Project title:	Daffodils: Developing alternatives to formalin The effects of HWT with an iodophore biocide and chlorothalonil fungicide on crop growth and yield (Extension to project BOF 61a)
Project number:	BOF 61b
Project leader(s):	Gordon Hanks Consultant
Report:	Annual Report (November 2010)
Previous reports:	None
Key worker(s):	Gordon R Hanks BSc, MPhil, FIHort, MSB, CBiol
Location:	A commercial daffodil farm in Lincolnshire
Project co-ordinator(s):	Dr Gordon Flint (Winchester Growers Ltd)
Date commenced:	24 August 2009
Date completion due:	31 November 2011
Keywords:	Basal rot, base rot, biocide, chlorothalonil, daffodil, disinfectant, *Ditylenchus dipsaci*, fungicide, *Fusarium oxysporum f.sp. narcissi*, hot-water treatment, iodine, iodophore, *Narcissus*, stem nematode

The results and conclusions in this report are based on an investigation conducted over one year. The conditions under which the work was carried out and the results obtained have been reported with detail and accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

[Researcher A Name]

[Position]

[Organisation]

Signature .... Date ....

[Researcher B Name]

[Position]

[Organisation]

Signature .... Date ....

Report authorised by:

[Organistion A's authority Name]

[Position]

[Organisation]

Signature .... Date ....

[Organisation B's authority Name]

[Position]

[Organisation]

Signature .... Date ....

CONTENTS

GROWER SUMMARY

Headline

- Following the earlier findings that an iodophore biocide, FAM 30, could be a replacement in HWT for the now-banned formalin and that a chlorothalonil fungicide, Bravo 500, could be an alternative to using thiabendazole-based products in HWT the first year's results from a commercial-scale field-trial have showed that these treatments are effectively crop-safe.

Background

Stem nematode (*Ditylenchus dipsaci*) is potentially the most devastating pest of daffodil crops worldwide, but has been controlled for decades by hot-water treatment (HWT) of planting stocks with formalin added to the dip. In 2008 the agricultural/horticultural approvals for formalin were revoked within the EU at short notice, and HDC Project BOF 61 was set up to find alternatives to formalin for HWT use.

Fusarium rots (base rot and neck rot caused by *Fusarium oxysporum f.sp. narcissi*) continue to cause concern to UK growers and the HWT dip often included a thiabendazole-based fungicide as well as formalin, a major component of managing *Fusarium* in daffodil crops. In 2008 this use of thiabendazole fungicides was restricted in terms of the maximum permitted concentration and number of treatments per year so alternative fungicides were also required.

As a result of initial tests in HDC Project BOF 61a, an iodophore-type biocide, FAM 30, was identified as a possible replacement for formalin, and a chlorothalonil-based fungicide, Bravo 500, as an alternative to thiabendazole-based products. It was necessary to test these novel treatments for crop-safety under commercial conditions, so Project BOF 61b was set-up to field-test FAM 30 and Bravo 500 HW treatments in a range of daffodil cultivars.

Summary

In 2009, bulbs of commercial stocks of *Narcissus* 'Actaea', 'Carlton', 'Dutch Master', 'Great Leap', 'Hugh Town', 'Kerensa', 'Red Devon' and 'Yellow Cheerfulness' were allocated for a field trial. Replicated, weighed lots of bulbs were subjected to standard HWT, at 44.4°C for 3 hours, using the following dip additives:

- Control – no biocide or fungicide added
- Iodophore biocide at half-rate – 4L FAM 30/1000L water
- Iodophore biocide at full-rate – 8L FAM 30/1000L water
- Chlorothalonil at half-rate – 0.5L Bravo 500/1000L water
- Chlorothalonil at full-rate – 1L Bravo 500/1000L water
- Iodophore biocide ('FAM 30') at half-rate + chlorothalonil (Bravo 500) at half-rate.

All dips included wetter and an anti-foam preparation added at standard rates. HWT was carried out, on 9-10 September 2009, in a 5-tonne front-loading tank of standard design. The trial plots were planted in a light silt soil in south Lincolnshire and grown employing typical, commercial husbandry for two years.

The crop was checked for pests, diseases and defects. Flowering dates, flower yields, flower quality, and stem and leaf heights at flowering were recorded. Three of six replicate blocks were lifted in July 2010 and the yield of bulbs recorded after the normal drying, cleaning and grading. The remaining three blocks are being grown-on for further recording in 2011.

In 2010 there were no evident gross differences in growth and development between the various plots of any given cultivar, with the exception that plots of 'Actaea' from the control HWT had obviously fewer flowers than other HW treatments. The development of the crop appeared normal and within the expected parameters, except that 'Hugh Town', a tazetta cultivar, presented emerging foliage as early as November, which was then damaged by the unusually cold winter.

The expected foliar symptoms of HWT damage (roughened, mottled leaf tips) were seen across the trial but were considered mild and not abnormal. Along with its usual leaf symptoms, smoulder was evident as white patches on buds and petals, though these were sporadic and not localised to particular plots or treatments.

Within cultivars, flowering dates did not differ substantially between the HW treatments. With the exceptions of the HWT and weather-related damage to leaves noted above, foliar growth appeared normal throughout the trial, with no evidence of stunted or weak growth.

Measurement of foliage height at flowering showed there were no significant effects due to HW treatments.

Cultivar differences accounted for the bulk of the variance in flower yield data, but the effects of HW treatments were also highly statistically significant. Most yields fell into two groups of treatments, with higher yields from bulbs treated with half-rate FAM 30, full-rate Bravo 500 and half-rate of both chemicals, and lower yields in the control and where full-rate FAM 30 had been used (half-rate Bravo 500 gave intermediate yields). There were some minor differences in response, probably not commercially significant, between the cultivars.

