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Grafting: Create Stress-Free Plants

Strong roots, large fruit size, and better quality are some of the reasons more growers are turning to this process. **page 8**

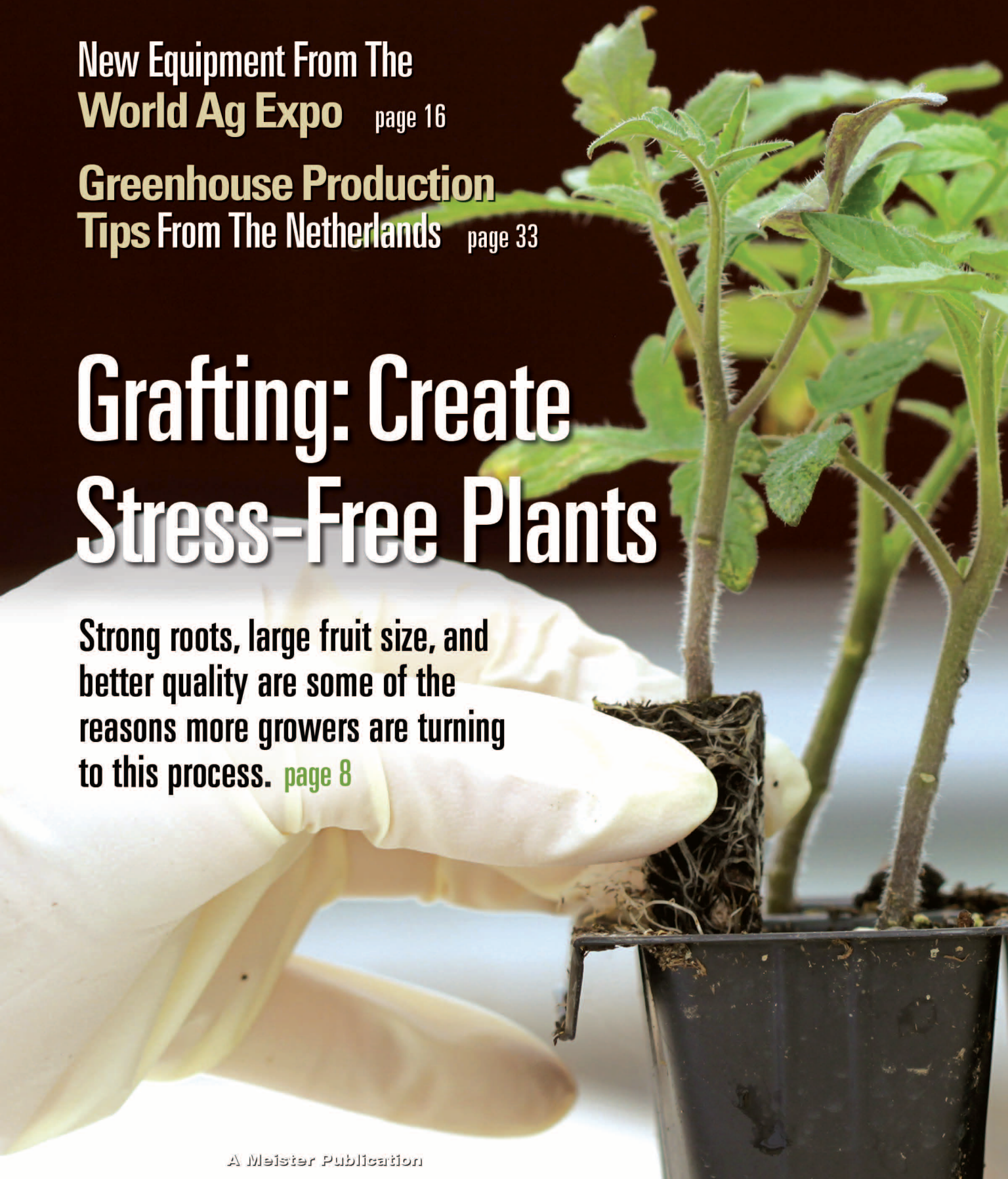


Photo credit: Dana Groff

By grafting, growers create plants with a stronger root system that is able to hold off disease longer than non-grafted plants.

Create Stress-Free Plants

Large, high-quality fruit grown on sturdy plants producing over a prolonged season are some of the advantages of grafting.

By Rosemary O. Gordon
Editor
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WHO wouldn't want vegetable plants that are stronger, healthier, and better equipped to deal with stress? That exactly describes some of the benefits of grafting, a technique that has been used in the tree fruit industry for years, but is recently gaining momentum in vegetables. (To read more about how grafting can limit disease, salinity, and stress, go to <http://bit.ly/14SlJta>.)

Grafting is defined as a process that includes splicing the shoot of a particular variety to the roots of another. The splicing makes an immediate hybrid that tends to be more vigorous and tolerant of soilborne disease, nematodes, and other types of stress than the variety that was not grafted. The process is beginning to gain momentum with some growers.

Just ask Kaitlin Dye, owner of Re-DiVined, a company dedicated to grafting vegetable plants. Located in Holtwood, PA, Re-DiVined grafts

tomatoes, watermelons, and peppers.

In addition to creating strong and healthy plants, Dye notes that grafting helps increase fruit size. "You are going to see larger fruit sizes, better fruit quality, and a prolonged season because the plants won't go down as quickly," she says.

Starting Out Small

A graduate of North Carolina A&T University with a degree in soil science, Dye began grafting tomato plants in

2009 for Steve Groff of Cedar Meadow Farm, also in Holtwood, PA. Groff operates a 200-acre vegetable farm and is known for his permanent cover cropping system, which includes no till, the use of cover crops, and crop rotation.

In addition to supplying Cedar Meadow Farm, Dye has customers in Virginia, Michigan, New Jersey, New York, and Ohio who mostly request grafted tomatoes. She also has sold plants in Texas, Indiana, Maryland, and North Carolina.

Tomatoes For High Tunnels

In the case of tomatoes for Cedar Meadow Farm, the operation typically plants 8,000 grafted plants in high tunnels about the third week of April. According to Groff, owner of the farm, he has been using grafted tomato plants for five years, thanks to Cary Rivard, a vegetable Extension specialist at Kansas State University.

"We have to give [Rivard] credit for starting us in grafting," recalls Groff. "I heard him speak on grafting at the Mid-Atlantic Fruit & Vegetable Convention and I thought, 'I have to do that.' We tried 100 plants the first year, and the last four years we have grafted all our tomatoes for high tunnels."

