high demand.
- Existing greenhouse structures and indoor grow facilities can be retrofitted for cannabis growing.
- Many of your existing supplier relationships can be leveraged for the cannabis industry. Companies like GGS Structures, Gavita and Heliospectra have built market expertise to help growers maximize cannabis yield.
- Understanding large-scale agricultural production and automation technology is a distinct advantage for production efficiencies.

Weaknesses

- Traditional horticulture and produce growers may not be knowledgeable with cultivating the cannabis plant. Don’t underestimate the value of >>>

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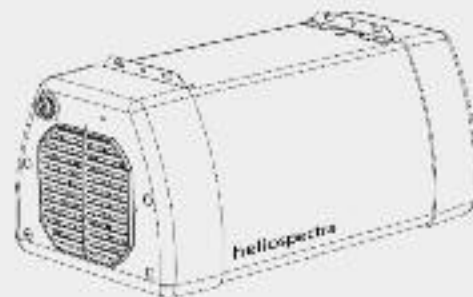
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plant-specific knowledge. This is something you need to acquire.

- You may not have the capital to cover the costs of becoming a licensed grower. State licensing fees and an arduous application process have cost hundreds of thousands of dollars for many growers who lost in the end. The upfront investment is a serious gamble to consider.

- Marijuana is a completely different market than traditional horticulture and produce. Differing customer needs and purchasing behaviors have to be learned.

Opportunities

- The marijuana market is in its infancy; there are no established brands to compete with.

- High growth potential, as more states and federal governments relax restrictions, and the distinct possibility of a recreational marijuana industry expanding.

- Many investors are anxious to get in on the "green rush" and partner with established growers. This could be an opportunity to gain a partner with strengths in your area of weakness.

- In Canada, grocery and pharmacy leader Loblaw has indicated interest in selling medical marijuana in its stores. If this happens, growers could potentially leverage their existing distribution channels.

- Vertical integration into edibles, oils and tinctures is another opportunity.

- For licensed cultivators, the restricted number of licenses issued by most states establishes smaller short-term competition, greater short-term profits and encourages market leadership should the licensing restrictions be loosened in the future.

Threats


- Big competition is coming. It would be naïve not to think that Big Pharma, Big Tobacco and Big Alcohol aren't paying attention and waiting for their opportunities.

- Increased and ever-changing government growing regulations can be costly to keep up with (i.e., odor control, security requirements, etc.).

- Currently, marijuana is still a Schedule 1 illegal drug federally in the U.S., which means that legal state growers may still be at risk of federal prosecution.

- The current inability to transport beyond state lines reduces the available market growth.

- Your bank may not want the risk and could drop you.

This is an exciting and challenging time for growers. Evaluate your core abilities and what you really want to be doing long-term. The marijuana industry isn't for everyone—do your due diligence and seek expert assistance. 

LEIGH COULTER is President of GGS Structures Inc., a manufacturer of greenhouses and indoor growing facilities. www.ggsstructures.com/ig

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Indoor Agriculture Can't Be Contained

An increasing number of companies are developing indoor agriculture production systems that have the ability to be installed wherever the space allows—including retrofitted shipping containers, reefers and truck trailers.

by **DAVID KUACK**

Glenn Behrman, founder and president of GreenTech Agro LLC and developer of the Growtainer, had an "a-ha" moment on his return flight from the 2010 Hortiflorexpo in China. Upon landing in Bangkok, he packed a bag and flew to the Netherlands to try and acquire the U.S. rights to a new indoor agriculture technology company.

"Because I had a 40-year career in horticulture, I knew what was happening and where this technology was going," Glenn said. "I realized that indoor agriculture was definitely the future. This Dutch company built an indoor farm rather than a vertical farm. The founders, who were engineers, were the first ones to really start to look at the variables, including climate control, LED lighting, computer control and the algorithms to do nature better than nature. I was very impressed with what the company founders were doing."

Although Glenn was unable to purchase the U.S. rights to the company's technology, he wasn't dissuaded from becoming involved in indoor agriculture.

"I'm not a grower, but I was always involved in the horticulture industry since 1971," he said. "I began to research the

whole concept of indoor farming. I decided that I was going to do this on my own and do it in the most difficult environment that I could find, which to me at the time was a shipping container. I felt this type of structure offered the most flexibility. It was also easier to divide up into two or three chambers. The first ones I built were half NFT, half ebb-and-flood. I was able to experiment with control systems, vertical production and LED lighting. It gave me an opportunity to kind of tinker and to try different things."

