Grower Summary

BOF 63b

Integrated control of bulb-scale mite in narcissus: Validation of bulb temperatures during hot-water treatment

Final 2012

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Headline

Hot-water treatment facilities of various types achieved precise control of bulb-core temperature, but in some cases the set (achieved) temperature differed by up to 1.5°C from the target temperature (usually 44.4°C), indicating greater vigilance is needed in monitoring and validating temperature settings.

In many cases, the bulb-core failed to achieve the required number of 'accumulated hot-water minutes'. This was due to a sub-optimal temperature being achieved, or to HWT controllers starting to time the (usually) 3 hour period before the bulb-core had reached the set temperature. At the end of the HWT period, however, treated bulbs could retain heat (for example, if unloading from the tank was delayed), which could contribute to the required number of accumulated hot-water minutes.

Depending on the situation, bulb-core temperatures took from 10 to 25 minutes longer to reach the set temperature than the surrounding dip.

As a rough guide, as bulb grade increased from <10cm, through 10-12, 12-14, 14-16cm to >16cm, an additional 6 minutes at the target temperature was needed to achieve the target heat treatment.

Neither cultivar, bulb position within the bin nor position of bin in the tank had a commercially significant effect on bulb-core temperature.

Background

Hot-water treatment (HWT) is the only practical way for UK growers to manage stem nematode and bulb-scale mite in daffodil bulbs. The standard treatment in the UK involves bulb immersion for 3 hours in water at 44.4°C a few days or weeks before planting. The quoted duration x temperature combination should be followed carefully if pest control is to be maximised and high-temperature damage to bulbs minimised. Until its use was banned in the EU in 2008, formalin was routinely added to the HWT dip to augment the control of stem nematode and of other pests and diseases. This legislation forced a re-think of the HWT process, but laboratory-based studies confirmed the effectiveness of the standard HWT regime in killing stem nematode, even without the addition of formalin (or another biocide or disinfectant) to the HWT dip. Even leaving aside the validity of extrapolating from small-scale, laboratory studies to practical, on-farm HWT, bulb growers and technologists have continued to question how well and how uniformly HWT achieved the target temperature

(44.4°C) in the centres of bulbs for the required duration (3 hours): for example, are temperatures consistent throughout commercial treatment tanks, and how might bulb size or cultivar affect the temperatures achieved? Such issues were re-emphasised by the findings of a recent Horticulture LINK project (BOF 63) that some bulb-scale mites and eggs survived HWT; this resulted in the funding of an extension to BOF 63 to examine these specific points.

Summary

The project comprised two parts: the examination of bulb-core temperatures (a) under standard HWT conditions using a sample of typical HWT facilities, and (b) in a range of bulb sizes and cultivars and in different locations within HWT bins and tanks. Thermistor probes (10mm long x 2mm diameter) were inserted into bulbs and used to measure temperatures in the centres of bulbs ('bulb-core' temperatures) at 1 minute intervals, and further thermistor probes measured the temperatures of the dip adjacent to the test bulbs ('adjacent-dip' temperatures) and close to the HWT tanks' integral temperature control sensors or in the flow of heated water entering the treatment tank from the heater ('control-dip' temperatures). Bulb-core and dip temperatures were logged and used to find minimum, mean and maximum temperatures during the HWT period. The numbers of minutes that bulb-cores were at a temperature of 44.3°C or more ('accumulated hot-water minutes') during the dipping process were calculated and compared with the target of 180 minute (3 hours).

Standard testing

Temperatures were monitored in bulbs of a standard cultivar and size ('Tamara', 12-14cm circumference) given HWT at five typical bulb farms. HWT facilities at these sites included a cross-section of the type of equipment used across the UK, including older top-loading and front-loading (drive-in) tanks and modern front-loading (drive-in) tanks, mostly fabricated by Secker Welding but some manufactured by Akerboom or produced locally. Tank capacities varied from two to twelve bins, equivalent to about 2.8 to 11.3 tonnes of bulbs. Three bulbs fitted with thermistors were placed near the centre of bins.

A typical standard test result is shown in the Figure A on the next page, which illustrates all the following general comments that applied to all five of the test sites. After immersion (or loading) of the bulbs the control-dip temperature fell sharply due to the effect of the cold bulbs, before recovering. Adjacent-dip temperatures also rose, fell back and then recovered. The adjacent-dip temperatures equalised and reached the set temperature 20 to 100 minutes after the start of dipping, reflecting the great variation of heating capacity between different facilities.

