VEGETABLE CROPS HOTLINE

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Tomato Brown Rugose Fruit Virus (ToBRFV): A New Concern for Tomato and Pepper Producers

(Dan Egel, egel@purdue.edu, (812) 886-0198)

Tomato brown rugose fruit virus (ToBRFV) is making headlines and eliciting USDA action. Growers need to learn more about ToBRFV biology, symptoms and control.

Tomato brown rugose fruit virus (ToBRFV) is a newly identified virus affecting tomato, pepper and possibly their relatives. ToBRFV first appeared in Israel in 2014. Since then, it has shown up in several other countries, including eradicated greenhouse outbreaks in 2018 and 2019 in Arizona and California. These back-to-back U.S. outbreaks indicate ToBRFV will probably be something that without good diligence has a high probability of happening again.

An added concern for the U.S. industry is ToBRFV is present in countries exporting tomato and pepper fruit to the U.S.; these include Mexico (where it was widespread in 2018) and the Netherlands. The virus has not been found in Canada, but some fruit imported into the U.S. goes through Canada. The U.S. Department of Agriculture (USDA) is tightening restrictions on imports effective Nov. 22, 2019. These actions include seed lot and transplant testing for countries where the virus exists, and inspection of tomato and peppers from these countries and Canada.

ToBRFV belongs to the same group as tobacco mosaic virus (TMV) and tomato (ToMV) mosaic virus. However, tomato plants tolerant to these two viruses are not tolerant to ToBRFV. Currently, no commercial tomato varieties are tolerant to ToBRFV. Peppers with tolerance to TMV and pepper mild mottle virus (PMMoV) have shown some tolerance.

Leaf symptoms of ToBRFV include wrinkling and bubbling with an accompanying mosaic pattern. Fruit has a browning calyx and is undersized with a rough surface (rugose means wrinkled). Fruit abortion may occur while remaining fruit will be blotchy, pale and may have brown, necrotic spots (Figure 1). Plants infected early will be stunted with poorly formed fruit. Plants infected later may not express fruit symptoms until the fruit turns red. To observe leaf and fruit symptoms, check out "Q&A on the New Tobamovirus: Tomato Brown Rugose Fruit Virus" from the American Seed Trade Association.

Figure 1. ToBRFV fruit symptoms. (A-C) Symptomatic mosaic pattern on leaves of cluster tomato plants cv. Mose. (C) Narrowing leaves of cluster tomato plants. (D) Dried peduncles and calyces on cherry tomato plants cv. Shiran leading to fruit abscission. (E) Necrotic symptoms on pedicle, calyces and petioles cv. Ikram. (F) Typical fruit symptoms with yellow spots cv. Mose. (G-I) Variable symptoms of tomato fruits cv. Odelia. (G) The typical disease symptoms. (H) Symptoms of mixed infections by the abundant TSWV and the new tobamovirus isolate. (I) Unique symptoms of the new tobamovirus isolate found at a single location at Sde-Nitzan village. Photos by Neta Luria et al./PLOS https://creativecommons.org/licenses/by/4.0/

Since ToBRFV is related to TMV and ToMV, its spread and control are similar. All viruses spread mechanically through people and equipment touching infected plants and transferring it to a

healthy plant. ToBRFV is very stable and very infectious. It has high mechanical infectivity, which is concerning since tomato and pepper plants are highly manipulated through transplanting, staking, tying, pruning and harvesting. ToBRFV's high stability allows it to stay infectious in the soil, in plant debris and on stakes for long periods—up to 20 years by some accounts. There are reports of spread by bumble bee pollinators in greenhouse situations. However, there are no reports of plant-to-plant transmission by aphids, leafhoppers or white flies.

Just as with TMV and ToMV, a high degree of sanitation is the key to avoidance. There are no sprays that can be applied that are effective in reducing the virus's spread. Seed and transplant production are the most critical steps since contamination at these steps creates a risk of contaminating hundreds, if not thousands, of plants. Recommended actions include:

- Start with certified seed from a reputable dealer. Do not plant seed from unverified sources, especially if they come from restricted areas.
- Have greenhouse workers wash and sterilize hands and tools often.
- Supply single-use gloves that are discarded between greenhouse ranges.
- Provide protective clothing that stays in that range or is well washed before going to another range.
- Dispose of symptomatic plants and plants within 5 feet of infected plants. Also, dispose of plants, trays and media through incineration—**DO NOT** spread it out on your fields!
- Monitor movement of equipment and workers between fields. Thoroughly wash equipment and possibly have workers bring a change of clothes.
- Rogue and incinerate symptomatic plants and conduct activity last in that field followed by good sanitation.