DESIGNING A FLEXIBLE SYSTEM

Glenn moved his family back to the U. S. from their home in Thailand in 2010. The next year, he began manufacturing Growtainers in Miami. He's retrofitting wind- and water-proof 40-ft., insulated reefer containers for the U.S. market. In Europe, Behrman is using 40-ft. steel containers insulated with sandwich panels to install his production systems.

"It took me about one and a half years to build a container, doing the engineering, construction and making modifications, but I still couldn't sell it at a reasonable

price and make a profit," he said. "It was about three and a half years from that beginning to having something with technology I was comfortable with that could be sold at a reasonable price."

"I tried to surround myself with people who could fill in the blanks for me—from HVAC to lighting to fertilization to irrigation."

A NEW STARTUP CONTAINER

Glenn has designed a container for new or younger growers without much experience who want to learn about indoor farming.

"This new container is going to be very low risk," he said. "We tried to develop something that novice growers can learn everything they need to know in a two-page brochure. The production system is down-sized for a 20-ft. container and it is crop specific. The system will have either 360 or 420 sq. ft. of production area."

"It's really a plug-in-and-play system. It's scalable. Every issue that I have heard people complain about or I think is problematic has been focused on. From building the unit to support, this new container will provide the beginning farmer the confidence and the economic return for their investment. It took me five years to get to this point—to understand the technology, to understand the market, to understand the customers, to watch the demand for certain products evolve."

WHAT HAPPENS IN VEGAS ...

GrowTrucks founders David Martin and Ron Evans initially thought they wanted to open greenhouses in Las Vegas to grow produce for resorts and restaurants.

"We were planning to build greenhouses and service a small portion of the Strip," David said. "That was our original intent five years ago. During our research for the equipment we needed, Ron had been into aquaponics for some time; he wanted to teach me about it. We learned a lot about aquaponics and decided that wasn't what we wanted to do as a means to have a successful commercial venture in Las Vegas. >>>



Photo courtesy of Growtainer.

Glenn Behrman, founder and president of Growtainer, is retrofitting 40-ft. reefer containers for indoor agriculture production.

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"I was involved in the real estate development and construction business for almost 30 years and Ron has a long construction background as well. Each of us has multi-generational ties to farming in the Midwest and had a passion for farming. We started looking at structures, but I wasn't happy about what I found out about trying to grow in greenhouses in Vegas. So I started looking at alternative structures, including warehouses."

MAXIMIZING PRODUCTION SPACE

David said he stumbled upon the concept of using semi-trailers and shipping containers for growing, so he started researching the feasibility of the containers. They looked at two startup companies that were using shipping containers, but weren't satisfied with the production systems and the number of plants they could produce.

"One day we looked at each other and said, 'Why don't we design our own truck?'" David said. "We decided upon designing a vertical aeroponic system because we thought it would be the cleanest, most efficient way to grow plants. The production system we have designed has two patents and we are expecting to be issued a third patent this fall.

"It took us 10 months to get the system



Photo courtesy of GrowTrucks.

GrowTrucks co-founder David Martin said the production system designed by his company can be used in a shipping container, a semi-trailer, a greenhouse or a warehouse.

parts production-ready for manufacturing. It is a double-sided, vertical flat panel system. The panels are suspended from a steel frame that is on roller bearings and move so that they can create the maximum amount of plant growing space. The system can be used in a shipping container, a semi-trailer, a greenhouse or a warehouse."

Each panel consists of a double-sided rectangular box that holds 325 plants in about 6 sq. ft. of floor space. With an 8-ft. ceiling height, David said the panels accommodate about 40 plants per square

foot of net farm area. In a warehouse, the panels could be arranged to go two or three stories high to cost effectively increase growing capacity.

INDOOR FARMING ARTISTS

Matt Vail grew up in a family that put a lot of emphasis on personal health and eating healthy, so when Local Roots Farms co-founder Eric Ellestad contacted Matt three years ago about the indoor agriculture company he was starting, it didn't take much convincing for him to become a partner.

Matt, who's the company's COO, said he always wanted to help people live healthier and to be more fit.

"Eric, who I had known for 10 years, called me and said he was starting this company to grow healthy and nutritious food in a responsible way that would have a positive impact on the environment," Matt said. "He asked me if I could help out with some of the engineering."

