Using water as an overnight temperature moderator to improve plant growth and germination in greenhouses

by Tony Martin

For many years I've used water in containers to help moderate the temperature of cold frames, greenhouses and conservatories – soaking up the excess heat of the day and releasing it at night to help keep tender seedlings from getting too hot/cold, and to speed up germination. I have used whatever containers are to hand, ranging from hundreds of little 0.25 litre glass juice bottles to 200 litre barrels.

The question

The rate of heat energy gained or lost by an object is related to its surface area and volume (amongst other things). I wanted to know if there is an optimal size of container for overnight temperature moderation, rather than using an ad hoc mix of sizes.

Testing time

I set up an indoors experiment at my home in Wales, using the sorts of containers that most people will be able to pick up for free or very cheap, filled with my leftover warm bath water (why waste it?). I used the following five sizes of plastic containers: 0.25 litre juice bottle; 0.5 litre pop bottle; 2 litre pop bottle; 5 litre vinegar container and a 25 litre water container.

The containers were shielded from draughts, other than the naturally produced convection currents, and I attempted to keep the ambient temperature stable. I then set a timer and measured the temperatures in each bottle for the next ten hours [Note 1] and placed the data in a spreadsheet.

Results

Using this data I produced a graph (see next page) showing time in minutes against temperature of the water (°C).

From this graph I was able to create the following table which shows the time in hours it takes for the different sized containers to give up 50% and 90% of their available heat energy. As you can see, the smallest bottle (0.25 litres) gave up about half of its heat in just over half an hour, whereas the 25 litre one took nine hours.

Energy released	0.25 litres	0.5 litres	2 litres	5 litres	25 litres
50%	0.6	1.4	3.4	6.0	9.0
90%	3.8	6.3	9.8	14.0 *	16.7 *

Times in hours (estimated values)*

Assumptions and calculations

There are many varied conditions: length of night, minimum and maximum tolerable plant temperatures, space, rate of heat loss, initial temperatures, position and quantity of containers, etc.

For example, the approximate length of night on different months [Note 2] in the UK is 1st March 13 hours, 1st April 11 hours, 1st May 9 hours. Minimum temperature for seedlings: carrots 5°C, peppers 13°C.

Calculating the quantity of water needed

With the aid of a calculator from the internet [Note 3] we can work out the power needed to keep a greenhouse warm for different conditions. Using an example of an 8ft x 6ft x 9ft high [2.4 x 1.8 x 2.7 metres] glass-covered greenhouse, we would need 530 litres of water [Note 4]. Adding a layer of bubble wrap to the inside of the greenhouse would approximately halve the energy needs.

Conclusions

Based on an 11 hour night [Note 5], I believe that the 2 and 5 litres bottles with their respective 90% energy release times of around 10 and 14 hours would give me the best results.

If however I was trying to moderate the temperatures over several days to cover a 'cold snap' then 25 litre or larger containers would be preferable.

The smaller 0.25 litre (3.8 hours) and 0.5 litre (6.3 hours) would likely have run out of useful amounts of heat long before daylight. Although they would help stabilise the temperature, especially early on, they would leave the plants vulnerable in the early hours of the morning.

Whilst every situation will vary greatly [Note 6], the use of any thermal mass (water or otherwise) will help reduce the risks to plants that are caused by wide variations in temperature from night to day and back again.

Further experimentation needed

Whilst this test has given some useful data, a full scale experiment that logs temperatures over a period of days or weeks is needed.

The effects of positioning the water, plants, the quantity of water, estimates of additional thermal mass, the use of solar powered fans etc, need to be investigated to see how well theory matches reality and what the optimum set-up is.

From previous experience, a solar powered fan drawing heat from the apex of the greenhouse down to containers at ground level is, I believe, likely to be part of the optimum solution. I would love to hear any experiences people have had with similar systems.

A permaculturist eating an ice lolly

A permaculturist's Ice cream van

A silver birch tree provides Tony with some vegan organic refreshment

Notes

1. The temperatures of the bottles were slightly different at the start, possibly due to evaporation from the surfaces from the time taken to fill the containers to the time of the first measurements. I used two identical digital thermometers which had an internal and an external thermometer on a lead, that displayed to 0.1°C and were matching to within 0.1°C of each other at the temperatures used.

2. Sunrise and sunset times calculator: www.timeanddate.com/astronomy (Type a city into the 'Sun' panel, click Go and then select a month.)