Suspected plant material can be tested for ToBRFV by submitting samples to the Purdue Plant and Pest Diagnostic Lab. As with any pest, the best way to deal with ToBRFV is to never get it. To do that, you will have to pay special attention to sanitation, something most do already. How severe of a problem this becomes remains to be seen.

Summary: Key points about ToBRFV

Developed by the American Seed Trade Association in "Q&A on the New Tobamovirus: Tomato Brown Rugose Fruit Virus."

- ToBRFV is a highly virulent very aggressive virus that can cause severe infection on tomatoes with resistance genes including Tm-22, and susceptible peppers that lack the L resistance genes.
- This virus can spread quickly and easily by mechanic transmission, especially under intensive production practices.
- Symptoms may vary by variety, and in some cases, infected varieties may be asymptomatic. Typically, infected plants have fruit with severe symptoms.
- Leaf symptoms include distortion, shoestring and fern leaf; calyx symptoms include browning of the veins. Affected fruit may be aborted or small with blotching or brown spots.
- The virus behaves similarly to other tobamoviruses such as TMV or ToMV, but the symptoms (especially in the fruit) may be much more severe.
- The virus can **very** easily be moved from plant to plant by workers or even from root to root contact. Personnel coming from an infected greenhouse can introduce the virus if proper sanitation measures are not in place.
- ToBRFV is very stable and can survive for long periods in infected debris, in the soil or on contaminated surfaces.
- Do not rely on genetic resistance to tobamovirus to provide control, especially with tomato. Strict sanitation measures must be implemented including using clean clothing, tools and implements, stakes, etc.
- Symptomatic plants can be removed and destroyed but **only** very carefully, being sure not to touch any other plants or surfaces. Do not move from infected to clean greenhouses. Approach each production as if there is no resistance to this highly transmittable and damaging tobamovirus.
- If you find plants with tobamovirus symptoms, especially if the variety has genetic resistance, obtain a professional diagnosis for confirmation.
- Overall, best practices for prevention are essential. Workers should wear protective clothing when moving between greenhouses, especially disposable coats and gloves. Even if the virus has not been detected, this should be standard procedure.

This article has been slightly modified from an article written by Ron Goldy of Michigan State University. The original article can be accessed at https://www.canr.msu.edu/news/tobrfv-a-new-concern-for-tomato-and-pepper-producers

Be Cautious When Using Low Tunnels for Early Watermelon Planting

(Wenjing Guan, guan40@purdue.edu, (812) 886-0198)

Watermelon is best grown at temperatures around 80-90°F. Temperatures above 90°F reduce the growth rate; above 105°F may cause plant injury. Temperatures below 42°F result in watermelon chilling injury; below 32°F will kill watermelon plants. Extended cool days that lead to soil temperatures dropping into lower 50°F can also kill watermelon seedlings.

Using low tunnels is one strategy to avoid chilling injury and encourage early plant growth. How does the plastic covered low tunnels modify temperatures in early watermelon season? Figure 1 shows the air temperature comparison between low tunnel (1 mil plastic film, perforated) and without low tunnels. The data was taken from April 24 to May 25, 2020 in a watermelon field at Southwest Purdue Agricultural Center.

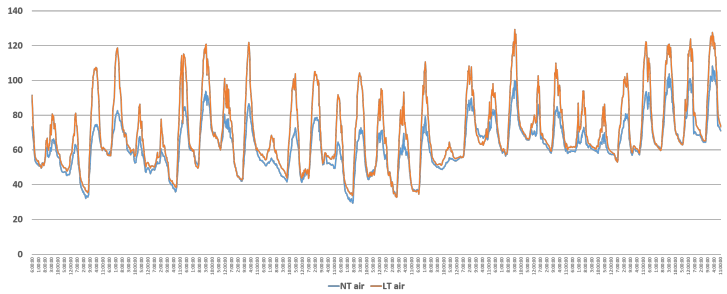

Figure 1. Air temperatures with (red line) and without (blue line) low tunnels from April 24 to May 25, 2020.

During the time period, the recorded minimal temperatures were below 40°F for 5 nights. Low tunnels increased the minimal temperature from 0-4.5 degrees (Table 1).

Table 1. Minimal air temperatures with and without low tunnels.

Date	Apr. 27	May 1	May 9	May 11	May 12
Without Low Tunnel	32	35.8	29.3	32.9	34.5
Low tunnel	35.7	38.5	33.8	32.9	36.3

Low tunnels dramatically increased maximal air temperatures. The difference on maximal temperatures range from 10-35 degrees. During this one month period, there were 17 days with maximal air temperatures below 80°F, but only three days that the maximal air temperature did not reach 80°F under low tunnels. Maximal air temperatures reached above 120°F under low tunnels when air temperature were above 90°F.