The founders of Local Roots Farms chose 40-ft. shipping containers to provide the shell for their farm. The containers are stand-alone independent units. They don't require any site level infrastructure.

"We chose the shipping container as the form factor for a number of reasons," >>>

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Matt said. "It is well insulated. It is ubiquitous. They can be found anywhere in the world. But the ultimate goal is to produce a scalable product that can grow for anyone in the world in a responsible way. We purchase the containers, remove the refrigeration and retrofit them ourselves. We are able to recycle and reuse something that would have ended up in a landfill."

The company does a combination of things with the system they've developed, including an R&D facility, growing for customers like SpaceX and local restaurants and retail chains.



Photo by Allison Towle.

Matt Vail, co-founder and COO at Local Roots Farms, said the 40-ft. shipping containers his company is retrofitting provide 320 sq. ft. of ground space, which translates into 1,260 sq. ft. of growing area.

DESIGNING THE BEST SYSTEMS

The container is 320 sq. ft. on the ground, which translates into about 1,260 sq. ft. of growing area. In that growing area, Matt said about 2,500 6-oz. heads of butterhead lettuce can be produced per week, which is about 50,000 lbs. per year.

"We have designed and manufactured our own LED light fixtures and use those within the units," Matt said. "To be able to equip the farm with economical fixtures, we decided to build our own. We designed a high efficiency light that allows us to control the red, blue and white light. This enables us to customize the lights for the type of produce being grown at a lower cost."

Matt said several different methods of irrigation have been trialed, including NFT, ebb-and-flow, drip irrigation and overhead foliar spray.


"We found that in our production system, in order to create a farm that is clean, simple and maintenance-free and grows produce rapidly, an ebb-and-flow system works best. We use ebb-and-flow benches. We treat the water with ozone and we have physical filtration.

"We install a proprietary HVAC system for environmental control. We design and code in-house. Using that system, a grower

is able to control all of the environmental variables, including the temperature, humidity and carbon dioxide. The system is basically prebuilt into the containers."

Matt said the company is working to automate the crop monitoring process, including the use of cameras to do visual monitoring of individual plants. He said computer vision and artificial intelligence will then be used to process that data to optimize the growing procedures for yields and to optimize the produce for antioxidant levels, nutrients and flavor.

"We are also automating the environmental controls and working to automate some of the tasks within the farm, including harvesting," he said. "We are building robotics to eliminate people having to transplant and harvest the crops so that food can be produced at a significantly lower cost.

"A plant is a unique and intricate living organism that interacts very differently to even the smallest changes. Over the last two years, not only have we designed and engineered a really elegant system, but we have also developed the expertise to be artists of farming." 

DAVID KUACK is a freelance technical writer in Fort Worth, Texas; dkuack@gmail.com.

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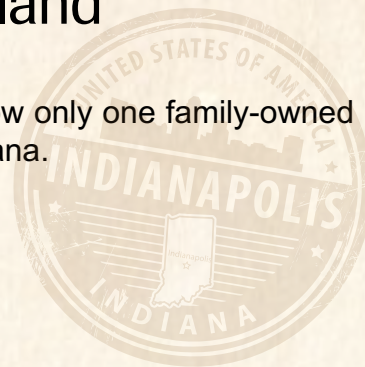
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Tomatoes in the Heartland

Once a prospering area for finished produce, there is now only one family-owned business left that's growing in Indiana.

by VIC TURKOT



When one thinks of Indiana agriculture, one thinks mostly of corn, wheat and soybeans, and the millions and millions of bushels produced from its approximately 14.7 million acres of fertile soil. Indianapolis—the state's largest city, capital and host to the renowned Indianapolis 500—usually brings to mind roaring race cars and the likes of Dale Earnhardt Jr. and Jeff Gordon sprinting around the Brickyard at mind-boggling speeds.

Indianapolis and greenhouse vegetable growing aren't usually mentioned in the same sentence ... or paragraph ... or story. But back in the 1950s and early '60s, the south side of Indiana's capital city was a hotbed of vegetable growing greenhouses.

From 150 to 1

Paul Schlegel of Schlegel Greenhouses remembers when his father had roughly 1,800 sq. ft. of greenhouse space devoted to tomatoes and lettuce in the '50s and '60s.

"At one time, our area was a force in the field. We (Marin County) were the second largest production area in the east, behind the Cleveland area," he said. "At the time it was a strong culture and we were a presence in the industry."