Any dead, distorted or damaged buds or flowers were recorded separately and, with the exception of frequent dead buds in 'Great Leap', very few dead flowers, and even fewer distorted or damaged flowers ('starry' flowers and split coronas typical of HWT damage) were seen. There was no indication that any of the HW treatments increased the number of flowers lost or damaged.

Stem length was recorded by measuring a sample of stems during flowering. There were significant differences between cultivars, but stem length was not significantly affected by either HW treatments or by the interaction between cultivar and HWT.

As equalised weights of bulbs had been planted in each plot, bulb yields could be expressed as the simple weight or number of bulbs lifted from each plot. The bulk of the variation in yields was due to cultivar differences, with only a small component due to HWT differences. 'Carlton' showed the heaviest yields, while yields of 'Actaea' were poor, and the other cultivars had intermediate yields.

The effects of the different HW treatments were small, though the highest total yield (for half-rate Bravo 500) was significantly more than the lowest (for full-rate FAM 30). There was a slight detrimental effect of using full-rate FAM 30. The interaction between cultivar and HWT was not statistically significant, indicating that all cultivars responded to the HWT chemicals in the same way. There were no effects of HW treatments on total bulb numbers, demonstrating that the treatments did not cause a significant shift in rates of growth or bulb-splitting.

The yield of saleable bulbs (usually grades from 10 to 14cm) showed the bulk of variation was due to cultivar differences, with a small component due to HWT differences. The full-rate FAM 30 treatment resulted in a greater yield of *saleable* bulbs than other treatments, apparently because fewer bulbs grew to the larger (>14cm) grades; however, although producing more saleable and less larger bulbs would generally be considered advantageous, this must be balanced against the slightly detrimental effect of full-rate FAM 30 on both flower yields and *overall* bulb yields.. Although bulb yields in this trial were not exceptional, very few bulbs were rejected at grading due to rotting or damage, and it is likely that most loss of yield occurred in the period shortly after planting so that no remains were present at harvest. There were no significant effects of HW treatments on the amount of rotted bulbs found at grading.

Financial benefits

Loss of control of stem nematode could be devastating to UK daffodil production, so having an effective treatment that will maintain this control is vital to UK growers. Bulb dipping treatments, including HWT, form a key element in controlling base rot, widely considered the most obvious threat to UK daffodil production, so the confirmation of the suitability of Bravo 500 for HWT use is similarly important. A full assessment of the financial benefits from the project will be given following its completion in 2011.

Action points for growers

Although the final recommendations should await the analysis of flower and bulb yields after two years growth in 2011, the following tentative treatments are suggested:

- An HWT regime of 3 hours at 44.4°C should continue to be regarded as the standard, and this is expected to control most or all stem nematodes
- Add FAM 30 to HWT dips at a concentration of 4 or 6L/1000L water for general hygiene and to enhance the management of stem nematodes and base rot
- If FAM 30 is not used, add Bravo 500 to HWT dips at a concentration of 1.0L/1000L water where base rot is of concern; alternatively use a tank-mix of 4L FAM 30 plus 0.5L of Bravo 500 per 1000L water
- Where base rot is of special concern, alternate the use of a thiabendazole-based product (such as Storite Clear Liquid) with Bravo 500, for example by using a thiabendazole fungicide as a post-lifting bulb spray treatment and Bravo 500 in HWT.

SCIENCE SECTION

Introduction

Stem nematode (*Ditylenchus dipsaci*) is potentially the most devastating pest of daffodil crops worldwide, but has been controlled for decades by the hot-water treatment (HWT) of planting stocks. Within the EU, stem nematode of daffodils is a 'quarantine pest', the only quarantine pest or disease affecting this crop. It has been a long-standing practice to include an appropriate concentration of the biocide (disinfectant) formalin (a.i., formaldehyde) in the HWT dip to 'augment' the kill of stem nematode, though the results of a recent HDC-funded project (BOF 61a) raised doubts about the necessity of this. However, using a biocide in this way is also considered good practice in promoting general hygiene, an important aspect of bulb growing and handling.

Fusarium rots (base rot and neck rot caused by *Fusarium oxysporum f.sp. narcissi*) are the daffodil diseases most consistently causing concern to UK growers, and probably to growers in other producer countries. The HWT of planting stocks, with formalin and often also a fungicide added to the treatment tank, is at the core of managing *Fusarium* rots. Standard HW treatments are also considered to give incidental control of other pests (such as large narcissus fly and bulb-scale mite) and diseases (various fungal foliar pathogens).

Both stem nematode and *Fusarium* rots are of especial concern to UK growers because of the practice here of growing daffodils on a cycle of two or more 'years down', meaning that the bulbs can no longer be dipped or treated with HW every year. While relatively few doubts have been raised about the effectiveness of HWT with formalin in managing stem nematode, *Fusarium* rots have proved much more difficult to manage consistently and, consequently, much of UK-based daffodil strategic and applied research has been targeted to this problem. Most applied research has involved defining optimal HWT regimes and the choice of fungicide, though the significance of a more 'holistic' approach - throughout the whole growing cycle - has also been emphasised. The control of stem nematode and *Fusarium* rots has also been studied in other producer countries, particularly the USA and the Netherlands. The R&D on stem nematode and *Fusarium* in daffodil has been fully reviewed in standard texts,[1,2,3,4,5,6] while advice has been (or is being) given in HDC-funded reviews and

[1] Lane, A (1984). *Bulb pests*. 7th edition, Reference book 51. HMSO, London, UK.