How did the temperature differences affect watermelons? With the five very cold nights, not surprisingly, 95% watermelon plants were dead without low tunnels. While the death rate was only slightly better under low tunnels (77%).

Watermelon plants grafted onto squash rootstock survived the extremely cold night. Low tunnels made a big difference in their growth. Under the low tunnels, the vines were about 3 feet long after the first month. While the vines were just starting to grow without low tunnels (about 1 foot long).

Heat injury was observed on plants under low tunnels. The tip of the vines were yellow in addition to necrosis leaves (Figure 2). It is clear that plants were stressed under low tunnels that made the temperatures climb above 120°F on this Memorial Day weekend. Plants recovered after low tunnels were removed, yellowing leaves became necrosis, and new growing tips look healthy.

Figure 2. Heat injury on watermelon plants. Left: tip of the vines is yellowing right after low tunnels were removed. Right: plants recovered after a few days low tunnels have been removed.

Take home message: Using low tunnels for early watermelon planting can be a gamble. Low tunnels can make a huge difference if environmental conditions are perfectly right. That is to say on most of the days, high temperatures should be lower than 80°F, but cannot be too low to kill seedlings. Meanwhile, temperatures should not be above 90°F, otherwise the low tunnels may cause negative impacts on plant growth.

Abiotic Factors may Cause Deformed Strawberry Fruit

(Wenjing Guan, guan40@purdue.edu, (812) 886-0198)

This article discusses the abiotic factors that may cause deformed strawberry fruit.

unevenly developed strawberry fruit (Figure 1):

Frost damage is probably the most common abiotic factor causing misshapen strawberry fruit. Temperatures lower than 30°F kill the pistil (female part) of strawberry flowers. Depending on the extent of the injury and the stage of fruit development. The entire pistillate portion of the flower may be killed, which will result in the loss of fruit; Or a few pistils may be killed, fruit expansion stops at where pistils were killed. The damaged fruit then develops unevenly, resulting in misshapen fruit.

Lack of wind for pollination is less likely a problem for field strawberry production but can be a concern for high tunnel production. Because high tunnels are typically closed at the peak strawberry blooming stage in order to attract heat. Air movement is very limited inside of the high tunnel that results in poor pollination. This problem can be solved by partially opening high tunnel sides a few hours during the day, or manually disturb foliage daily at pick blooming stage. This typically happens in March in southern Indiana.

Figure 1. Unevenly developed strawberry fruit.

Fasciation fruit (Figure 2):

Fasciation fruit has fully developed receptacle and lack seediness area, which means this kind of malformation is not related to poor pollination or frost damage. Fasciation is generally considered a varietal characteristic, It was suspected that Fasciation fruit maybe accentuated by environmental conditions in fall, such as too short of day length that influences flower bud development. Fasciation fruit may not necessarily mean they are defect fruit. Actually, they may be attractive in the local market because of the large size and unique shape.

Figure 2. Fasciation strawberry fruit

Hollow heart and split fruit (Figure 3)

This deformed strawberry fruit is also a varietal characteristic and less likely caused by poor pollination and frost damage. In a cultivar trial involving ten recently released cultivars, we noticed it happens most frequently on cultivar Fronteras. The fruit splits, has two tips and a hollow center. Similar to Fascination fruit, hollow heart fruit does not affect the quality and may be attractive in the local market. But in the USDA standard, it may be rated as a defective. Other than genetically related, we are not sure why this happens. Some suspect that it might be caused by the fruits rapid growth due to excessive fertility.

Figure 3. Hollow heart and split strawberry fruit.

Waterhemp

(Jeanine Arana, jcordone@purdue.edu, (765) 588-7787) & (Stephen Meyers, slmeyers@purdue.edu, (765) 496-6540)

Waterhemp is prevalent in the Midwest and the Great Plain States. It became a significant agricultural weed in 1990s. Before then it was present in crop fields, but it is presumed that it rarely reached economic infestations. It became a problem in Indiana by 1998. Waterhemp is best adapted where less aggressive tillage is practiced. The adoption of conservation tillage might have aided in its widespread establishment. Also, the use of herbicides in the late 1980s coincided with the spread of waterhemp, and it quickly became resistant to Group 2 herbicides (ALS-inhibitors). Today waterhemp populations have been documented to also have resistance to Groups 5 (Photosystem II-inhibitors), 9 (glyphosate), 14 (PPO-inhibitors) and 27 (HPPD-inhibitors or “bleachers”).