Now that presence is down to one person—Gus Wiegman of Wiegman Greenhouse.

"Come get my tomatoes soon because I don't know how much longer they will be available," Gus says. He's grown a variety of tomatoes over the years, from the Missouri-Ohio variety to the Jumbo Caruso to his current Trust in Geronimo variety, which he says is the best ever. He's proud of his product.



Gus Wiegman is owner of Wiegman Greenhouse—now the only family-owned produce grower in the Indianapolis area. In the 1950s and '60s, there were more than 150 growers. This photo was taken sometime in the 1980s.

"People are wary of hothouse tomatoes," he says. "But mine are so good, some people have stopped growing their own and use me."

Gus estimates that at one time there were over 150 greenhouse growers in his neck of the woods. He's a third-generation grower, following the footsteps of his grandfather and father.

"My grandfather started the business in 1905, my dad took over in the '40s and I took over from him. We've grown tomatoes all along. We also grew leaf lettuce until the '80s when the economy changed and the market died," he says.

Wiegman's output varies from year to year, but Gus figures he averages over a couple thousand bushels a season, which he sells on his own stand.

"I can't grow enough to keep up with demand," he says. If he ever gets "long in his output," there are plenty of nearby stands ready to scoop up his excess.

He does it his way

Gus times his tomatoes so they're ready to pick around May 1. Any earlier than that and the fuel charges take away too much of the profit.

"At one time, we started picking in March," he explains. "But when fuel costs went way up, we had to start planting later." But the early start gives him the local grown market all to himself. "The demand for my tomatoes drops off when July gets here. The field-grown tomatoes become available and people's backyard gardens start producing, too," he said.

His biggest challenge? "Labor. Nobody wants to work. It gets 120 degrees in the houses sometimes and it's too hot for most people," says Gus. But the tomatoes love the heat. "My father always said the hotter it gets the better they taste."

Gus waters with an overhead sprinkler system. "A fellow grower told me I should use the spaghetti tube system; it gets the nutrients right to the roots where you want them. I understand all that, but I just do it my way," he explains. >>>

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Changing times

Ask Paul Schlager how profitable it was growing back in the day and he says, "We did okay growing the vegetables, but it was always a struggle producing and having enough product at the right time," he recalls. "One thing that wasn't an issue was labor," he laughs. "My father had eight kids and there was always something for us to do."

When asked why there's only one greenhouse vegetable grower left in the area, Paul gives a short, quick answer. "Refrigerated trucks," he replies. "My father always told me when they came on the scene, everything changed. They had much better growing conditions in California, Florida and Texas and now they could ship them in and sell them in the stores cheaper than we could grow them. It hurt all the growers in the northern parts of the country."

Other factors also contributed to the demise of greenhouse vegetables.

"The next generation never took over," notes Paul. "They went to college, got educated and didn't want to be growers anymore. You saw one grower after the next dropping out and we weren't that much of a presence any more. We weren't relevant after a while."

Like Gus Wiegman, Paul remembers harvesting tomatoes as early as March, which his father then took to the wholesale market. But as fuel prices rose, planting dates got pushed back and Memorial Day became a target for the first picking, which left the greenhouse growers a little more than a month before big completion started.

Another veteran of the greenhouse era is Bill Heidenreich, a third-generation grower, who started growing vegetables under glass in the '60s.

"I mostly did it for my kids," he says. "It wasn't a big part of our business, but I had them picking and packing the tomatoes. Then we'd put them outside to sell with honor boxes."

Eventually, Bill's kids grew up, the honor boxes became less honorable, and more and more produce from warmer states put a big damper on the greenhouse business and another tomato grower packed it in.

The Brehob family were also greenhouse growers back then. John Behob was just a kid when his father got out of greenhouse vegetable growing and turned to nursery stock and running a garden center.



Wiegman has been growing tomatoes since 1905, when Gus' grandfather started the business. In the 1980s, they grew thousands of bushels. That's two of Gus' children, Christina and Gussie, in the background, along with his mother Lucy, who has since passed away.




At one point, Wiegman—and the other growers in the area—started harvesting their tomatoes as early as March. But as fuel prices started to increase, the planting dates were moved. Now, Gus said he's usually ready to pick around May 1.

"I worked in the houses when I was 2-, 3-ft. tall," he remembers. "And it got really hot. We would start picking at 5:00 in the morning to try to beat the heat. The tomato stalks grew all the way up to the gutters and prevented any kind of air circulation." John figures that his dad had about an acre under glass. He would take his produce to the co-op to sell.