[2] Moore, WC, with Dickens, JSW (editor), Brunt, AA, Price, D & Rees, AR (revisers) (1979). *Diseases of bulbs.* 2nd edition, Reference book HPD 1. HMSO, London, UK.

factsheets (BOF 31 and 68, factsheet 13/04). Illustrating the range of approaches used, earlier HDC-funded projects have covered the biological control of base rot (BOF 6), the factors involved in neck rot (BOF 28), the use of a range of fungicides for controlling base and neck rots (BOF 31a/b), the influence of soil nitrogen on base rot (BOF 39), the effect of foliar fungicides on bulb rots (BOF 41a), appropriate bulb handling practices for susceptible stocks (BOF 42), optimising the use of thiabendazole fungicide (BOF 43, 43a and 64) and using biocides for controlling stem nematode on equipment and structures (BOF 49); these HDC reports are freely available to levy-payers. Defra-funded projects have investigated a biotechnological plant breeding approach to base rot, though this long-term approach has now been terminated.[7,8]

In 2008 the agricultural/horticultural approvals for formalin in the EU were revoked at short notice, following its re-classification as carcinogen. In the same year HDC Projects BOF 61 and 61a were set up to study alternatives to the use of formaldehyde in HWT tanks. The main findings were as listed here.

- ► *A literature review* concluded there were no practical, physical alternatives to HWT for the control of stem nematode and *Fusarium* spores, though:
  - ► A number of alternate biocides, nematicides and fungicides merited small-scale testing
  - ► The time-temperature regime used for HWT needed re-evaluation.

- ► *Laboratory-based tests* confirmed the value of:

---

[3] Gratwick, M & Southey, JF (1986). *Hot-water treatment of plant material.* 3rd edition, Reference book 201. HMSO, London, UK.

[4] Chastagner, GS & Byther, RS (1985). Bulbs – narcissus, tulips, and iris. Pp 447-506 in Strider, DL (editor), *Diseases of floral crops*. Praeger Scientific, New York, USA.

[5] Hanks, GR (1993). Narcissus. Pp 463-558 in De Hertogh, AA & le Nard, M (editors), *The Physiology of Flower Bulbs*. Elsevier, Amsterdam, the Netherlands.

[6] Hanks, GR (editor) (2002). *Narcissus and daffodil, the genus* Narcissus. Taylor & Francis, London, UK.

[7] Final report available at:
http://randd.defra.gov.uk/Document.aspx?Document=HH1033SBU_3202_FRP.doc

[8] Information available (final report awaited) at:
http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=13033&FromSearch=Y&Publisher=1&SearchText=narcissus&GridPage=1&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

- ► Using 3 hours at 44.4°C as the preferred HWT regime
- ► Using an iodophore disinfectant (‘FAM 30’) and a chlorothalonil-based fungicide (‘Bravo 500’) as effective additives for HWT tanks.

► *A field trial* was set up in 2008 to compare the effects of formalin, ‘FAM 30’ and ‘Bravo 500’ as HWT additives using a 3-hour treatment at 44.4°C, on crop toxicity and on the management of stem nematode and *Fusarium* rots in an infested daffodil stock. By summer 2009 bulb survival, flower yields, and flower and leaf lengths and quality were unimpaired by the treatments, with similar results irrespective of whether formalin, ‘FAM 30’ or ‘Bravo 500’ has been used in the HWT tanks.

The management of stem nematode and *Fusarium* rots is crucial to the continued success of UK daffodil production. It was inadvisable to rely on the results of laboratory-based results and a single field trial conducted with a single stock. Having received encouraging signs about the effectiveness of ‘FAM 30’ and ‘Bravo 500’ as HWT additives, a project extension, BOF 61b, was set up in August 2009, to field-test HWT with ‘FAM 30’ and (or) ‘Bravo 500’ on a range of daffodil varieties and specifically to study the effects of HW treatments on phytotoxicity and bulb yields. This report describes the first year of the trial, in which three of the six replicate blocks planted were harvested for assessment, the remaining blocks being grown-on for lifting after a further year’s growth in summer 2011. The original project and its extensions would then provide robust advice for daffodil growers. Good pest and disease control will improve yield and quality, maintaining or even enhancing markets.

The specific objectives of BOF 61b were therefore:

- ► To determine whether ‘FAM 30’, ‘Bravo 500’ or a mix of ‘FAM 30’ and ‘Bravo 500’, applied as part of standard HWT, have any adverse effects on two-year-down daffodil crops in respect of crop timing, crop appearance, and flower and bulb yields and quality
- ► To record the effects of treatments on pest, disease and disorder incidence and severity
- ► To report the results to the HDC and facilitate knowledge transfer to levy-payers.

Materials and methods

Bulbs

Untreated bulbs of *Narcissus* cultivars ‘Actaea’ (9W-YYR), ‘Carlton’ (2Y-Y), ‘Dutch Master’ (1Y-Y), ‘Great Leap’ (4Y-Y), ‘Hugh Town’ (8Y-O), ‘Kerensa’ (1Y-Y), ‘Red Devon’ (2Y-O) and ‘Yellow Cheerfulness’ (4Y-Y) were sourced from various UK growers in August 2009. The bulbs were grade 12-14cm (circumference, slotted riddle), except for ‘Actaea’ bulbs which were 10-12cm grade. All were from typical commercial stocks and were used as supplied, without any further sorting. Until use the bulbs were stored in nets at ambient temperatures in a large agricultural shed with good air movement.

For each cultivar, 36 lots of 6.35(±0.05) kg were weighed out and allocated to six replicates of each of six treatments. So that the bulbs could be planted in netting to assist full recovery when eventually harvested, each 6.35-kg lot was spread evenly along a 4m-long length of labelled, knitted, nylon tubular netting (LC Packaging UK Ltd, Long Sutton, PE12 9EF), and the ends knotted. The nets of bulbs were placed in wire-mesh crates (holding about ½-tonne), ready for HWT.