During warm-up the bulb-core temperatures lagged behind adjacent-dip temperatures. Bulb-core temperatures equalised and reached the set temperature 10 to 25 minutes later.
During the HWT period (from 3 hours to 3 hours 15 minutes) bulb-core, adjacent-dip and control-dip temperatures were remarkably close to each other, steady at the set temperature, and similar in replicate bulbs, irrespective of the type of facility used. Bulb-core temperatures lagged slightly behind dip temperatures during ‘heating cycles’ (when the heater cut-in to maintain the set temperature). The temperature set on the controller did not always agree with the target temperature, usually 44.4°C.

At the end of the HWT period (when the dip was pumped out of the treatment tank, or when the bulb bins were lifted out of the tanks), bulb-core temperatures were largely maintained for the period until the bulb bins were actually unloaded from the tanks.

The effective duration of the HWT period (taken as when bulb-core temperatures were at or above 44.3°C) varied, depending when (a) the HWT controller judged the set temperature to have been regained (following immersion of the bulbs by the dip, or loading of the bulb bins in top-loading tanks) and therefore started the timing of the HWT period and (b) when the bulbs started to cool at the end of treatment.

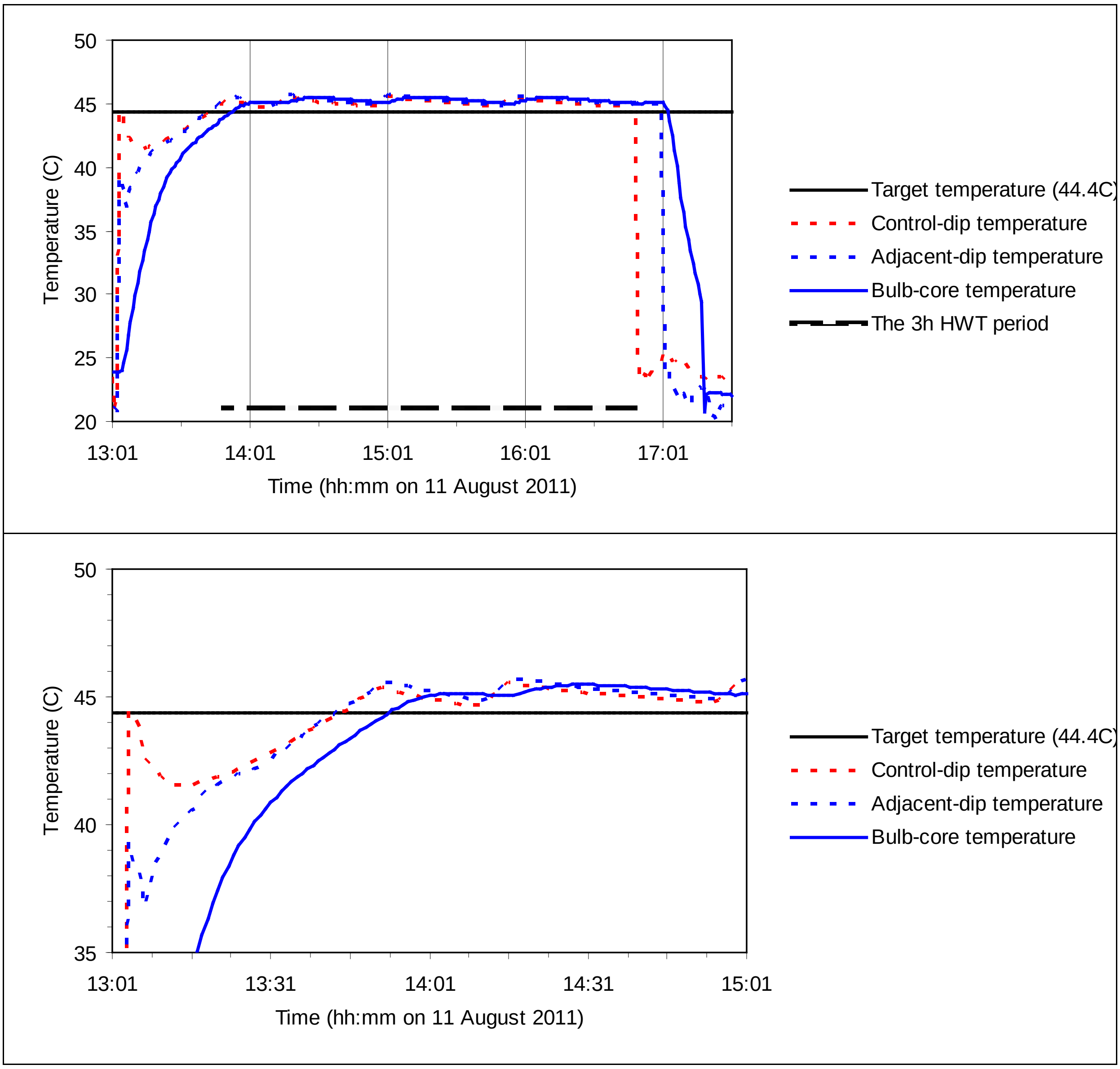

Figure A. A typical result from standard testing of HWT temperatures, showing dip and bulb-core temperatures (top graph) with the scales expanded for the first half of the test (bottom graph). Example taken from data from site 1, run 2.

In addition to these general findings, some site-specific issues were identified. At site 1 the facility consisted of older, Secker Welding-built, front-loading tanks. The following points were noted.The set temperature was 0.5 to 1.0°C above the target temperature of 44.4°C.

In two runs the HWT controller started timing the 3 hour HWT period shortly after the bulbs had been immersed but before bulbs had reached the target temperature, and hence when the timed period ended the bulbs had not yet acquired the target of 180 accumulated hot-water (HW) minutes (i.e. 3 hours at the target temperature).

Subsequent discussions revealed that the grower's practice at the start of the day's HWT was to pre-heat the dip in one operating tank to about 54°C on the expectation that, after immersing the freshly loaded bulbs in the other tank by pumping over the pre-heated dip, a dip temperature close to the target 44.4°C would be achieved. The data recorded however indicated that the bulbs had not warmed to the required temperature when the tank's temperature control sensor began to time the 3 hour period based on the dip temperature of 44.4°C. In contrast, in HWT runs later in the day, water at about 44.4°C was pumped from the other operating tank to the freshly loaded tank and topped up with water from the holding tank: the temperature control sensor then registered a temperature below 44.4°C and timing did not begin until this temperature was reached. Procedures for the first dip-of-the-day were easily modified to achieve the required HWT period.