"Back in the early 1900s, about 80 German farmers got together and formed the Hoosier Boy Cooperative. That's where he took his produce," he says.

It's the same story on why the Brehobs got out of greenhouse vegetables: "I remember my dad said to me that he saw the handwriting on the wall with the coming of refrigerated train cars and trucks. He thought it would be very tough to compete with the warmer states," John said.

Indianapolis had its day, but almost all of the old-time growers had to step aside for progress—except for Gus Wiegman.

"I'm going to keep growing tomatoes because tomatoes are what got us here," he says proudly. 

VIC TURKOT has been in the flower and garden center business since 1979. Vic and his wife Cindy run Freshest Flowers in Haddon Heights, New Jersey.

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From Tragedy to Triumph

How one shelter-turned-working farm is growing survivors.

Story & Photos by **SUSAN MARTIN**

It turns out that "Life does not have to be perfect to be wonderful" is not just a quaint refrigerator magnet quote after all. When you visit GreenHouse17, a 32-bed emergency shelter-turned-working farm in Lexington, Kentucky, you experience the profound, real-world meaning of this expression and a part of you can't help but be changed forever.

I had the honor and great privilege of spending a warm and sunny afternoon with four of the most compassionate and dedicated women I've met on staff at GreenHouse17. My goal was to learn their story so I could share it with the hopes of inspiring my colleagues in horticulture to participate in and perhaps continue their mission in other parts of the country.

Originally named the Bluegrass Domestic Violence Program, the non-profit changed their name to GreenHouse17 in 2013 to more accurately reflect the spirit of the organization. On their website, this explanation is given: "The protection of a greenhouse



nurtures plants so they grow healthy and strong, even in harsh weather. In the same way, we nurture lives harmed by intimate partner abuse, helping survivors grow and flourish and leave the trauma of abuse behind." The shelter serves 17 counties in Kentucky, housing women who have fled unsafe, often violent situations, bringing their children and little else with them when they come. All services are free of charge.

Called by the land to serve

Executive Director Darlene Thomas, M.S.S.W., grew up in a good home on a farm in rural Kentucky and ironically attended college to escape farm life. She went to work for a shelter right out of college after earning her master's degree in social work and has served in her industry for 27 years. Many of Darlene's colleagues discouraged her from opening a shelter in rural Lexington, a site that was off the bus line and not close to emergency support services. When she first discovered the then-vacant 12-bedroom home sitting on 40 acres of rolling land, it had absolutely no soul, but the spirit of the land strongly called her name. And after weighing her options for a few months, she answered that call. They moved in July 2005.

GreenHouse17 is run by a board of directors and 26 support staff, none of which had experience with growing vegetables or flowers. They had no idea how to use the 40 acres of land that came with the shelter. There was no model to follow; this concept of a working farm/shelter combination had never been executed to their knowledge, so they had to make it up as they went along. There were many bumps in the road.

For the first four to five years, they largely ignored the land and it quickly became overgrown. It was obvious that it needed to be tamed—at least to the point where the children could go outside and play. Around that same time, payroll was getting tougher to make each week, the government was months behind in reimbursements and the well was running dry. They needed to find a way to make the land work for them and bring in revenue.

The birth of community gardening

At that time in the Lexington area, community activists were beginning to open community gardens that featured raised vegetable beds from which produce was sold locally. "Buy Local" and "Kentucky Proud" slogans were slung on banners at local farmers markets and community events. That sparked an idea.

The board at GreenHouse17 brought in consultants from the University of Kentucky College of Agriculture and from the State Department of Agriculture to help them devise a plan for what to do with their land. Should they grow grapes to sell to local wine producers? Should they board horses like most of their neighbors did? Too expensive, the state said. You aren't ready to handle working the land, the state said. Just watch us, said the ladies of GreenHouse17. We are a team of survivors.

Admittedly, their first raised gardens weren't perfect. The weeds grew faster than the vegetables and the beds weren't super sturdy. But life doesn't have to be perfect to be wonderful. The kids gleefully pulled up and ate the carrots they grew, moms picked and washed the lettuce they'd planted from seed, and the staff saw how the experience of growing their own food was transforming the survivors' lives.