3. Greenhouse power calculator: www.hartley-botanic.co.uk/greenhouse-power-calculator

4. Example of an 8ft x 6ft x 9ft high greenhouse with 6ft eaves (291 sq ft) and standard glass. With minimum external 0°C, minimum internal 5°C and a water temperature change of 15 °C it needs 844 watts (using calculator in Note 3) .

Energy required in joules to heat the greenhouse = watts x the number of seconds (11 hours = 39600 seconds). That gives us 844 x 39600 = 33 megajoules or around 9.3 kWh.

The amount of energy stored by water in joules equals mass (in kilograms) x temperature difference (°C) x 4200 (specific heat capacity of water).

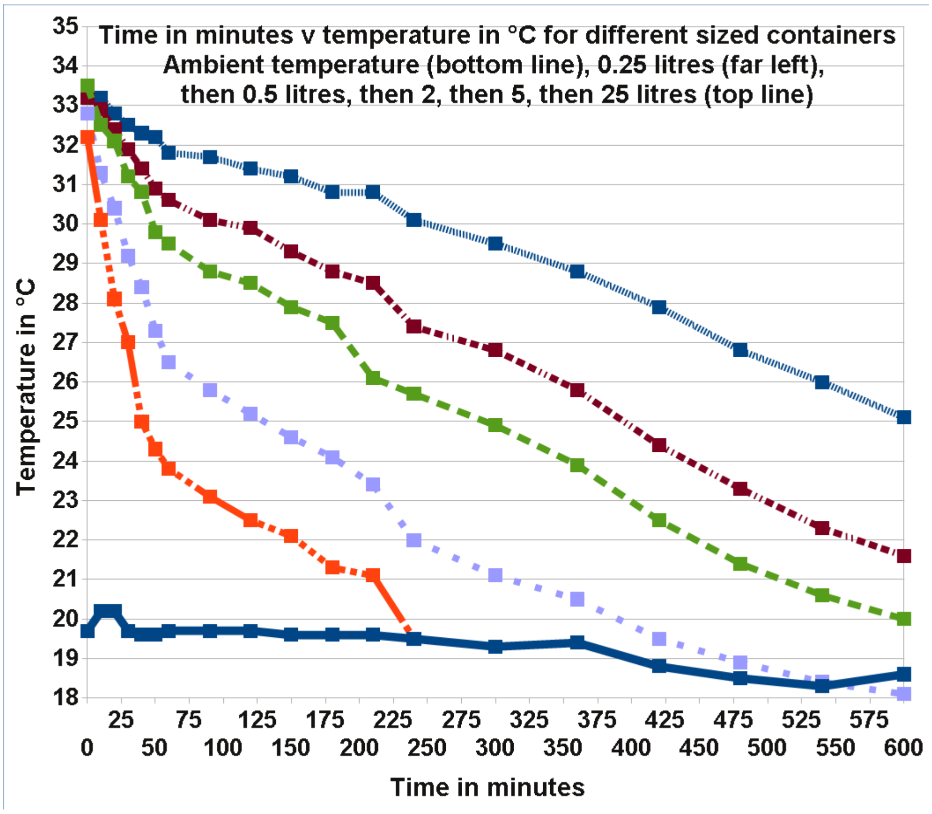
So to find the amount of water we need (assuming say a 15°C overnight drop of water temperatures): 33,000,000 = mass of water x 15 x 4200. Rearrange to find the mass of water: 33,000,000/63,000 = 530kg = 530 litres.

The rate of heat released by the water will initially be high and then drop as the water cools. Also the external temperature will drop over time so I have used the average power.

5. 11 hours for London on April 1st.

6. The testing of the bottles was done in a relatively fixed temperature environment. In a greenhouse the ambient temperature would vary more, being raised due to the heat released by all the water containers and lowered depending on the night time weather conditions. I have ignored the thermal mass of plants and racking in the greenhouse, but in real life these would contribute some heat storage capacity.

Article, photo and graph produced using free software including PCLinuxOS, GIMP photo editor and LibreOffice



New date for Permaculture Design Course in South Wales

The full Permaculture Design Course, due to be held at Tony's 5½ acre site near Swansea this July, has been postponed to 30th May - 13th June 2015, giving Tony more time to improve visitor facilities and do work on his projects. The cool and very damp spring made progress slow, and more than a little frustrating!

Course details at www.designedvisions.com/gw.html

See Tony's article in GGI 32 (pages 12-13): A forest garden on a South Wales hillside