Hot-water treatment

HWT was carried out over 9 and 10 September 2009 in a 5-tonne capacity tank of standard ‘front-loading’ design. Prior to each treatment, the tank was washed out and filled to the 7500L mark; ‘FAM 30’ and ‘Bravo 500’ added as appropriate, and the tank brought to temperature. All dips included wetter (‘Activator 90’, 1L/1000L water) and an anti-foam preparation (‘Dow Corning Antifoam RD Emulsion’, added until foaming stopped, about 0.025L/1000L water).

There were six biocide or fungicide treatments:

- Control – no biocide or fungicide added
- Iodophore biocide at half-rate – 4L ‘FAM 30’/1000L water
- Iodophore biocide at full-rate – 8L ‘FAM 30’/1000L water
- Chlorothalonil at half-rate – 0.5L ‘Bravo 500’/1000L water
- Chlorothalonil at full-rate – 1L ‘Bravo 500’/1000L water
- Iodophore biocide (‘FAM 30’) at half-rate + chlorothalonil (‘Bravo 500’) at half-rate.

‘FAM 30’ (Evans Vanodine International PLC) is a widely used farm biocide containing alcohol ethoxylate (20-25%), sulphuric acid (5-10%), phosphoric acid (5-10%) and iodine (1-5%). ‘Bravo 500’ (Syngenta Crop Protection UK Ltd) is a frequently used horticultural/agricultural fungicide containing chlorothalonil (500g/L).

Each HWT was for 3 hours at 44.4°C, with the 3-hour period timed from when the target temperature had been regained following addition of the bulbs. After HWT the crates of bulbs were removed from the tank and cooled, ventilated and surface-dried by placing in an enclosure under a powerful downwards-directed fan at ambient temperatures for 24 hours. Subsequently, the crates were held outdoors until planting.

Planting and husbandry

The field trial site was located in south Lincolnshire on a light silt soil. The previous crop was vining peas, giving an N index of 1, and agricultural soil analysis gave P and K indices of 3.5 and 1.5, respectively. Fertiliser was applied (1142kg/ha of N:P:K 3.5:0:18 fertiliser) and the site ploughed, cultivated and formed into ridges.

The trial layout was a randomised block design with six replicates, three blocks being randomly allocated for lifting after growing for 1 year and three for lifting after growing for 2 years. Each block comprised 48 plots (six treatments x eight cultivars), and each plot consisted of a 4m-long length of ridge, giving a planting rate of 17.5t/ha in ridges at 0.90m centres. To provide ‘guarding’ (i.e. to equalise the environment around each plot) an un-planted ridge was left between each planted ridge, and, along the ridges, 2m-long un-planted sections were left between adjoining plots. Roadways (5 or 10m-wide) were left between blocks as appropriate to allow for turning tractors (such that three blocks could be lifted after one year without driving over the adjacent, two-year-down blocks). The position of the plots was marked in the furrows using canes, following which the nets of bulbs were lain evenly in the furrows and the ridges split back to cover the bulbs. The bulbs were planted over 14 and 15 September 2009.

The trial received the grower’s standard commercial husbandry, including the spray programme listed here:

Dates	***Products***	***Rates***
09 September 2009	‘Clinic Ace’ + ‘Spryte’ + ‘Shark’	2.5 + 1.0 + 0.3L/ha
19 October 2009	‘Clinic Ace’ + ‘Spryte’ + ‘Shark’	2.5 + 1.0 + 0.3L/ha
29 October 2009	‘Jupiter 40 EC’ + ‘Linuron’ + ‘Clinic Ace’	5.0 + 1.2 + 3.0L/ha
15 February 2010	‘Cinder’ + ‘Goltix Flowable’	2.9 + 3.0l/ha
16 March 2010	‘Amistar’	1.0L/ha
08 April 2010	‘Riza’	1.0L/ha
22 April 2010	‘Amistar’	1.0L/ha
25 May 2010	‘Bravo 500’ + ‘Delsene 50 Flo’	1.0 + 0.5l/ha
01 July 2010	‘Shark’	1.0L/ha
09 August 2010	‘Spotlight Plus’	1.0L/ha
31 August 2010	‘Clinic Ace’	4.0L/ha

N fertiliser was top-dressed on 3 March 2010 (155kg/ha of Nitro Chalk, 27%N).

Records taken in growing season

After planting the trial was checked at intervals through winter/spring 2009-2010 to ensure development was normal. In general, detailed records were made only for the three replicate blocks being lifted after one year's growth.

Starting before flowering, the crop growth stage (GS) was recorded as follows:

GS	***Definition***	***Measurement made***
0	No buds emerging	Overall height of shoots
1	Buds starting to emerge	Height to top of buds
2	Stems elongating, but not yet at upright pencil stage	Height to top of buds
3	Upright pencil stage (irrespective of stem length)	Height to top of buds
4	Flowers starting to goose-neck or split	Height to top of buds
5	Flowers starting to open	-
6	Flowers fully open	-
7	Flowers starting to die	-

Where it became evident that no flowers had developed or that stems were 'blind', this was noted. Any faults, such as HWT damage or pest or disease symptoms, were noted.

When a cultivar was flowering the following were recorded (on 11 April 2010 for 'Dutch Master' and 'Carlton', 18 April for 'Kerensa', 'Red Devon' and 'Yellow Cheerfulness', and 26 April for 'Actaea' and 'Great Leap'):

- ► Number of stems still elongating (upright buds)
- ► Number of flowers goose-necking or starting to split
- ► Number of flowers starting to open or open
- ► For 'Hugh Town', the number of florets per stem was also recorded
- ► Number of dead buds (including 'drumsticks' and other necrotic buds)
- ► Any of the above that had damaged buds or flowers
- ► Leaf height and stem length (height of the leaf tip or the uppermost part of the bud or flower above ground level) at ten fixed points along each plot

► Stem length was also assessed by measuring the heights of the tallest and shortest stems in each plot.