Groff also cites plant health as the main reason to graft. Specifically, he uses grafted tomato plants to combat Verticillium wilt, which had been a major headache in the past.

"Verticillium wilt race 2 is one of the diseases that is the most influential in the negative way," he explains. Resistant varieties are available for Verticillium race 1, but for race 2 there are no resistant varieties, he adds.

"With the prolific roots created with grafting, [the roots] out-compete the Verticillium longer and it gives us three or four more weeks of production in contaminated soil," he explains. "It is because the rootstock is so strong and vigorous, it holds off the disease longer than a plant that has not been grafted."

In addition to holding off disease, grafting has been compared to fumigation. Groff agrees that grafting does provide the same outcome as fumigation to a degree, but it doesn't solve all the problems.



These recently grafted tomato plants are in a healing chamber where no sunlight is allowed for two days.

Photo credit: Kaitlin Dye



Photo credit: Brooke Morton



Photo credit: Kaitlin Dye

FAR LEFT: Kaitlin Dye operates Re-DiVined, a company that grafts vegetable plants for growers in several states.

LEFT: Steve Groff of Cedar Meadow Farm in Pennsylvania shows grafted versus non-grafted plants. The grafted tomatoes are the tall ones on the left.

“Fumigation is like chemotherapy; it kills the bad and the good organisms,” he explains. “Grafting doesn’t kill anything. It does help overcome some of the bad influences, allowing the crop to perform better.”

Adjusting The Process

When creating these plants for Groff’s high tunnels and other growers, Dye begins planting in the greenhouse in December. The grafting process begins the first week of February.

Last year, she implemented some small adjustments as to how she cares for tomato plants prior to grafting to ensure their health *before* the process takes place. For example, she now applies nutrition and crop protection products to encourage growth, decrease stress, and prevent bacterial disease.

After grafting, however, when the plants are in the “healing chamber” no fertilizer or water is applied. The healing chamber is where the newly grafted plant must reconnect tissue so water and nutrients can help the scion continue to grow. “The goal is not to encourage top growth but to cut out all stress so the plants can focus on healing at the wound,” explains Dye.

To encourage healing in the chamber, humidity, light, and temperature are regulated. For example, plants in the healing chamber need to receive up to 95% humidity and no sunlight during the first two days after grafting, says Dye. The reason for the ban on light is to stop the plants from “performing photosynthesis and thus calling for more water and nutrients from the roots,” she says. “The increased humidity allows the leaves to be sustained through receiving water from the air until the connection is made.”

After the second day, she gradually allows light in by removing a layer of black plastic — which had been placed over the

plants after grafting to reduce light — and using varying degrees of shade cloth. “It is not until day nine after grafting that I allow [the plants] to go into direct sunlight.”

Experience And Cost

According to Groff, the biggest drawback is that it takes education and experience to graft plants. “You don’t just say ‘I’m going to grow two sets of plants and graft them, and then let them grow.’”

The other drawback is the increase in cost. According to Dye, it depends on how many plants are being grafted. On a small scale, the cost would be close to

\$2 per plant, she says. In Groff’s case, however, the process has paid for itself.

“It only takes a couple pounds of additional fruit from the grafted plant to make up for the cost,” explains Dye. “You should be able to count on a healthy increase in yield, depending on the amount of disease pressure in your soil. In our trial in 2009 [at Cedar Meadow Farm], we showed a 40% increase in yields using grafted over non-grafted. This was with a significant amount of *Verticillium wilt* pressure.”

Grafting’s Future

As Dye currently does all her grafting

Tube Versus Cleft Grafting

WHEN asked about some of the difficulties she faces when grafting vegetables, Kaitlin Dye of Re-DiVined in Holtwood, PA, says matching stem size can be a challenge. “You want [the stems] to be the same diameter when you graft, especially when you are doing tube grafting. You want as much surface area as possible touching. In the end, sometimes I’ll have to do cleft grafting, which takes longer to do.”

In general, tube grafting is noted as being a faster process than cleft grafting as it requires just one straight cut on the root and shoot areas of the graft. It is the size of the rootstock that can determine the grafting method used, she says.

Dye opts to use the cleft grafting method when the rootstock is wider in diameter than the scion. The process involves inserting the smaller scion with a sharp “V” cut angle into a slip along the top of the rootstock stump.

“The bottom line is that the more uniform the scion and rootstock are ac-



Photo credit: Dana Groff

Tube grafting, shown here, is said to be a faster process than cleft grafting as it requires just one straight cut on the root and shoot areas of the graft.

ording to stem diameter, the better they will match using a single diagonal cut to each stem,” says Dye. “The goal is not to use the smallest seedlings to graft. It’s all about matching the stem diameter. Otherwise, I have to use the cleft graft which requires at least three additional cuts than tube grafting.”

Cover Story

by hand, the question remains: Will hand grafting be the norm or will the process become automated in the U.S.? According to Dye, automation will happen eventually, but it won't happen any time soon.

Mentioning a grafting symposium she attended in Florida late last year that attracted people from around the world, Dye cites the huge volume of one attendee: a grower from Israel who is currently grafting 80 million plants a year.

She adds that in Japan, about 80% to 90% of the vegetable plants are grafted. "Automation will have to happen, as numerous machines have been developed, and we know it works. There will still be challenges growing the plants uniformly, but I think automation will be coming in the future," she adds.

As for the future of her own operation, Dye says an immediate goal for this year is to graft 30,000 tomato plants. As the business continues to expand, she now has a small staff helping with the process and follow up. "It is a lot of work," she concludes, "and I couldn't do it by myself."

AVG

How To Get Started In Grafting

ACCORDING to Steve Groff, owner of Cedar Meadow Farm in Pennsylvania, and Kaitlin Dye, owner of Re-DiVined, a Holtwood, PA-company dedicated to grafting vegetable plants, several factors must be considered before a grower opts to use grafted plants or tries the process on his own. (Additional information on grafting can be found at www.vegetablegrafting.org.)

1. **Get educated.** Read up on the process and start out small.
2. **Choose experience.** Purchase grafted plants from an experienced grafter.
3. **Remember there is a learning curve.** "Grafting is not something that you just 'decide to do,'" says Groff. "There is no prescription that you can pull off the shelf. You have to create the healing chamber, provide the proper nutrition, etc."
4. **Learn how to keep your cost down.** According to Dye, several tactics can be used to reduce expenses including:
 - **Increase plant spacing.** Growers can increase their plant spacing with grafted plants because the plants are larger, and so fewer numbers are required. "We are using 24-inch spacing for hybrids and 36 inches for heirlooms grafted," she says.
 - **Use water and fertilizer efficiently.** Grafted plants utilize water and fertilizer more efficiently so growers will see a small decrease in cost due to that efficiency.
 - **Save the scion.** As for the grafting process itself, costs can be kept down by saving the scion plant stumps that cuttings have been taken from and grow them to sell as non-grafted plants.
 - **Use a reputable source for rootstock seed.** Find a good source for rootstock seed as seed is the most expensive part of the grafting process.