Within a year or two, they hired a full-time farm manager—a recent graduate from the University of Kentucky named Jessica Ballard—whose salary is supported by the Berea College Appalachian Fund. Jessica devised a plan to work the land 100% organically, using little to no tilling to maintain the structure of their sandy soil, which tests at an impressive rate of 9% organic matter, to provide a revenue stream for the shelter. She's the quintessential modern day "farmer," dressed in Keens and a flowing skirt, which keeps her cool during the hot Kentucky summers. The day I visited, she was busy pulling an order of freshly cut flowers for a local wholesale florist.

Growing stronger through gardening

Survivors at GreenHouse17 are given the opportunity, but aren't required, to work the farm and learn how to grow vegetables and flowers, and they're given a small stipend supported by the Berea fund in exchange for their work. >>>

Clockwise from far left: Cut flowers are grown and sold to a local wholesale florist, several area restaurants and the flower CSA program. ■ Calendula flowers are dried for use in the handmade soaps produced by GreenHouse17 survivors. ■ All of the herbs, flowers and vegetables used in the farm's handmade products are grown organically on the 40 acres of GreenHouse17. ■ Farm-to-table coordinator Christina Lane works with an on-staff chef to prepare recipes for nightly meals for the survivors. A hefty amount of produce is needed to feed 38 to 45 residents each day. ■ Jessica Ballard, Farm Manager at GreenHouse17, has devised a 100% organic method of growing vegetables and cut flowers which support the shelter. Here she is pulling an order for a local wholesale florist.



"Harvesting herbs and arranging flowers for sale is satisfying. There's no substitute for the sense of achievement you feel from seeing something through from seed to bloom," said Darlene. The survivors are "growing flowers and fruits, vegetables and herbs while growing strong in body and mind. Eating food fresh from the garden models good nutrition and healthy eating habits for parents and kids."

Diane Fleet, Assistant Director of Programs for GreenHouse17, shared a story with me about one of the farm's first successes. Theresa, a former resident, had caught every bad break in life there was to catch. During her stay at the shelter, she became interested in growing vegetables, specifically those used to make salsa. And boy, could she make salsa! The nickname "Salsa Girl" quickly stuck. Her life was forever changed when a locally famous chef visited the farm and proclaimed that Theresa's salsa was the very best he had ever tasted. The recognition literally transformed her life from tragedy to triumph and it confirmed to the staff that the farm was an essential part of the shelter experience.

With an average stay of three to four months, the turnover of help on the farm is a challenge for Jessica, who's constantly training new workers. Most have little to no experience working in a garden and the simplest things like putting water in the bucket before you add the cut flowers need to be taught. The adult residents learn alongside their children how to grow vegetables and flowers from seed, then how to harvest, pickle and preserve food for the winter months. They're eager to learn and a few have returned to the farm to share stories of their own gardens with Jessica.

Making the land work for GreenHouse17

Today, GreenHouse17 is making every one of their 40 acres work for them. A large vegetable patch is burgeoning with peppers, beans, carrots, beets, tomatoes, garlic, cucumbers and more beside a small orchard that contains about a dozen craggy, yet productive, apple and pear trees. All of the food crops are planned by their farm-to-table grower, Christina Lane, who coordinates with the cook, who prepares the nightly meals for the shelter. All of the produce grown on the farm is consumed by the 38 to 45 survivors who reside at the shelter at any given time—there's never an empty bed.

Hoop houses are filled to the brim with colorful poppies, sweet peas, calendula, sweet william and other annuals for cutting during the summer months, and then replanted with cool-season vegetables in the fall to last through the winter months, enabling the survivors to eat fresh vegetables nearly year-round. If you listen closely, you'll hear the faint buzzing of happy bees making their way through the houses overflowing with organically grown, pollen-laden blossoms.

Growing cut flowers is one important way that GreenHouse17 brings in revenue to support the shelter. In addition to selling flowers to a local wholesale florist, they also provide flowers for three restaurants in town and do about eight weddings per year. They encourage the community to get involved through their CSA (Community Supported Agriculture) cut flower program in which people from the community can purchase a full or partial season membership that awards them a fresh flower bouquet each week. Bouquets are delivered from the farm in Ball canning jars twice per week to four local retailers, where they can be picked up by those who've purchased a membership. Canning jars are always in short supply and are high on their donation wish list.