The very short, late-flowering stems produced from lateral buds were ignored.

Bulb lifting and recording

The three first-year blocks were lifted by hand on 15 July 2010. Net integrity and bulb recovery were deemed good. On lifting, each net of bulbs was placed in a wooden bulb tray and the trays stacked in the open air under a lean-to roof to air-dry (about 2 weeks). The bulbs from each plot were recovered from the netting and cleaned and separated manually using normal commercial practices. Following further air-drying (about 4 weeks) the plots were graded into <10, 10-12, 12-14, 14-16 and >16cm sizes using a conventional daffodil bulb-grading machine. After removing and aggregating any obviously rotted and otherwise damaged bulbs and counting these separately, the number and weight of bulbs in each grade were recorded.

Statistical analysis

The trial was of a replicated block design with six blocks, with three replicate blocks lifted after one year and the remainder after two years. Each year's data were investigated using the analysis of variance (AoV), where appropriate after transformation of the data.

Results (year 1)

The more noteworthy findings are shown in this section, usually graphically, while more detailed tables of results and statistics are provided in the Appendix.

Crop development in general

There did not appear to be any gross differences in growth and development between the various plots of any given cultivar, except that, by flowering time, plots of ‘Actaea’ from the control treatment had obviously fewer flowers than other HW treatments.
Development of the crop was considered to be normal and within the expected parameters, except for the Division 8 (tazetta) cultivar ‘Hugh Town’. Here, the foliage emerged in November and was later severely damaged by the unusually cold winter, with relatively sparse, chlorotic foliage and damaged, blackened leaf tips.

The expected foliar symptoms of HWT damage were seen across the trial, but this was considered mild and not abnormal, with roughened, mottled leaf tips (particularly in ‘Carlton’ and ‘Great Leap’).

There were no significant pest or disease problems. Along with the usual leaf lesions, smoulder was evident as white patches on buds and petals, though this was very sporadic and was not localised to particular treatments.

Progress to flowering

Within cultivars, the rate of progress towards flowering did not differ substantially between the HW treatments, and Figure 1 illustrates this for the five later cultivars, showing the uniformity of growth stages (for details of GS, see Materials and Methods).

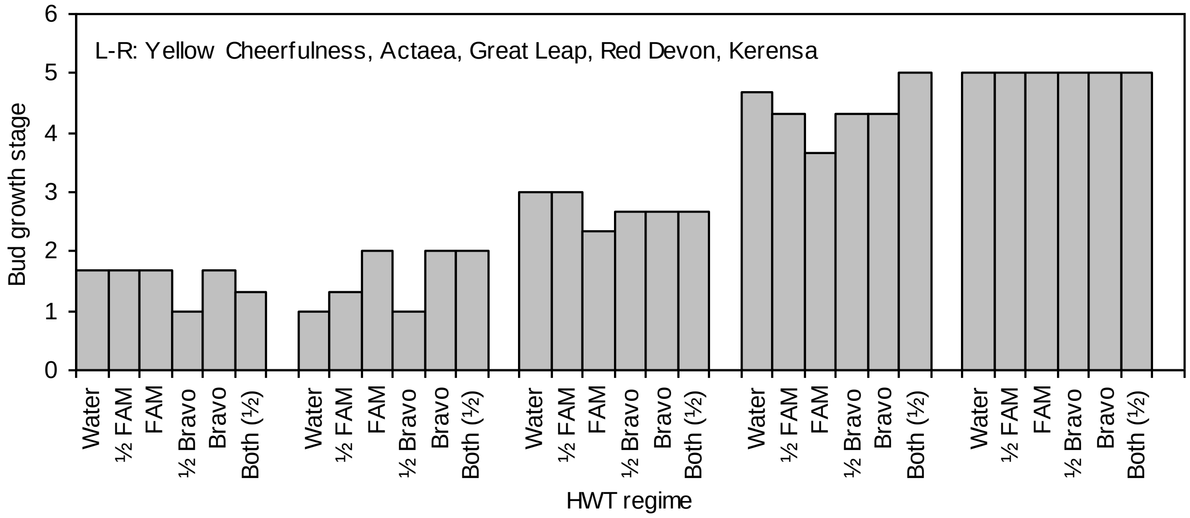


Figure 1. Growth stages of five cultivars from eight HW treatments on 3 April 2010 (for details of GS, see text)

The uniformity of the onset of flowering was also checked by recording the percentage of flowers at different stages (upright pencil, spathe-splitting/goose-neck and open flower) during the cropping phase of each cultivar. The full data are shown in Table A1 (see Appendix), where analysis of variance of the $\log_{10}$-transformed percentage of flowers at the open-flower stage showed the effect of HW treatment was not significant. This is also illustrated in Figure 2.