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Rising Interest In Grafting

Although the number of grafted plants in the U.S. is low today, that could change in just a few years.

AS MANY know, most vegetable grafting in the U.S. is done by hand, as manual processes have proven to be appropriate for many situations. Automated grafting, however, is on the rise in other parts of the world. When will the U.S. adopt the technology?

To get an answer to that question and to find out about the latest in manual grafting, automation, and the future of grafting in the U.S., *American Vegetable Grower* had a chance to talk with grafting researcher Chieri Kubota, a professor in the School of Plant Sciences and Department of Agricultural and Biosystems Engineering at the University of Arizona. Find out what she has to say about the state of the industry and what she sees as necessary to move it forward.



Chieri Kubota

Q1 What are the latest developments in manual grafting for vegetable crops? What is being done to increase manual grafting speed?

Kubota: If you look at the past 20 to 30 years, the biggest improvement happened in the early 1990s when tube grafting for tomatoes was developed by a scientist in Japan. This is the system where you cut the scion and the rootstock at a sharp angle and then hold the grafted union using a plastic tube. A Japanese Extension article was published about this technology that indicated it improved grafting speed three times compared with the older technology called approach grafting. Today, this technology — tube grafting — is used by virtually all growers worldwide, including North America.

It is important to note, though, that

most of the grafting propagators are outside of the U.S., and they are grafting tens of millions of plants every year. Nearly 10 million grafted plants are annually imported by greenhouse growers in the U.S. from Canada. This is still a very small number compared to other countries in Asia or Europe that use grafting more extensively. For example, Japan is grafting about 450 million plants per year and their largest propagator is grafting 12 to 15 million plants each year.

Q2 What are the latest developments in automation? How have things changed since the first commercial model of a grafting robot was created in 1993?

Kubota: In the 1980s and 1990s, the Japanese government promoted technology in horticulture by putting a lot of money into research and development. One application was to create grafting robots. Several models were launched during that time period.

Since then, many grafting robots were also developed outside of Japan. Korea developed some in the early 2000s that are what we call semi-automated robots. Specifically, there are two types of robots: fully automated and semi-automated. For the semi-automated ones, someone has to feed the plants to the machine. For fully automated units, a person can place a tray of 100 or 200 plants into the machine, and the machine takes the plants and grafts them.

In 2006, a fully automated machine was developed in the Netherlands for grafting tomatoes. Unlike semi-automated ones, all that is necessary is to have one person provide rootstock and scion trays. In 2010, the Dutch company started developing the second-generation machine, with improved operation and speed (greater than 1,000 grafts per hour) using a grafting clip widely used



Photo credit: Iseki & Co., Ltd., Japan



Last year, the automated robot pictured here was developed for cucurbits, specifically melons and cucumbers, in Japan. It is an upgraded version of the semi-automated robot developed in the 1990s.

by the nursery industry. The company is currently testing the machines for large-scale grafting operations.

A fully automated machine was also developed for cucurbits (melons and cucumbers) in Japan in 2011, as an upgraded version of the semi-automated robot developed in 1990s.

There are other robots, both semiauto-

matic and fully automatic, in Spain, Taiwan, and Italy that are under development.

Q3 What is currently being done in the area of automation for vegetable grafting in the U.S.? When do you think automation will become more prevalent in the U.S.?

Kubota: There is some work going on in Florida, a researcher there is interested in developing automated grafting equipment. To me, it is just a matter of time.

We recognize increasing interest to introduce grafted plants for open field production, so the demand is going to increase and growers will begin grafting in U.S. nurseries.

When you develop an automatic system, you also have to take into consideration what kind of trays will be used, the plant species, the expected size of plants, and the substrate type. For example, the Dutch system uses a rock-wool substrate and that won't be suitable for U.S. open-field production. So when developing a grafting robot, you have to target certain applications because the robot needs strict specifications. In addition, horticultural trays for nurseries are available in many different sizes and items such as grafting clips and razor blades must be widely available in the U.S. This is another reason we need U.S.-based technology development for this particular area.

Plus, the way the plant is grafted impacts how it can be managed in the field. For example, a grafting method that potentially increases the chance

of inducing shoot growth from the rootstock may be manageable in small farms in Asia or Europe, but will be a serious problem in large U.S. operations. A USDA researcher in Florida, Michael Bausher, is looking at this issue to address in our on-going USDA Specialty Crop Research Initiative project. Bausher and another researcher, Richard Hassell in South Carolina, will be evaluating grafted plants' performance

union to be very strong to withstand windy open fields. Grafting methods, including automation, would impact the strength of the union.

Q5 Where do you think the U.S. vegetable grafting industry will be in 10 years?

Kubota: In 10 years I see more grafting used in the U.S., hopefully with effective use of grafting automation. It may be

"We recognize increasing interest to introduce grafted plants for open field production, so **the demand is going to increase and growers will begin grafting in U.S. nurseries.**"

in the field when grafted by machine. All these will help us better understand the issues and possibilities.

Q4 What are some key points on vegetable grafting you have learned from your research?

Kubota: My work focuses on propagation technology to increase the efficiency and to reduce the costs, which is why automation is under my watch. One of the things that is very important to make grafting successful is the uniformity of the seedlings. Machines can't do the grafting unless there is some system or technology to make uniform plants. Uniformity in plant quality attributes increases grafting efficiency.

It is also important for a grafted

difficult to envision it as currently only a small amount of plants are grafted in the U.S. (most grafting is done in Mexico and Canada). For example, in Turkey there was no grafting several years ago and now almost all watermelon plants are grafted in that country. The change was within the last four or five years. That change could happen in the U.S., too.

For that to happen, though, automation is the key. Large operations will need to adopt the technology. Initially, grafting could start with high-end producers such as organic or high tunnel growers that will slowly get into the technology — maybe 20% to 30% even within a few years. For example, in some areas there is no option, other than grafting, to overcoming soil-borne disease and pests. **AVG**

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Grafting Gains Momentum

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Find out how this process can help
growers overcome challenges in
the field and increase profits.