Some flowers and herbs grown on the farm are intended specifically for their line of handmade soaps and balms, which are branded under the name Handmade by Survivors and sold on

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- Inquiring about potential opportunities to serve your local community through your local department of agriculture or ag school
- Offering to be a guest presenter or mentor at your local high school, community college or neighborhood club
- Donating surplus product to community hospitals, schools and community centers
- Supporting your local community garden financially, through product donations or through education

Support GreenHouse17 by donating:


- Seeds and plants of cut flower varieties
- Vegetable and herb seeds and plants
- Organic flower and vegetable fertilizers and soil amendments
- Hand tools, including pruners, trowels, weeders, folding saws
- Additional tools such as buckets, rubber boots, aprons, gloves, long-handled shovels and rakes
- Pint or quart-sized glass mason jars (used for weekly cut flower CSA program)
- Financial donations are always welcome!

Etsy (www.etsy.com/shop/GreenHouse17). Fresh Start lavender and lemongrass goat's milk soap and Reclaim Calm lip balm are two of their most popular items. The day I visited, a rack of calendula blooms and buckets of corn cobs were drying in preparation for making Wholesome corn and calendula exfoliating soap.

Jessica says, "Making products has a special connection to our mission. Survivors experience restorative healing, collaborative work experiences and new skill development during the process. There is nothing more beautiful and affirming than to see survivors take on the role of leaders."

A growing need

Currently, GreenHouse17 purchases all of the seeds and tools needed for the farm—a cost that rises every year and limits how much they can produce and sell to help sustain the shelter. New pruners, trowels, gloves, boots and buckets are constantly needed for the survivors who come and go every few months. More flowers and vegetables could be sown, grown and sold to benefit the shelter if they didn't have to purchase all of the seeds and plants with their own limited funds.

Though they're growers in their own right, the kind folks at GreenHouse17 are not yet well-connected nationally to the horticulture industry. They have no idea how much of our product goes unsold every year and have never inquired about donations. What do you have in your storage closet, your greenhouse or warehouse that could be put to good use for this worthy cause? Please take a moment to learn more at www.GreenHouse17.org or call (859) 233-0657 to find out how you can help today. And if you're inspired to start your own version of GreenHouse17 in your state, look to these trailblazing women for their innovative model of growing success for survivors. 

SUSAN MARTIN specializes in horticultural marketing, content generation and management, working with green industry clients in trade and consumer sectors. She can be reached at gardenersuesnews@gmail.com.

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Symptoms of Common Nutrient Deficiencies in Hydroponic Basil

Trial results from Cornell University show a timeline of progression and symptoms.

by NEIL MATTSON & TANYA MERRILL

In hydroponic production, the fertilizer solution must provide all plant essential elements, as a growing substrate is either not present or merely provides physical support and access to water and oxygen. Monitoring plants to look for visual symptoms is an important tool that can be used to detect plant nutrient deficiencies.

Basil (*Ocimum basilicum*) is the most commonly grown hydroponic herb crop. Currently, there are few resources in literature regarding photographs and descriptions of common nutrient disorders in hydroponic basil. Therefore, the objective of this study was to grow sweet basil Genovese in nutrient solutions deficient of individual macro- and micro-nutrients to document visual symptoms of nutrient deficiencies and the timeline and progression of their development.

MATERIALS AND METHODS

Basil Genovese seeds were sown in 1-in. (200-cell) rock-wool cubes that were previously soaked in reverse osmosis water for five minutes and then drained and soaked and drained in a Sonneveld's nutrient solution for lettuce (Mattson and Peters, 2014). Seedlings were placed in a greenhouse at 68 to 72F (20 to 22C) with ambient light and hand watered daily (or as needed) with the Sonneveld's nutrient solution.

Fourteen to 20 days after seeding, the basil seedlings in rockwool were placed in the lid of 1-gal. buckets filled with the Sonneveld's solution. Each bucket had air bubbled in from plastic tubing with an air stone on the end, which was connected to an aquarium air pump. There was one plant per bucket.

After the plants had been established in hydroponics for one week, the nutrient solutions for each bucket were replaced with either a control solution prepared in reverse osmosis water (Table 1) or the control solution minus one nutrient element of interest (-N, -P, -K, etc.). Every other day, reverse osmosis water was used to raise the solution level in each container back to 1 gal. Every week, the nutrient solution in each container was completely replaced with new solution. Plants were monitored every week and visible symptoms of nutrient deficiency (with reference to the control plants) were noted. There was one plant for each nutrient deficiency condition; the experiment was repeated over time for a total of three replications.