At site 2 the facility consisted of modern, Secker Welding-built, front-loading tanks, and the standard HWT regime used was longer than usual at 3 hour 15minutes. Temperature control was excellent, but, in a variation of an effect found at site 1, two runs achieved more than the target of 180 accumulated HW minutes, while the other run did not, the shortfall being 10 to 15 minutes. In the 'unsuccessful' run, the bins were unloaded from the tanks very promptly, while in the other runs there was an interval before unloading took place. Achieving the required time at the target temperature was successful only due to the combination of (a) the longer treatment period used at this site and (b) the delay in unloading bins at the end of the run, which allowed further HW minutes to be accumulated.

Subsequent discussions revealed that, at the end of the working day, treated bulbs were removed more promptly than normal, another protocol that could easily be corrected. Faster unloading might also have implications due to the shorter drain-down time, with increased spillage of dip.

At site 3 the facility consisted of older, locally sourced top-loading tanks. The adjacent-dip and bulb-core temperatures took up to 2 hours to reach the set temperature. Although the filler bulbs used here were all non-graded stocks (and therefore the number of small grades included may have been sufficient to hamper fast heat transfer), it was thought that the slow warm-up was probably partly due to the age and (or) design of the facility.

Although temperature control was precise (i.e. the error on the set temperature was small), the set temperature did not agree with the target temperature of 44.4°C. In different tanks and runs the temperature was either a little below or above the target, or in some cases only reached 44.4°C during heating cycles. Consequently different batches of bulbs would either fail to accumulate sufficient (or any) HW minutes, or accumulated slightly more than needed. This problem was swiftly addressed by checking the accuracy of set points and starting closer temperature monitoring. As a result of the long warm-up period, reaching the 180 minute target depended on a further accumulation of HW minutes in the period before the bulbs were unloaded.

At site 4 one HWT run was made in an older, Akerboom front-loading tank (using a HWT of 3 hours at 44.8°C) and two runs in older, Secker Welding front-loading tanks (HWT for 3 hours at 44.4 to 44.6°C). Both types of facility achieved good, steady temperature control. Time to achieve the target temperature was relatively long (50 to 100 minutes) and varied with tank type.

Achieving the require 180 HW minutes was dependent on the extra period of time that bulbs spent at 44.3C after the timed HWT period had been exceeded but before the bulbs were unloaded and had begun to cool.