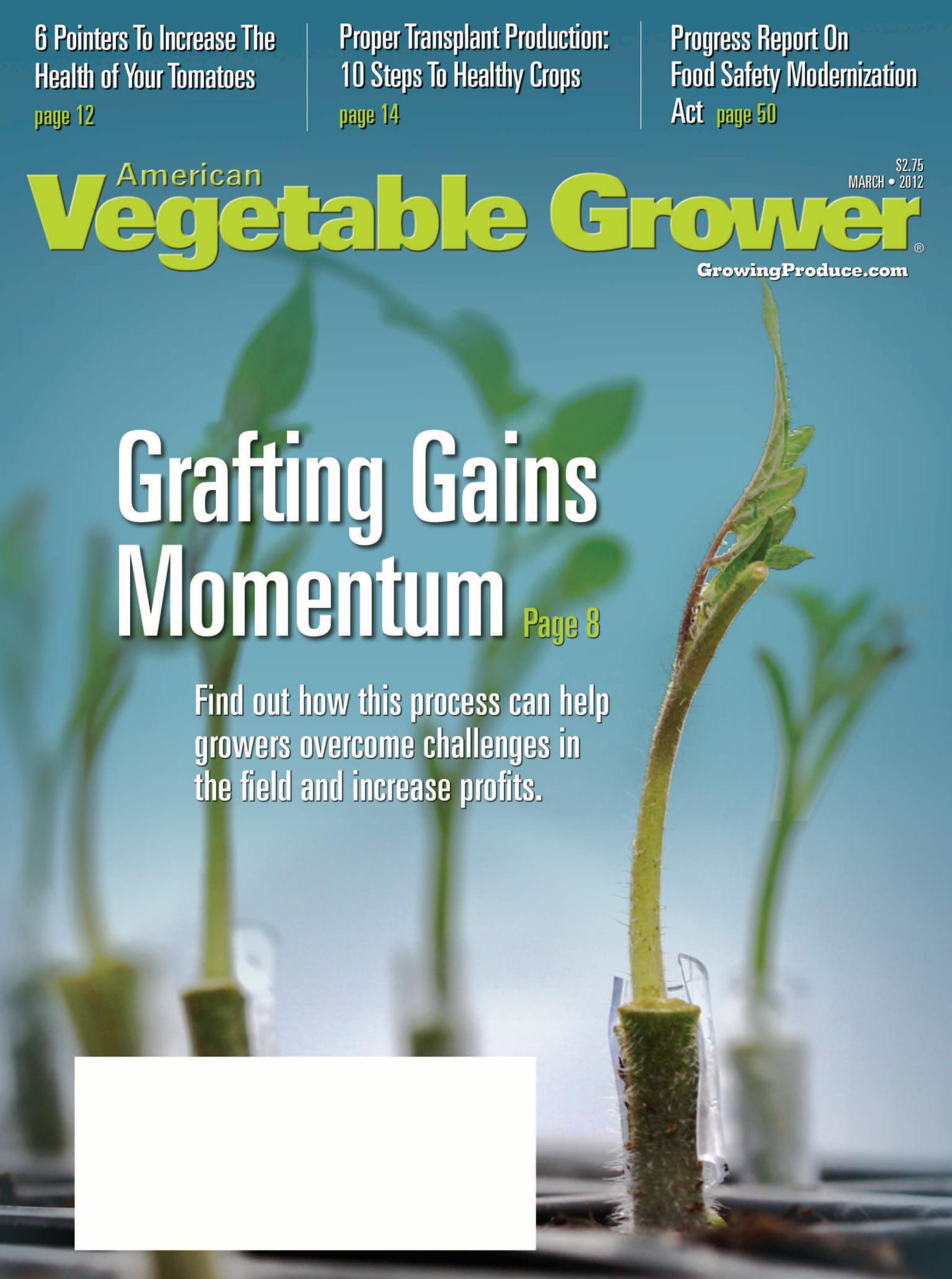
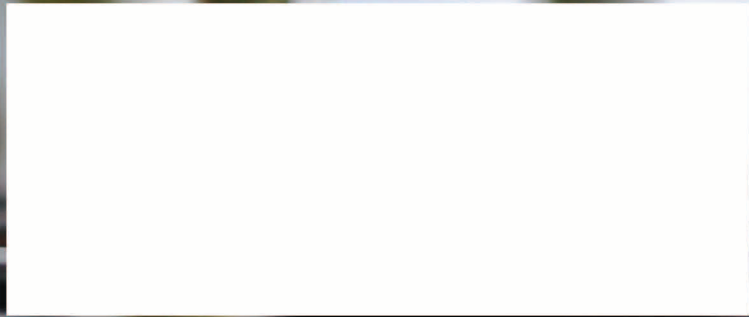




Photo credit: Deneae Wolfe, Vegetable Production Systems Lab, Ohio Agricultural Research and Development Center.

Grafting Gains Momentum

The age-old process has the potential to add new opportunities for growers looking to overcome challenges and increase profits.

EDITOR'S NOTE: This is the first in a series of articles on grafting that will follow the progress of a group of researchers from several universities throughout the U.S. The funding for the research has been made possible from a grant from USDA with matching support from many industry partners.

This by no means marks the first time USDA and industry have opted to invest in grafting technology. In recent years, Ohio State University- and North Carolina State University-led teams received funding through USDA and USAID (United States Agency for International Development) to work on grafting issues in conventional and organic production. That and related work done by others has led to much of the home-grown Extension materials on grafting that are available today.

The education will continue. Be on the lookout for how-to grafting articles, which will include new grafting technology for tomato and cucurbit crops, the latest in automation, and more.

THE Merriam-Webster Dictionary defines grafting as “the point of insertion of a scion upon a stock.” The process and the benefits that can be reaped by growers, however, go far beyond that simple explanation.

Grafting is a technology that has been around for hundreds of years and it is an established production practice in Europe and Asia on tomato and cucurbit crops. In this country, however, grafting has been less widely adopted in producing these crops.

Why the push to increase U.S. adoption of this technology? As those who have used grafted plants know, they can help limit losses due to disease, salinity, and other stress. Grafting has become important in crop management toolboxes. In addition, grafted plants themselves can be a commodity for suppliers. Overall, grafting may represent opportunity.

According to researchers, these plants can be stronger, healthier, and better equipped to fend off various stresses, biotic and environmental. This, in turn, leads to increased yields and better overall production. In the end, it means higher profits for growers.

Thanks to the recently awarded grant, six universities, USDA, and corporate partners will work in tandem to shed



Matt Kleinhenz

light on how best to incorporate grafting into the toolbox of large and small growers and into the product line of suppliers.