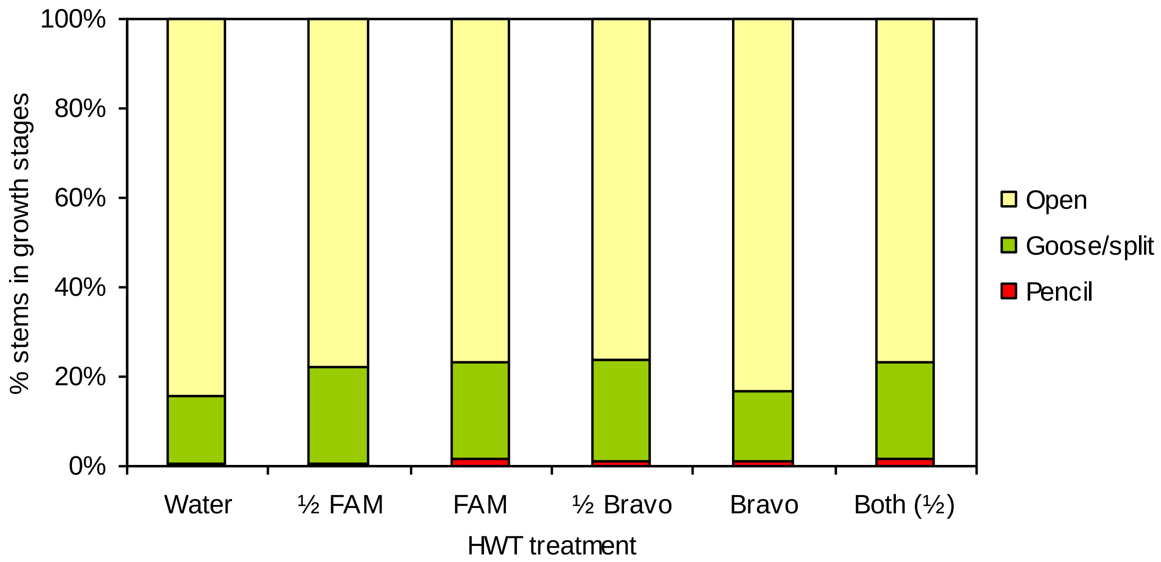


Figure 2. The percentage of stems at upright pencil, spathe-splitting/goose-neck and open flower stages at appropriate dates in the flowering period in year 1; the values are means bulked across all eight cultivars

Foliage condition and height

With the exceptions of the HWT and weather-related damage to leaves noted above, foliar growth appeared normal throughout the trial; for example, there was no evidence of stunted or weak growth. Height measurements of a sample of leaves at flowering showed that, while there were some significant, and expected, differences in average leaf height between cultivars, neither the HW treatments nor the interaction between cultivar and HWT were statistically significant (Figure 3, Table A2). Due to weather damage, these data were not available for ‘Hugh Town’.

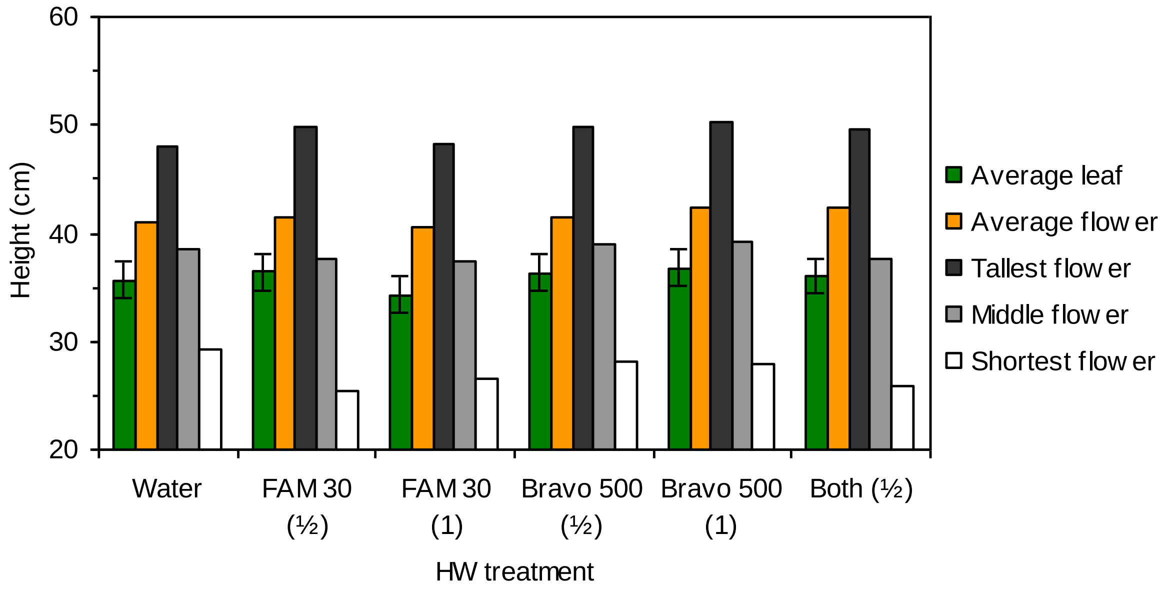


Figure 3. Leaf and stem heights assessed at the flowering stage in year 1 (vertical bars for leaf heights are LSD values at the 5% level)

Flower yield

Although the first-year flower crop is relatively unimportant, it can serve as a good indicator of crop vigour in general, so providing interim guidance on any effects due to the HWT additives. As would be expected with such a range of cultivars, there was considerable variation in flower yield. Even excluding ‘Hugh Town’, which was damaged by winter temperatures and yielded an average of only 13 undamaged stems per plot, yields ranged from 61 (for ‘Great Leap’) to 161 per plot (for ‘Red Devon’).

Although cultivar differences accounted for the bulk of the variance in these data, the effects of HWT and of the interaction (between cultivar and HWT) were also highly significant. The full results are given in Table A3.

► Most average yields fell into two groups of treatments: there were higher yields in bulbs treated with half-rate ‘FAM 30’, full-rate ‘Bravo 500’ and half-rate of both chemicals, but lower yields in the control and where full-rate ‘FAM 30’ had been used, with half-rate ‘Bravo 500’ giving an intermediate yield (Figure 4).