Figure 1. Waterhemp cotyledons ovate-shaped (Travis Legleiter).

Identification: At the seedling stage, it can be difficult to distinguish waterhemp from other pigweeds. Cotyledons are egg- to ovate-shaped (Figure 1). When plants are larger, waterhemp can be differentiated because it has no hair on the stem or leaves like most pigweeds. It can be distinguished from Palmer amaranth because its petioles are shorter than its leaf blades (Figure 2) unlike Palmer amaranth which has petioles at least as long as its leaf blades. Waterhemp leaves are elongated and have a shiny/waxy appearance (Figure 3).

Figure 2. Leaf blade with folded petiole showing waterhemp short petiole length (Travis Legleiter).

Figure 3. Leaves arrangement and shape on large waterhemp plant (Travis Legleiter).

Growth habit: Waterhemp is a summer annual weed that emerges late in the season with a growth rate of approximately 1 inch per day. Its high growth rate makes it very competitive with the crop and other weeds. Late emergence allows waterhemp to avoid pre-emergence herbicides. The first waterhemp plants to emerge are the most competitive and have the greatest potential

to produce large numbers of seeds. Later emerging plants are often less competitive, but are still capable of producing seeds that will have to be controlled the next season.

Reproduction: Waterhemp reproduces by seed and has male and female flowers on separate plants (dioecious). A female plant can produce 250,000 seeds, but some plants have been found to produce 1 million or more seeds in optimal conditions. Because waterhemp is dioecious, plants have more potential to evolve and spread herbicide resistance genes.

Integrated weed management strategies

Cultural and mechanical/physical practices:

- Mulch: Plastic mulch provides a physical barrier that prevents waterhemp from growing. Avoid excessively large planting holes and tears that will provide a space for weeds to establish. Row middles will still need to be managed with one or more of the methods below. (Note: Rolled cover crop residue can also provide a physical barrier and aid in waterhemp suppression. The degree of control is often related to the amount of biomass produced by the cover crop, where more is better.)
- Deep tillage: Because waterhemp seeds are small, they only emerge from the uppermost portion of the soil. Tillage that inverts the soil and buries the seeds deeply can reduce waterhemp pressure and facilitate decay of waterhemp seeds.

Chemical control:

Waterhemp resistance to multiple herbicides is well documented. The best chemical control options will depend on the crop grown and the specific population of waterhemp present. For more information on chemical control options, consult the *Midwest Vegetable Production Guide* at **https://mwveguide.org/** and the product labels.

- *Don't rely entirely on post-emergence herbicides.* Post-emergence options for broadleaf weed control in vegetable crops are limited and typically rely on Group 5 and 2 herbicides, both of which have documented waterhemp resistance. Where permitted, the use of a broad-spectrum herbicide applied as a directed or hooded spray to row middles will control susceptible plants. Post-emergence applications should be made to small (less than 4" tall) waterhemp.
- *Do use pre-emergence herbicides.* Season-long control may require more than one application of residual herbicides. If the production system allows, the use of pre-emergence herbicides at planting then again at layby will provide longer-term control. Use multiple modes of action when possible and apply to a weed-free surface as most pre-emergence herbicides will provide little or no control of emerged weeds. Commonly used herbicides that offer control include those from Group 15 (Dual Magnum®, Zidua®), Group 4 (Valor®/Chateau®, Reflex®), and Group 3 (Prowl®, Treflan®).
- *Evaluate if the herbicide application was effective.* After any control measure it is important to scout fields to determine treatment effectiveness. This allows for follow-up action if needed. It will also help you identify which herbicides your waterhemp population is susceptible and resistant to.
- *Consider rouging, if possible.* When possible, do not allow waterhemp escapes to establish; rogue them before they get to a reproductive stage. Although this is often done by hand and hoe when labor is available, mowing or electrocuting ("zapping") may also be suitable options to manage escapes.
- *Consider combining chemical control practices with cultural and mechanical control practices.* Better control is achieved when using cultural practices and focusing on pre-emergence plus post-emergence herbicides applications.

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FDA Announces Temporary Policy During the COVID-19 Public Health Emergency

(Scott Monroe, jsmonroe@purdue.edu, (812) 886-0198) & *(Amanda J Deering, adeering@purdue.edu)*

Recently, the Food and Drug Administration (FDA) announced a temporary policy regarding eligibility for the qualified exemption under the Food Safety Modernization Act (FSMA) Produce Safety Rule. The policy is designed to provide flexibility to growers during the COVID-19 public health emergency. The policy and guidance may be found on FDA's website at https://www.fda.gov/media/138316/download.

