The use of heat in horticulture for pest and disease control

Aileen Reid, Strawberry Industry Development Officer, Agricultural Produce Commission

You may be familiar with heat being used for virus elimination in plants (thermotherapy), but heat, as hot water, has been used for many years in horticulture to control or eliminate various pests and diseases, particularly in bulb crops for the elimination of nematodes.

The first protocol for heat treatment of strawberry nursery stock was developed to control broad mite (*Phytonemus pallidus*) in 1991. It recommended plants be directly submerged in a hot water bath at 48-49°C for 5 to 7 minutes. However, this treatment delayed growth for up to 2-3 weeks making it unsuitable for plants destined for fruit production. More recently, hot-water treatment at 37.8°C for 30 minutes has been used by some nursery, government, and university breeding programs to eliminate broad mite.

Although once popular, few growers now routinely use hot-water treatment for managing pests and diseases, because of concerns about delaying, stunting or killing plants, and the spread of pathogens. More recent protocols that use aerated steam and heat shock pre-treatments have overcome these issues.

Research has shown that aerated steam can be used to control several pests and diseases in strawberry plugs and runners without plant or yield loss by pre-treating for 1-hour at 37°C then cooling to room temperature for 1 hour before treating at 44°C for 4 hours.

Powdery mildew

Repeated trials in Norway and Florida showed aerated stem treatments completely eradicated powdery mildew in strawberry transplants. The standard steam treatment of 4 hours at 44°C used against other pathogens and pests can be reduced to 2 hours at 40°C without any loss of efficacy in eradicating the powdery mildew. So, if the primary aim is powdery mildew-free planting material, this may enable a reduction in time and cost, which is highly beneficial when treating large plant volumes.

It should be noted that powdery mildew fruiting bodies (that produce the spores you see on the leaf surface) were not present on the plants in this experiment. These structures are thicker but much smaller than some other fruiting bodies so may also succumb to the steam treatment.

Nematodes

Aerated steam treatments have been evaluated for their efficacy in managing three nematode species: *Aphelenchoides besseyi* (a foliar nematode), *Meloidogyne hapla* (root knot nematode), and *Pratylenchus penetrans* (root lesion nematode). Four hours of exposure to aerated steam at 44°C completely eradicated the foliar and root knot nematodes. Unfortunately, root lesion nematode is quite heat tolerant and populations were only reduced by 85% with the treatment.

Two spotted mites

Estimated complete mortality of two spotted spider mite using steam at 48°C was achieved after 2.7 hours of treatment for adult females and 1.9 hours for eggs. Treatments at 44°C and 46°C for up to 4 hours killed 20% and 60% of the mites, respectively.

Phytophthora

Nursery transplants exposed to aerated steam treatment at 37°C for 1 hour followed by 44°C for 4 hours were much less likely to die from *Phytophthora* crown rot.

Botrytis

Using the same protocol for control of *Botrytis* species (37°C pre-treatment followed by 44°C for 4 hours), the presence of fungal fruiting bodies was strongly reduced but not completely eradicated. Smaller fruiting bodies were killed by the treatment, but larger ones remained.

Controlled Atmosphere Temperature Treatment

As an alternative to methyl bromide fumigation (MBr), a controlled atmosphere temperature treatment (CATT) was developed and scaled up by Wageningen University in cooperation with the Dutch plant propagating association Plantum. During CATT, plants are treated at 35°C, 50% CO2, and 10% O2 under high relative humidity for 48 hours. Under those conditions, mortality of the broad mite (*Phytonemus pallidus*) is over 99.8%.

From 2009, CATT was scaled up to a commercial level and widely applied by Dutch nurseries. In 2011, this method was modified to eradicate the root knot nematode (>99.7% mortality), which was not effectively controlled by MBr fumigation. To be effective the temperature must be raised to 40°C. Temperatures must not exceed 40° or damage will result.

Putting this into practice

It is apparent that strawberry cultivars vary in their ability to survive heat treatments. It has been reported that strawberry plants tolerate heat treatments better if the roots are well-developed and soil moisture is low. The more dormant the plants are, the better they tolerate warm-water treatments. Storing plants for two weeks at 0°C increases the tolerance to the warm-water treatments. Use of heat-shock pre-treatment increases the tolerance to heat of both cold stored and freshdug plants.

Despite proven efficacy in small-plot trials, persuading commercial growers to adopt precision thermotherapy in commercial settings has been difficult.