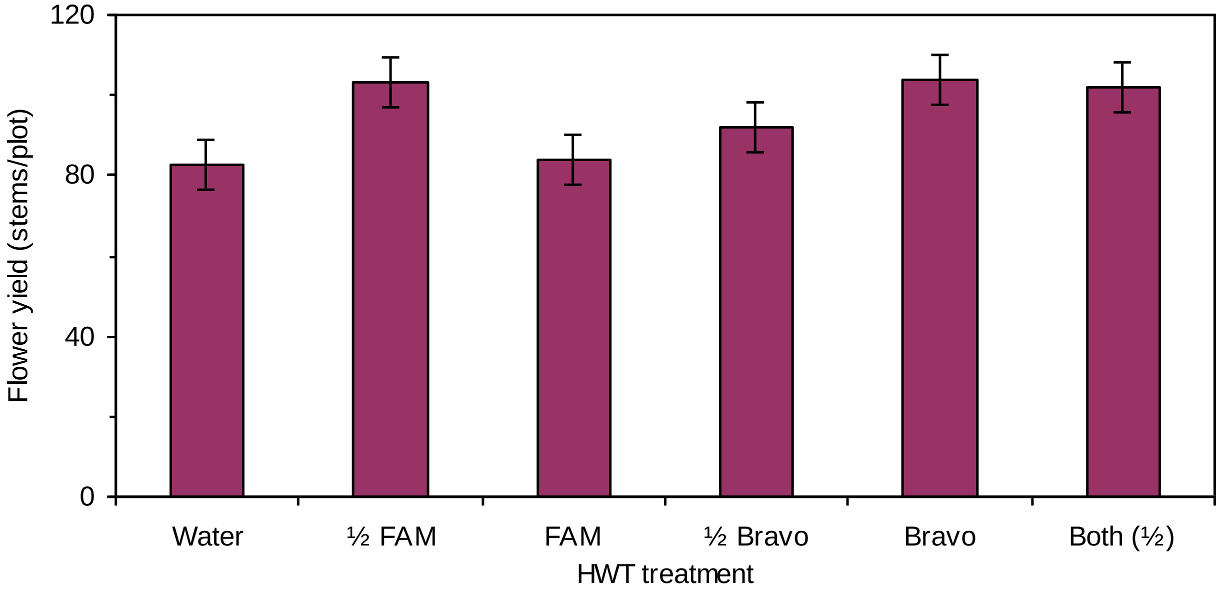
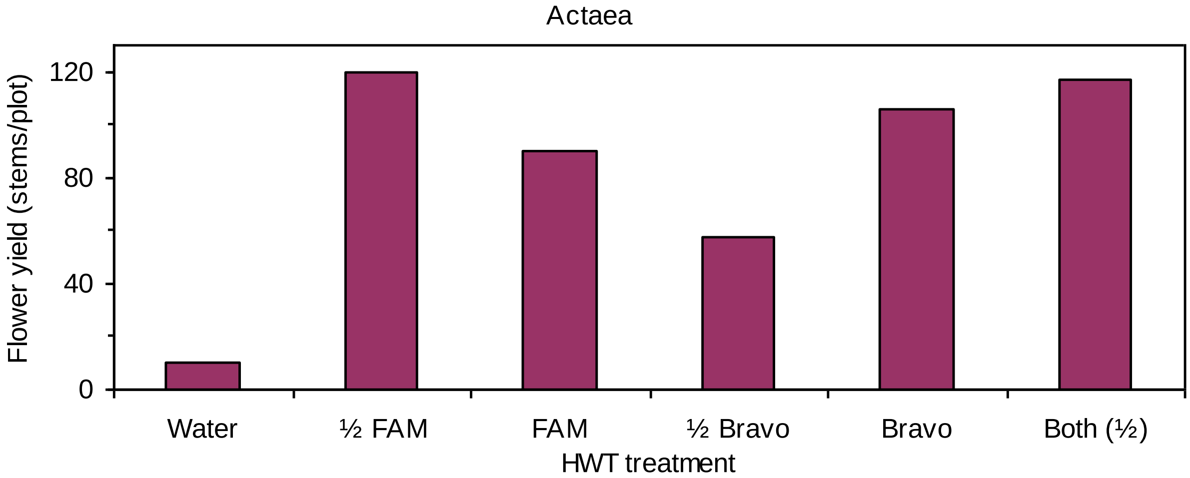


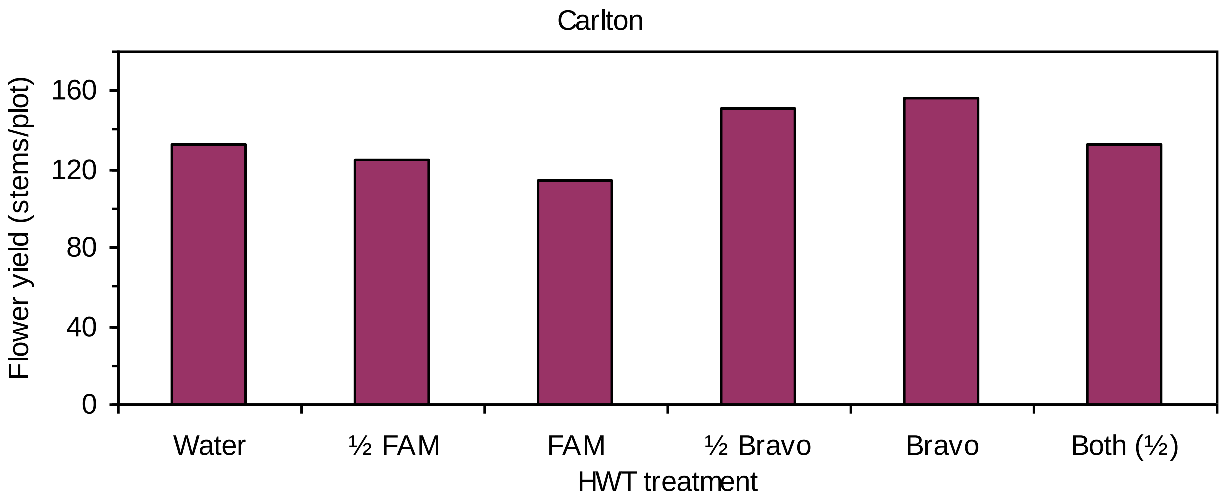
Figure 4. The effects of HWT chemicals on stem yield per plot after one year (the values are marginal means across all cultivars, with any stems with damaged flowers excluded) (vertical bars are LSD values at the 5% level)

► Because of the great differences in response between cultivars, flower yields are shown for individual cultivars in Figure 5 (a-h).