American Vegetable Grower recently caught up with one of the

members of the university-led grafting team, Matt Kleinhenz, an associate professor and Extension vegetable specialist at The Ohio State University, to find out more about the team's goals and what the future may hold.



Q1 What are the advantages of using grafted plants to both large and small vegetable growers?

Kleinhenz: Grafting is an important tool for vegetable growers because it has a proven capacity to help overcome some production challenges. It is also important because grafting is scale-neutral. A grower can use one or many thousands of grafted plants as a strategy to counteract different types of crop stress.

The process relies on employing a wider range of genetics efficiently. The rootstock root system has attributes that the root system of the scion — which produces the fruit taken to market — lacks.

Basically, grafting is organ transplantation. In crop production terms, grafting replaces an inferior root system with a superior one. Other advantages may follow but the most fundamental advantage of grafting comes from the combination of two varieties.

Normally, these combinations take generations and years to obtain. In grafting, the combination is instantaneous. Since grafting is organ transplantation, the trick, of course, is to obtain the benefits while avoiding the risks. Cleanliness, for example, is key throughout the grafting process.

Q2 Disease control has been mentioned as an example of a production challenge that can be overcome by grafting plants. What are some other solutions grafting can offer growers?

Kleinhenz: Grafting is designed to

Enhancing Techniques

ACCORDING to Matt Kleinhenz, an associate professor and Extension vegetable specialist at The Ohio State University, the obvious goal of the grafting team is to enhance the success of U.S. fruiting vegetable industries by integrating grafting technologies into them.

“This is a coordinated team effort covering the waterfront of grafting issues,” he says. “Stakeholders and team members set the agenda. All are interested in grafting because its greater use stands to help farmers and other businesses.”

It will require objective evaluation, testing, and thorough communication for the entire process to work, he continues, encouraging anyone interested in vegetable grafting to contact a project team member at The Ohio State University, North Carolina State University, Virginia Tech University, Clemson University, University of Florida, University of Arizona, and USDA. (Go to GrowingProduce.com for a listing of the members of the grafting team.)

“Still, it is clear that most vegetable growers in the U.S. are near someone familiar with vegetable grafting,” he says. “In fact, vegetable grafting has been explored and discussed in at least 25 states.”



Photo credit: Danae Wolfe

help reduce plant stress in abiotic and biotic forms. Abiotic stresses such as salinity, low fertility, drought and freezing temperatures, are environmental. The other form of stress, biotic, involves another organism. With grafting, in nearly all cases the organism is a pathogen or nematode. So basically we are talking about disease management. Most often it is a soilborne disease that is being targeted.

melons have been the main crops grafted with a high rate of success. When will other crops be grafted with the same success rate?

Kleinhenz: In short, when information is available to support it and when the laws of supply and demand call for it. The advantages of grafting other vegetables and the methods for doing so will have to become clear. Specifically, using grafted plants to overcome production challenges will have to be superior to using other tactics.

An anecdote may be useful here. The

Q3 Cucumber, tomato, watermelon, and other



Photo credit: Danae Wolfe, Vegetable Production Systems Lab, Ohio Agricultural Research and Development Center

The three images depicted here highlight a part of the grafting process. The photo on the far left shows a tomato rootstock seedling being cut between the cotyledons and the first true leaves. In the center photo, a plastic clip is being applied that will help the grafted plant heal. The last picture highlights a scion stump being inserted into a rootstock stump. The goal is to create plants that are high yielding and disease resistant.

story of the history of grafting says that it began as a way for poor farmers to create very large-fruited gourds in which rice could be stored. These farmers produced larger gourds with grafted plants than they could by any other means. The gourds were hollowed out and filled with rice. Bellies remained full. No one would suggest using grafting commercially for storage purposes today. But, many are evaluating grafting in comparison to the tools and tactics they now employ to deal with certain production challenges.

Q4 As mentioned earlier, grafting is an ancient technique. How has the process become more efficient?

Kleinhenz: Practice and study make perfect. In historical terms, vegetable grafting has been rigorously tested by many people under many circumstances for only a short time. A high level of intense scrutiny by many talented people leads to improvement. Also, each bit of knowledge gained is not simple addition, it can create exponential increases in performance if shared and implemented.

Q5 Why is hand grafting still the main way the process is handled in the U.S.?

Kleinhenz: Hand grafting is still the norm in the U.S. and in many other areas. There is no one answer as to “why” but the most often cited one is that hand grafting works and is appropriate for many circumstances. That said, automated grafting is on the rise and is a significant part of the future.

Grafting should not necessarily be thought of as done only by hand or machine. More than likely, when the largest possible number of grafted plants is needed, the process will involve man and machine. But, to be clear, companies in Europe and Asia routinely produce millions of grafted plants by hand each year. That capacity is developing in the U.S. Improvements in all aspects of the grafting process will be market driven.



Greenhouse Growers Capitalize On Grafting

SOME greenhouse producers have already figured out that even in optimal growing conditions, such as the greenhouse, grafted plants can give them “one up” on the competition, with their grafted plants out-yielding the ungrafted ones.

“These growers discovered that they can make better use of their square footage with grafted plants, partly because rootstocks of grafted plants are so vigorous and efficient,” explains Matt Kleinhenz, an associate professor and Extension vegetable specialist at The Ohio State University.

“As a result, grafting caught on rapidly in the greenhouse sector,” he says. “The same appears to be happening in the high tunnel sector where growers are also interested in potentially overnight increases in yield.”

To date, though, Kleinhenz says adoption has been slower in open field production, but the situation can change quickly.

“Experienced growers recall many examples of practices that were initially regarded as ‘fringe’ but are now mainstream,” he explains. “The use of grafted vegetable plants in high tunnels and fields may be the next one.”

Q6 Grafting automation, in terms of robotics and developments in Japan and other countries, continues to develop. What are the barriers and opportunities to greater automation in the U.S.?

Kleinhenz: Automated grafting is less prominent in the U.S. than elsewhere. Barriers appear to be primarily business-related. The prevalence of grafted plants produced using automated approaches will increase as the market for grafted plants increases and the efficiency and reliability with which they can be produced using automated approaches increases.

Q7 What are the grafting team’s future plans to help increase the market for grafted plants?

Kleinhenz: What we can do as a team is provide information on both ends of the spectrum. On the production side of grafted plants, we can continue to optimize and demonstrate ways in which grafted plants can be made and distributed, both involving people and equipment.