Precisely applying the conditioning treatment to commercially boxed plants is challenging. Factors such as packing density, cleanliness of the nursery stock, and temperature of the nursery stock at the beginning of treatment all make it hard to quickly and evenly heat plants.

It is possible to initially set the temperature of the precision thermotherapy unit (PTU) above 37°C to generate a greater volume of aerated steam to overcome this issue, but it risks damaging the plants if the temperature stays too high for too long. However, even with the best of circumstances, it takes nearly an hour for a "conditioned" box of plants to reach 44°C in the PTU, so it seems unlikely that plants are in danger of being damaged.

In the CATT system, work showed plants exposed to 40°C up to 28 hours experienced only minor damage. Given the unavoidable and inherent variability in plant packaging and the associated difficulties in precisely regulating the ramp-up to 37°C, it is perhaps best to consider 37°C as a minimum temperature to achieve the desired heat-shock response and simply redefine the conditioning treatment to a range between 37 and 42°C for 1 hour given the thermal "cushion". The heat-shock response should not be affected, because others have shown that exposure to elevated temperatures for as little as 15 minutes was sufficient for heat-shock protein production.

There is generally less room for error at the temperature extremes. In nearly all trials, obtaining and maintaining 44°C was achieved without having to raise the temperature far above the target temperature.

Unlike the conditioning treatment, boxes of plants entering the eradicative treatment phase have been "conditioned" and start the treatment with a homogenous temperature profile. Conditioned plants seemed to achieve their target temperature at a quicker and more uniform rate.

Although the protocol is written that plants be exposed to 44°C for 4 hours, in practice the PTU is set to run for 4 hours at 44°C. This means plants packed on the top will quickly reach the target temperature, but plants in the middle may take up to an hour longer to reach the 44°C target temperature.

Figure 1. The chambers used for aerated steam treatments in Norway and Florida were constructed by Plantsauna AS (now Moleda AS) https://moleda.nl. Photo credit: Moleda

Details and images of the aerated steam units used in the actual experiments described here can be found in: https://apsjournals.apsnet.org/doi/10.1094/PHYTOFR-08-20-0012-R

References and further reading

Baggio, J. S., M.V. Marin and Natalia A. Peres 2021. Phytophthora Crown Rot of Florida Strawberry: Inoculum Sources and Thermotherapy of Transplants for Disease Management. Plant Disease Vol. 105, No. 11, 1-7. https://doi.org/10.1094/PDIS-11-20-2476-RE

Khanal C, Gu M, Peres NA, Desaeger JA. 2020. Steam-based thermotherapy for managing nematodes in strawberry transplants. J Nematol. E2020-95, Vol 52: 1-10. https://doi.org/10.21307/jofnem-2020-095

Peres N.A., Marin M. and Juliana S. Baggio 2023. Phytophthora Crown Rot of Strawberry. https://edis.ifas.ufl.edu/publication/PP350

Renkema J. ,Dubon F., Peres N. and Braden Evans 2020. Two-spotted Spider Mites (Tetranychus urticae) on Strawberry (Fragaria × ananassa) Transplants, and the Potential to Eliminate Them with Steam Treatment, International Journal of Fruit Science, https://doi.org/10.1080/15538362.2020.1755769

Stensvand, A., Wang, NY., Le, V.H. et al. Aerated steam eradicates powdery mildew from strawberry transplants. Eur J Plant Pathol (2023). https://doi.org/10.1007/s10658-023-02744-6

Turechek W. W., Myrhene, O., Slovin J., and Natalia A. Peres 2020. The Use of Aerated Steam as a Heat Treatment for Managing Angular Leaf Spot in Strawberry Nursery Production and Its Effect on Plant Yield. Phytofrontiers: Vol 1 No. 2; 1-16. https://doi.org/10.1094/PHYTOFR-08-20-0012-R

Turechek, W. W., and Peres, N. A. 2009. Heat treatment effects on strawberry plant survival and angular leaf spot, caused by Xanthomonas fragariae, in nursery production. Plant Dis. 93:299-308. https://doi.org/10.1007/s10658-023-02744-6

Zuniga, A. I., Nan-Yi Wang, and Natalia A. Peres 2023. Heat Treatment as a Possible Means to Reduce Botrytis Inoculum on Strawberry Transplants. Plant Health Progress 2023 24:3, 345-352 https://doi.org/10.1094/PHP-08-22-0078-RS

apc
AGRICULTURAL PRODUCE COMMISSION