At site 5 the HWT facility consisted of modern, Secker Welding front-loading tanks. Concurrent HWT runs were made in three tanks, treating warm-stored bulbs that were first pre-soaked at 35°C for 2 hours before the dip temperatures were raised to 46°C for a 3 hour-HWT. Dip temperatures rose rapidly to 35°C, with bulb-core temperatures taking about a further 40 minutes to reach this temperature. It then took bulb-core temperatures about 90 minutes to reach the HWT temperature.

Temperature control was steady, but fell short of the 46°C target by about 1.5°C in all three cases. However, by the end of dipping all bulbs reached and slightly exceeded the target of 180 HW minutes (based on a temperature of 44.3°C or more). Once again, shortfalls in the number of HW minutes accumulated during the 3 hour HWT period were made up to an average of 208 minutes because the bulbs stayed warm when the bins were not immediately unloaded.

The effect of bulb grade

Bulbs of 'Tamara' of grades <10, 10-12, 12-14, 14-16 and >16cm were tested in HWT (3 hour 15 minutes at 44.4°C at site 2) and the results are shown in Figure B below.

Larger bulbs warmed up more slowly than smaller ones, but also retained heat longer at the end of HWT. Over three tests, >16cm grade bulbs required about 30 minutes longer than <10cm bulbs to reach the required core temperature. Once the target temperature was acquired, temperatures of dip and bulb-cores were very closely maintained at the target temperature throughout the rest of the HWT period. All grades of bulbs accumulated in excess of 180 HW minutes by the end of dipping, though this was again dependent to some extent on the relatively slow unloading from the tank. As a rule-of-thumb, analysis of the data suggests that about six additional minutes of treatment are needed for each increment in grade. The time x grade relationship was apparently affected by the greater range of bulb weights and shapes that would have been included in the >16cm grade, while smaller grades of bulbs were much more consistent in this respect.

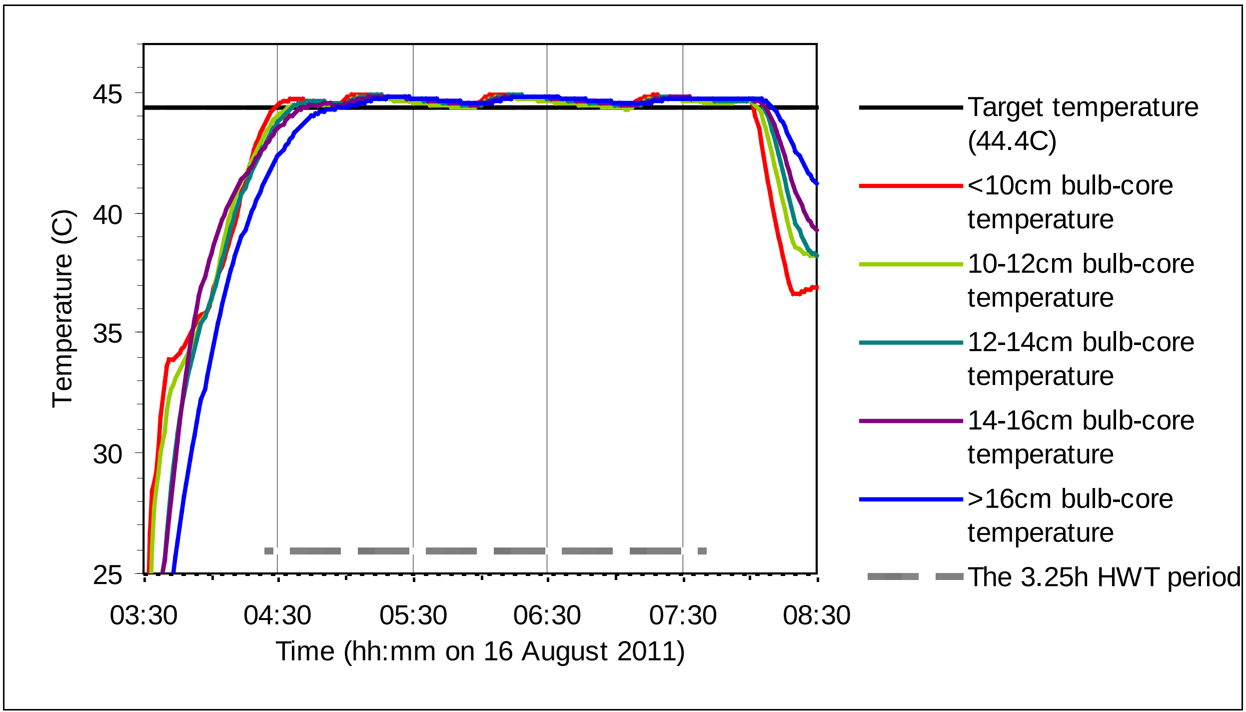

Figure B. A typical result from testing different sizes of bulbs, from <10 to >16cm grades, showing bulb-core temperatures for each grade. Example taken from data from run 2.