Under the FSMA Produce Safety Rule, growers may receive a qualified exemption if total **food** sales (defined as anything that may be used as food and drink for humans and animals) are less than $500,000 annually and more than half of all sales are to a qualified end user. A qualified end user may be (a) the consumer of the food or (b) a restaurant or retail food establishment that is located in the same state or the same Indiana reservation as the farm or not more than 275 miles away.

The COVID-19 public health emergency has made it very difficult for growers to interact directly with consumers and has resulted

in the closure of many retail food establishments, such as restaurants. As a result, growers may need to find new or additional marketing venues. The purpose FDA's temporary policy is to give flexibility and allow growers to seek out new or additional marketing venues while still being considered eligible for the qualified exemption. Under the temporary policy, "Growers who are eligible for a qualified exemption and associated modified requirements will still be considered eligible, even if they shift sales away from qualified end-users, so long as they continue to meet the requirement that their average food sales during the previous three years total less than $500,000 (adjusted for inflation)".

The temporary policy will be in effect only for the duration of the public health emergency. After that time, FDA intends to issue additional guidance.

COVID-19 Resources for Agriculture Workers and Employers Available

(Scott Monroe, jsmonroe@purdue.edu, (812) 886-0198) & (Amanda J Deering, adeering@purdue.edu)

As we continue to move toward harvest for many of our produce crops, numbers of workers will continue to increase on produce farms. Management of worker health has been, and continues to be, critical to insuring that farms have adequate labor.

The following are a few resources available to growers as they continue to monitor and manage worker health:

1. Centers for Disease Control (CDC) and the U.S. Department of Labor:

Joint guidance for agriculture workers and employers during the COVID-19 public health emergency. Available at https://www.cdc.gov/coronavirus/2019-ncov/community/guidance-agricultural-workers.html.

2. Indiana State Department of Health:

Spanish and English versions of guidance documents are online at https://www.in.gov/isdh/23276.htm.

a. Guidance for Migrant Farm Workers, Labor Camps Operators and their Employer

b. Steps to help prevent the spread of COVID-19 (poster)

c. Stop the Spread of Germs Like COVID-19 (poster)

3. Purdue Extension:

Management of Farm Labor During the COVID-19 Pandemic (Publication FS-38-W) available from the Education Store at https://www.extension.purdue.edu/extmedia/FS/FS-38-W.pdf. A companion video may be viewed in the resource section at www.SafeProduceIN.com

June Outlook Calling for Above-Normal Temperatures

(Beth Hall, hall556@purdue.edu)

The month of May was sprinkled with a record-breaking freeze over Mother's Day weekend, followed by heavy rainfall the following weekend, with a roller coaster of cool periods and extremely warm periods. We often think of spring as being that transition between winter and summer with lots of ups and downs, but those extremes from one week to the next made it difficult to know what to expect more than a few days out. By the time the month ended, precipitation was slightly below normal in the southwestern and west-central parts of Indiana with the rest of the state slightly above normal. May's temperatures averaged to only 1°F to 2°F below normal. This is a great example of how averaging data can mask the extremes that made up reality!

What will June be like? The latest national Climate Prediction Center outlooks for June are showing increased confidence for above normal temperatures and too much uncertainty for whether precipitation will be above or below normal (Figure 1). Over the next few weeks, temperatures are forecasted to be in the upper 80s to lower 90s with some intermittent rainfall due to convection. After that warm period passes, temperatures are predicted to return to more seasonal levels by mid-June.

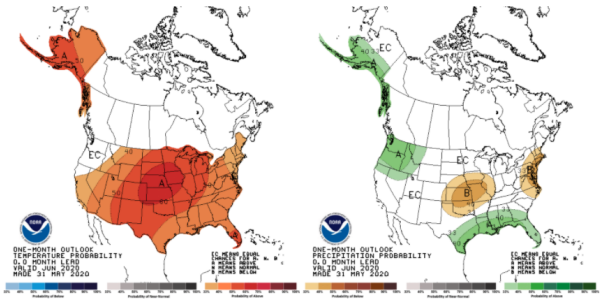

Figure 1. June overlook

Question for the Issue (6-3-2020)

(Liz Maynard, emaynard@purdue.edu, (219) 548-3674)

Question: Why are the water droplets arranged so evenly around the edge of this cucurbit leaf?

Answer to Question from Last Issue (5-21-2020)

(Wenjing Guan, guan40@purdue.edu, (812) 886-0198)

What is wrong with these strawberries?

Answer: The deformed fruit is likely caused by frost damage or poor pollination.

More information about deformed strawberry fruit can be found in this issue's article *Factors may cause deformed strawberry fruit*.

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