On the consumption side, we can provide information that illustrates why growers would want to use grafted plants. We can tell them exactly what a grafted plant can do for them that a standard, ungrafted plant usually cannot.

The overall goal is to increase the information base so growers can make informed choices. The assumptions are that more and more people will be convinced that grafted plants have a role in their operation and that the market will climb as it has in other parts of the world. **AVG**

Photo credit: Vegetable Production Systems Lab, Ohio Agricultural Research and Development Center



Grafted Vegetables Could Be Critical New Production Tool

December 19, 2012

By Frank Giles

When it came to specialty crop pest control, the terms “foolproof” and “methyl bromide” were nearly synonymous. In many ways, it was the “magic bullet” that helped growers manage some of the most troubling pests in production.

Under the Montreal Protocol and the Clean Air Act, methyl bromide has been phased out except for diminishing critical exemptions each year. This has set the scientific community off in a search for replacements for the former go-to material in growers’ arsenals to manage key pests.

Recently, the International Research Conference on Methyl Bromide Alternatives and Emissions Reductions was held in Maitland. The event drew researchers from around the world to discuss the latest research on replacements for methyl bromide and how different countries have dealt with the phase-out.

Grafting Gets Noticed

More and more growers are investigating grafting vegetables as a means of improving production and quality. Because grafting has shown benefits in fighting nematodes and disease pressure, it was emphasized during the conference. The Vegetable Grafting Symposium was held in conjunction with the event.

Why Is Grafting Increasing?

During the Vegetable Grafting Symposium, Sakata Seed America’s Bryan Zingel listed the following benefits of the practice:

- Grafting confers resistance to soil pathogens
- It can increase yields by more than 30%
- It reduces the effects of soil salinization
- Grafting increases production longevity
- It is less expensive than chemical treatments
- It provides positive health and food safety benefits
- Grafting has a positive environmental profile
- It fits well in organic production.

Nancy Roe provided attendees a grower’s perspective on how grafting can help production. She owns Farming Systems Research in Boynton Beach. Her farm includes 10 acres of mixed seasonal vegetables and is in production from 10 to 11 months per year.

She said she has approached grafting with a number of questions: Will it help with disease

resistance (fusarium, viruses, and bacterial)? Will it provide nematode resistance? Will it help crop vigor and build a stronger root system?

She reported a good success rate with as high as 60% of grafted plants going into production. They produced the grafted plants on the farm. However, she cautioned it would be difficult for most smaller farmers to graft because of the careful monitoring required of the growth of the scion and rootstocks.

In addition, cost is a limiting factor. Grafted transplants cost around \$1 each (not including shipping costs) versus 15¢ for standard transplants. Workers will need training on handling and planting grafted plants. She also cautioned these plants will “take off like a rocket” in a hydroponic system. Growers will need to be prepared for a change in growth habit in grafted plants when compared to non-grafted.

Despite the inherent challenges, Roe said grafting vegetable plants could allow growers to use land more efficiently and sustainably.

Breeding Stock

Bryan Zingel, Sakata Seed America product manager for tomatoes and peppers, discussed the challenges of breeding a commercial rootstock during the symposium. He said seed companies are looking for rootstocks with multiple disease resistance, good germination and uniformity, easy grafting, and high vigor.

He noted seed companies are taking notice of the increasing popularity of grafting. He said developing rootstocks with multiple disease resistance packages takes a lot of time to perfect and develop. In addition, rootstock and scion compatibility must be addressed. Strong vigor scions generally need medium vigor rootstock and vice versa. “We have to supply a rootstock variety that is suitable for its scion,” he said. Finally, the balance between yield and quality (taste) also must be taken into account in the breeding process.

Giles is editor of Florida Grower, a Meister Media Worldwide publication.

Tags: nematodes, bacterial disease, fursarium

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Graft Tomatoes for Higher Yields, Better Fruit -Web Exclusive!

3/12/2012

Graft Tomatoes for Higher Yields, Better Fruit

by Dorothy Noble

Steve Groff in Lancaster County, Pa., achieves consistently greater yields by grafting his high tunnel tomatoes.

Bret Fahrmeier harvests over 90 percent No. 1 fruit from his Cherokee Purple heirloom tomatoes at Fahrmeier Farms' high tunnels in Lexington, Mo. What's more, he says, "I've never seen 3 to 4-pound fruit from my regular [nongrafted] tomatoes," but his grafted Mr. Stripey and Great White heirlooms have produced 3.5-pound specimens.

Growers in Asia have been grafting vegetable transplants for well over 50 years. Although common for fruit trees and prevalent in greenhouse vegetables, relatively little grafting is performed for field and high tunnel vegetable production in the U. S.



Kansas State Extension Vegetable and Crop Specialist Dr. Cary L. Rivard began studying how grafting the heirloom tomato German Johnson to disease-resistant rootstocks managed soilborne diseases while a graduate assistant at North Carolina State in mid-2000. Following the favorable results, other studies and educational presentations ensued.

Rivard concludes, "Tomato grafting shows promise for growers who face disease challenges, specifically organic, heirloom and high tunnels."

The concept is simple. A disease-resistant seedling (the rootstock) is grafted onto a seedling with desirable fruiting characteristics (the scion). There are many ways to perform this fusion; Rivard uses the Japanese tube method, while Ohio State researchers prefer the cleft method. USDA has a robot for grafting.

Regardless of the grafting method, researchers agree that the next steps—rootstock choice, sanitation while handling and providing the desirable humidity, light and temperature to the seedling while healing—are critical.

Because hybrids bred specifically for rootstock use typically resist a wide range of diseases but vary in their resistance levels and in the diseases they resist, a grower must choose one that can control his particular disease situation. Rootstocks are currently available with resistance to tomato mosaic virus, corky root rot, fusarium races 1 and 2, verticillium wilt, root-knot nematode, bacterial wilt and Southern blight. In addition, rootstocks vary in vigor—overly rampant growth can be a problem in some environments. Also, a rootstock bred for tomato grafting is generally recommended. Seed companies are developing more rootstocks; many intended for greenhouse tomato grafting could work well in high tunnels.

Sowing the rootstock and scion seeds about two weeks prior to transplanting allows time for healing the union

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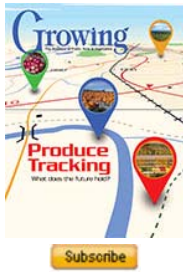
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and acclimation. However, the rootstocks and the scion should be the same diameter for grafting, consequently the grower may need to adjust the growth of one or the other by manipulating temperature.

At North Carolina State, a team of three trained workers can graft 700 seedlings an hour, with a high success rate.