Nitrogen (N)

Nitrogen deficiency resulted in uniform chlorosis (yellowing) of old leaves, which was observed after two weeks of deficient conditions. Reduced plant size was evident as compared to control plants and mature leaves had severe chlorosis after three weeks.



Table 1. Control nutrient solution used during the experimental period; single elements were removed to impose the nutrient deficiencies.

Element	Name	ppm
N	Nitrogen	210
P	Phosphorus	31
K	Potassium	235
Ca	Calcium	200
Mg	Magnesium	49
S	Sulfur	64
Fe	Iron	4.0
Mn	Manganese	0.5
Zn	Zinc	0.1
B	Boron	0.5
Cu	Copper	0.10
Mo	Molybdenum	0.01

Phosphorus (P)

Phosphorus deficiency was first evident as numerous small purple spots on old leaves, evident with three weeks of deficient conditions. Over time, purple regions on lower leaves became larger and also some interveinal chloro-

sis was evident (Figure 1). By week 5, phosphorus-deficient plants had flowered earlier than control plants.

Potassium (K)

Necrotic spots between the veins of the oldest leaves were noted within two weeks of potassium-deficient conditions, which became much more pronounced after three weeks (Figure 2). After three to four weeks of potassium deficiency, large chlorotic and necrotic regions along leaf margins and in scattered regions between veins were present.

Calcium (Ca)

Symptoms of calcium deficiency began with necrotic spots towards the base of young leaves, which was present within three days of deficient conditions. Within a week, the growing point was dead and necrotic spots had further developed. The root system was very noticeably brown.



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Magnesium (Mg)

Magnesium deficiency presents itself initially as faint interveinal chlorosis of recently mature (middle) leaves, which was observed after two weeks of deficient conditions. As the deficiency advanced, interveinal chlorosis progressed to younger leaves (Figure 3), while chlorosis developed into necrotic regions between veins of more mature leaves.

Sulfur (S)

Within two weeks of sulfur deficiency, plants exhibited uniform chlorosis across the entire leaf blade and with all leaves on the plant affected. The chlorosis became more pronounced over time and plant size was greatly reduced compared to control plants (Figure 4).

Iron (Fe)

Iron deficiency resulted in interveinal chlorosis of upper (young) leaves,

while lower leaves remained green (Figure 5). In our experiment, symptoms were not observed until four weeks of iron-deficient conditions.

Boron (B)

Boron deficiency was first evident as faint necrotic regions between the veins on the base of young leaves, which was first noticeable after three weeks of deficient conditions. As the deficiency progressed, youngest leaves were distorted/strap-like and young leaves also exhibited interveinal chlorosis. The root system was noticeably smaller than control plants with short primary roots and many stubby lateral roots.

DISCUSSION

While visual diagnosis is an important tool, it should be noted that many nutrient disorders are similar in appearance. Therefore, laboratory leaf tissue analysis is necessary to



Figure 3

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Figure 4



Figure 5



verify symptoms. Laboratory tissue analysis can help identify a nutritional problem after it's occurred. A more proactive approach, which will help you avoid economic losses from nutritional disorders, is to periodically have the nutrient solution analyzed by a laboratory. Based on nutrient solution analysis, the fertilizer regime can be modified to ensure adequate supply of nutrients.

It should be noted that the timeline for development of symptoms may vary based on your environmental conditions. In our experiment, plants were well-fertilized before we initiated the deficient conditions. Therefore, the symptoms may have taken longer to develop than if

they'd been lacking from the beginning. In many cases, nutrient deficiencies may be due to environmental or biotic causes rather than to lack of nutrients in the fertilizer solution. For example, high pH (>6.5) reduces solubility of iron, manganese, boron, etc. and can lead to nutrient deficiencies. Disease or insect damage may also look like nutrient disorders; therefore, the plant must be examined carefully to ascertain the true cause of symptoms. [4]

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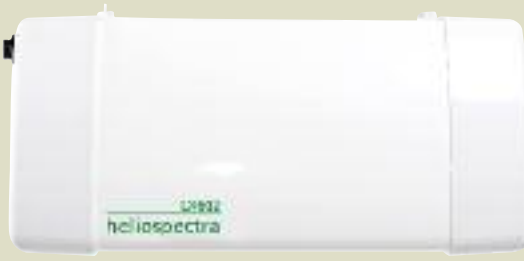
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