The effect of cultivar

It was suspected that bulbs with a tighter or looser arrangement or density of bulb-scales might heat-up at different rates, affecting the time the bulb-core takes to reach the target temperature. Differences in bulb shape – for example, between short- and long-necked bulbs – might also affect heat transfer and how bulbs pack within bins. Bulb-core temperatures were assessed in 12-14cm grade bulbs of ‘Actaea’, ‘Camelot’, ‘Carlton’, ‘Fortune’, ‘Golden Dawn’, ‘Silver Chimes’, ‘Tamara’ and ‘Cheerfulness’ under commercial HWT conditions (3 hours 15 minutes at 44.4°C). Bulb-core temperatures followed a very similar course irrespective of the cultivar assessed. Cultivar ‘Actaea’ is often cited as having a relatively ‘loose’ arrangement of bulb-scales and a long neck, and, although in our samples this cultivar had a lower density (0.81g/cm3) than the other cultivars tested (between 0.91g/cm3 for 'Cheerfulness' and 1.03g/cm3 for 'Carlton'), the results did not suggest the rate of temperature change in 'Actaea' was any different to the other cultivars.

The number of accumulated HW minutes acquired was similar across all eight cultivars and, as observed previously, some additional HW minutes were added after the end of the 3 hours 15 minutes HWT period. All test bulbs acquired the required 180 minutes of HW time during the 3 hours 15 minutes HWT period, and a further about 20 minutes were added during the drain-down and unloading period.

The effect of bulb position within the bin

To determine to what extent the position of a bulb in a bin affects its core temperature during HWT, bulbs with thermistor probes were placed centrally in a bin or near the corners and tested for 3 hours 15 minutes at 44.4°C. Bulbs near the bottom of bins warmed up faster than those near the top, presumably as the tanks fill from the bottom upwards. There were significant differences in average bulb-core temperatures during the HWT period between runs, but differences between bulbs in different positions were not statistically significant.

The effect of bin position within the tank

To test for differences in temperatures in bins placed in different parts of the HWT tank, thermistor probes were inserted centrally in bins placed in various positions in the tank, and subjected to HWT for 3 hours 15 minutes at 44.4°C. The results showed there were no substantial differences in dip temperatures in different bins in any of three test runs.

Financial benefits

Inaccurate HWT will inevitably lead to nematode outbreaks which will render stocks unproductive as flower crops and unsaleable as bulb crops.

Minor changes to HWT protocols, ensuring that bulbs are treated long enough and at the correct target temperature, are relatively cheap to implement, and should also improve the control of bulb-scale mites and other pests. Without effective HWT, even a 1 year down system would not prevent the build up of potentially devastating nematodes.

The financial benefits of this work can therefore be considered as highlighting to growers the importance of making sure that they fully benefit from the estimated £50 per tonne investment they make when hot water treating their bulbs.

Action points for growers

Check that the HWT controller is properly calibrated at the start of the year's HWT, and monitor to check that dip temperatures are maintained through the season.

Ensure that the HWT controller is set to start timing the HWT period only when the temperature of the circulating dip reaches the target temperature.

In addition to a correctly timed HWT period of 3 hours, add an additional time to allow the bulb-cores to reach the target temperature, based on the predominant grade of bulbs being treated, say 18 minutes for 12-14cm grade.

Standardise HWT procedures to gain better control of the duration of temperature treatment applied to bulbs, remembering the drain-down period prior to unloading tanks can contribute significantly to the accumulated hot-water minutes bulbs receive.

The HDC Project Co-ordinator commented: "This investigation into the efficiencies of HWT tanks and practices has shown there can be significant differences between one batch and another, even on the same farm. Growers would be well advised to heed this information and to examine their procedures to make sure temperatures and times are achieved accurately. Cutting short HWT does not do the job, and too much HWT can be damaging to the bulbs. This short project has shown really useful results in one season."