Rivard says tube grafting should be done when the seedlings have two to four true leaves and stems are 2 to 2.5 millimeters in diameter. Aim for early in the morning or just after dark to minimize the plant's water stress. Practice strict sanitation by washing hands, using latex gloves and sterilizing tools. Cut the rootstock seedling-razor blades are commonly used-at a 45-degree angle and below the cotyledon (the first leaves of the rootstocks). Slide a grafting clip over the rootstock. Matching the angle and the stem diameter, cut the scion. Insert the scion stem into the clip so that the cut angles fit.

Place the grafted seedling into a healing chamber immediately. Excluding all light for a few days, maintain 80 to 95 percent humidity and a temperature of 70 to 80 degrees Fahrenheit. Allow minimal sunlight for the next several days. After the seedlings show no signs of moisture stress in about a week, gradually acclimate them for transplanting as one would harden a greenhouse-grown seedling. When planting, be sure the graft union remains above the soil line.



Luis Urdaneta, while a visiting scholar to Penn State, displays a dome to be used as a healing chamber for newly grafted tomato seedlings. With proper care, the tomatoes on the right will cease drooping and be ready to transplant within a few weeks.

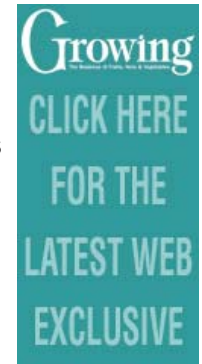
Working with Dr. Frank J. Louws and Dr. Mary M. Peet of North Carolina State, Rivard found that Beaufort, Big Power, Maxifort and RST-105 rootstocks reduced incidence of bacterial wilt, root-knot nematodes and Southern stem blight.

With continuous tomato production in Groff's high tunnels, *Verticillium dahliae* became problematic. In a 1988 study sponsored by the Sustainable Agriculture Research and Education (SARE) program, BHN 589 was grafted onto Maxifort rootstock. The 20 percent marketable yield increase translated into 9.4 additional tons per acre, or 752 more boxes per acre. At \$12 a box, this represents a \$9,024 increase in gross income, or \$1.88 per plant. Even accounting for the higher costs of grafted plants-some reports range from 50 cents to \$1 per plant-grafting was profitable.

Groff has continued producing high tunnel tomatoes in the same location. Kaitlin Dye, who monitored the original study and now performs Groff's grafting, reports that the 2011 season's grafted crop, which were all heirloom tomatoes, performed better than the nongrafted plants. She uses 36-inch spacing on the heirlooms and encourages twin leaders, which has resulted in higher production. "The Beaufort rootstock can support two stems. I was very pleased with the yield," she observed, "And, the longevity of the plants was impressive."

After Fahrmeier Farms' yield increases were publicized, more Missouri farmers began grafting a year or two ago. Horticulture specialist Dr. Sanjun Gu, Lincoln University of Missouri, reports that most tomato growers increased their yield and vigor with grafting. He notes, though, "A few people failed because they did not remove suckers from rootstocks." That can be avoided in the future. Recent research by Dr. Michael Bausher, USDA, observed recurring suckering in open field grafted tomatoes when cotyledons had been left intact.

Rivard, Louws and others have noticed benefits of grafting beyond disease control, reporting in the SARE fact sheet, "Scientists have discovered that it can increase stress tolerance and productivity while maintaining high fruit quality. Using the right rootstock can also help overcome abiotic stressors, such as high salinity, excess moisture and soil temperature extremes, even allowing the extension of the growing season. In addition, grafted plants have produced increased yields and have shown increased water and nutrient uptake." This reference, published October 2011, includes rootstock resistances, instructions for building a healing chamber, grafting tips and resources and is accessible at www.sare.org/factsheet/12AGI2011.



The University of Arizona's vegetable grafting information site, www.cals.arizona.edu/grafting, presents comprehensive grafting instructions and resources. Horticulture engineer Dr. Chieri Kubota works with grafting other vegetables as well as tomatoes.

Ohio State's vegetable production systems laboratory has links to videos in English, Spanish and Chinese, resources including websites and publications, plus a complete and a condensed grafting guide. The electronic versions of the guides are free. The site can be accessed at www.hcs.osu.edu/vpslab.

Ohio State geneticist Dr. David M. Francis directs a multiyear USDA-sponsored organic transitions study to test how grafting can provide solutions to the stresses that limit field and high tunnel tomato production. Both he and Dr. Matthew D. Kleinhenz, along with Louws and Rivard, continue to conduct workshops, field days and webinars that instruct growers and other researchers to assess tomato grafting.

In October 2011, researchers around the world held a symposium on grafting in Viterbo, Italy. Factors affecting the quality of grafted transplants, rootstock breeding and grafting opportunities to enhance tomato flavor and health-promoting compounds were among the presentations. After peer review, the papers will be available on their site, www.grafting2011.com.

By combining the traits of two plants, grafting opens the possibility of enjoying the best characteristics of both. At this time, use of tomato grafted plants is greatest in greenhouse and high tunnel production, but it is becoming more valuable for organic, sustainable and conventional open field production of any size. As techniques become more efficient and refined and more rootstocks, equipment and supplies become more widely available and known, fumigants become more restricted, and more commercial businesses supply grafted transplants, usage should grow.

Grower Bret Fahrmeier offers grafting advice to his fellow farmers: "Be smart about it. Do what you need to do to make your business profitable. Try it by starting small and becoming good at it."

The author is a writer/researcher currently residing in central Pennsylvania. Photos by Bob Ferguson.



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Conventional or Organic, Grafting is a Key Tool in Nematode Management

Root-knot nematodes (*Meloidogyne spp.*) are extremely destructive in the southeastern United States. Vegetable crop infection often leads to significant yield loss. Soil fumigation, especially with methyl bromide, is a common root-knot nematode control tactic. The mandatory reduction in methyl bromide use and the restricted use of other chemical fumigants place crops and conventional growers at risk. Organic producers rely on crop variety resistance and management practices designed to maintain stable and diverse soil communities. These management practices can keep nematodes (and other soilborne pathogens) in check. However, once established, pests can cause repeated and significant yield losses. Also, nematode resistant vegetable varieties are often not available, are not horticulturally acceptable, or are only partially effective (resistance breaks down under high temperatures common in places like Florida). Crop rotation also limits the damage caused by nematode populations. Still, few growers can rely on it strongly for a number of reasons. For example, *Meloidogyne spp.* affect many crops and many weeds also host the pest – giving it refuge between crops. So, additional tools are needed to manage root-knot nematodes. The Tomato Magazine contacted two experts in the area to get an update on root-knot nematode control. Dr. Nancy Kokalis-Burelle and Dr. Erin Rosskopf of the USDA-ARS in Ft. Pierce, FL shared their insights on the topic.

TM Question 1: What is the current status of methyl bromide alternatives for vegetable crops?

Rosskopf: The amount of methyl bromide available for soil fumigation for the production of vegetables like tomatoes and peppers is very small. Methyl bromide that is available is regulated through applications for “Critical Use Exemption” (CUE) material. The 2013 nomination from EPA to the Parties to the Montreal Protocol for open-field tomato production, for example, included enough material to treat less than 100 acres. So, alternatives are needed immediately for all previously-covered crops. Currently registered fumigant alternatives include dimethyl disulfide (a recent registration), 1,3-dichloropropene, chloropicrin, and metam sodium and metam potassium (which have been available for many years). Growers use these materials in various combinations but these materials still do not fill all of the gaps created by the removal of methyl bromide. Areas treated with chemical fumigant alternatives must also be surrounded by large buffer zones. Buffer zone requirements grow larger with each label change.

TM Question 2: What major issues remain to be addressed in the post methyl bromide era?

Rosskopf: A good deal of excellent research has been done on the development of non-

fumigant, integrated pest management systems including cultural, mechanical, and biological control measures. These approaches need to be brought together to give growers as many tools as possible in order to address the specific problems of their location. For example, few effective herbicides are registered for some specialty crops and no new nematicides are available. These deficiencies will become more and more critical as the time away from methyl bromide grows.

TM Question 3: What is the role of grafting in nematode management?

Burelle: Grafting vegetable crops has shown excellent potential to contribute to root-knot nematode management alone and in combination with chemical treatments. Those who do not use these chemicals should note that grafting horticulturally desirable scions onto nematode-resistant or tolerant rootstock could help fill an important pest management niche. Growers who fumigate or use chemicals should note that the combination of nematode-resistant plants and chemical treatments may be even more powerful. Regardless, the use of grafted plants may be a key component in strategies for managing soilborne pests and diseases going forward.

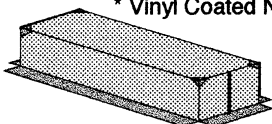
Overall, grafting more than doubles the role that genetics can play in vegetable production. Rootstock and scion varieties play different roles. It is no longer necessary to develop one variety that has all the desired characteristics, which is difficult. With grafting, scion varieties with desirable horticultural characteristics are paired with rootstocks that provide some level of resistance or tolerance to soilborne pathogens including nematodes. Growers can select rootstock/scion combina-

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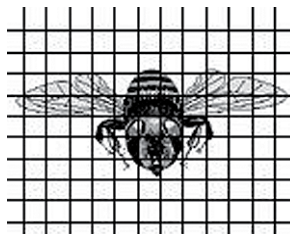
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tions that fit their needs – that is, that perform well in the presence of pest complexes common to their farms. Grafting should also increase the yield of heirloom varieties, which are typically very susceptible to pathogens.

TM Question 4: You have a lot of experience studying nematodes and grafting. What should growers know about them?

Burelle: In short, I recommend that growers stay tuned. That they continue to evaluate the potential for grafted plants to make a difference on their farm. That they talk with people who have grown grafted plants or experimented with them. And that they read articles and attend programs where grafting is discussed. Many thousands of farmers have used grafted plants for many years; we continue to learn more about how they perform in soil-based production in the U.S. Farmer and scientist experience and input is very important in that process. For example, we have completed multiple trials in Florida since 2007. Our goal has been to evaluate grafting for control of root-knot nematodes on tomato, watermelon, cantaloupe, and bell pepper. Greenhouse and microplot trials, with very controlled conditions, have been used to identify potential nematode resistant or tolerant rootstocks. Field trials demonstrate how grafted plants perform under different production scenarios – for example, under organic management and with and without fumigation.

In greenhouse trials, several rootstocks used with bell pepper limited the formation of root galls, an early sign of nematode resistance. We look forward to following up on this work since it will result in better nematode control options for bell pepper growers. We use microplots to assess the effects of plants on nematodes and vice versa. Stalling nematode population growth or reducing their numbers may be just as important as preventing them from infecting plants. Tomatoes, melons and very precisely controlled inoculum levels are used in these trials. In them, the number of nematodes in soil remained the same in all

plots. However, fewer nematodes are usually found in roots of grafted than ungrafted plants. In melon (cantaloupe), one of the experimental rootstocks (*Cucumis metuliferus*) also reduced root-knot nematode galling.

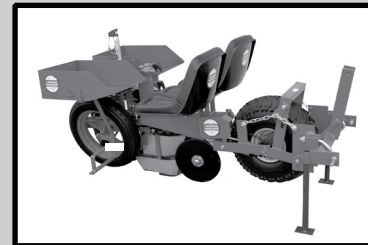
In other experiments, grafted and non-grafted tomatoes and melons in a double-crop field trial were placed in four types of plots: fumigated but not herbicide treated, fumigated and herbicide-treated, not fumigated but herbicide-treated, and neither fumigated nor herbicide-treated. Galling by root-knot nematodes was highest in non-fumigated plots containing non-grafted tomatoes. All of the alternative fumigants tested controlled nematodes adequately. Grafted plants in nonfumigated plots showed less nematode galling. For melon which was planted into the same beds following tomato, *C. metuliferus* rootstock had less galling in all fumigant treatments compared with the non-grafted melons.

Similar studies have been repeated on commercial farms. For example, working with a certified organic grower in Ft. Pierce, FL, we evaluated the effects of tomato rootstocks grafted to heirloom variety scions on parasitic nematodes. Galling by root-knot nematodes was high on all ungrafted varieties. However, roots of the variety ‘Tygress’ (grafted to the heirloom variety ‘Purple Calabash’) showed less galling. Similar results were obtained with other specific combinations. These results are further evidence that rootstock/scion responses are not ‘one size fits all.’ Combinations must be selected to combat specific problems.

Also, some combinations may not produce a superior yield but they may actually reduce nematode populations in the soil, a potential long-term benefit. 🍅

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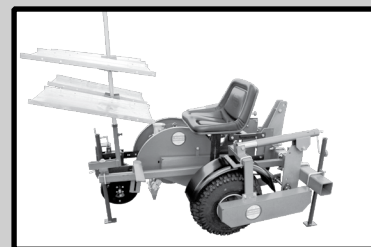
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