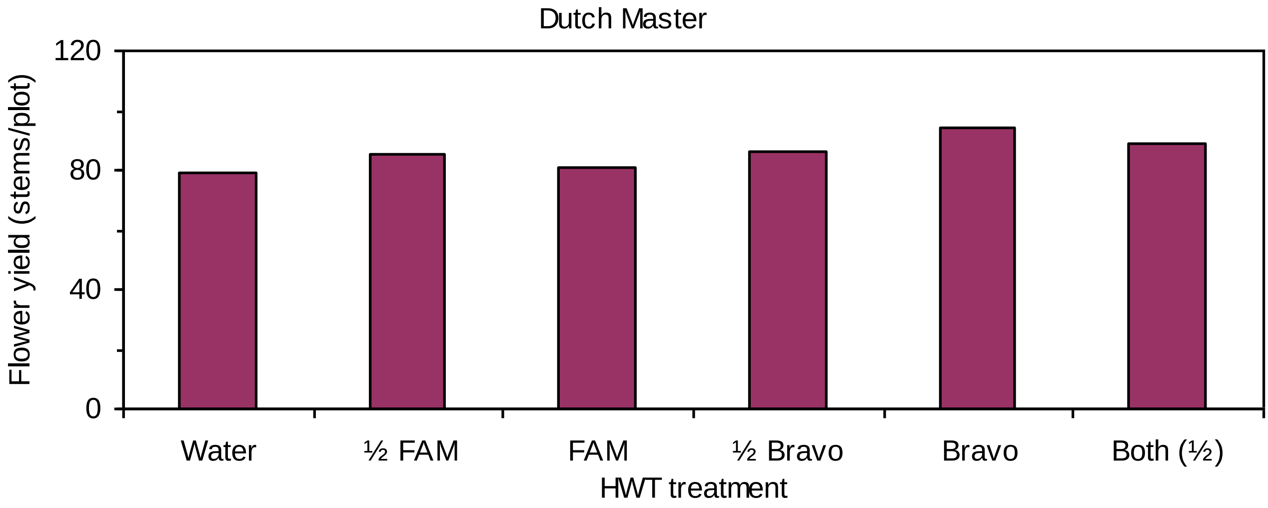
Figure 5 (a - h below). The effects of HWT chemicals on stem yield per plot after one year (any stems with damaged flowers excluded) in the eight cultivars tested; for 'Great Leap' the number of blind stems is also shown, and for 'Hugh Town', the number of florets



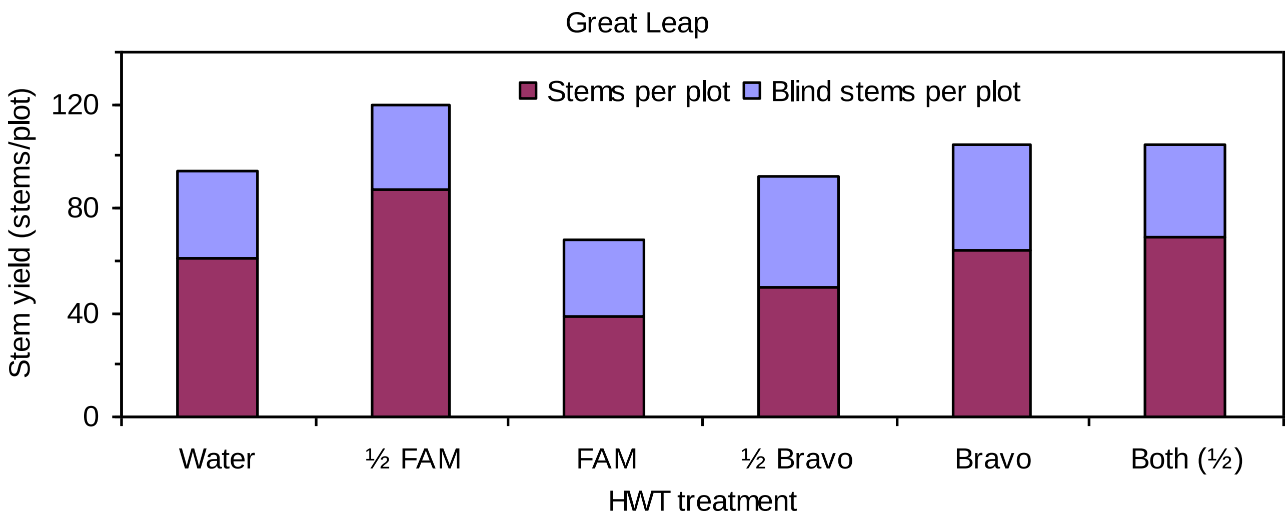
a) 'Actaea': the findings indicated a stock problem with base rot, with sufficient bulbs rotting between planting and flowering to result in an average of only 10 stems in the control (no additives in HWT); full-rate 'FAM 30' and half-rate 'Bravo 500' were only partly effective in controlling bulb rots, though the other three treatments (half-rate 'FAM 30', full-rate 'Bravo 500' and half-rate of both chemicals) resulted in reasonable stem numbers.



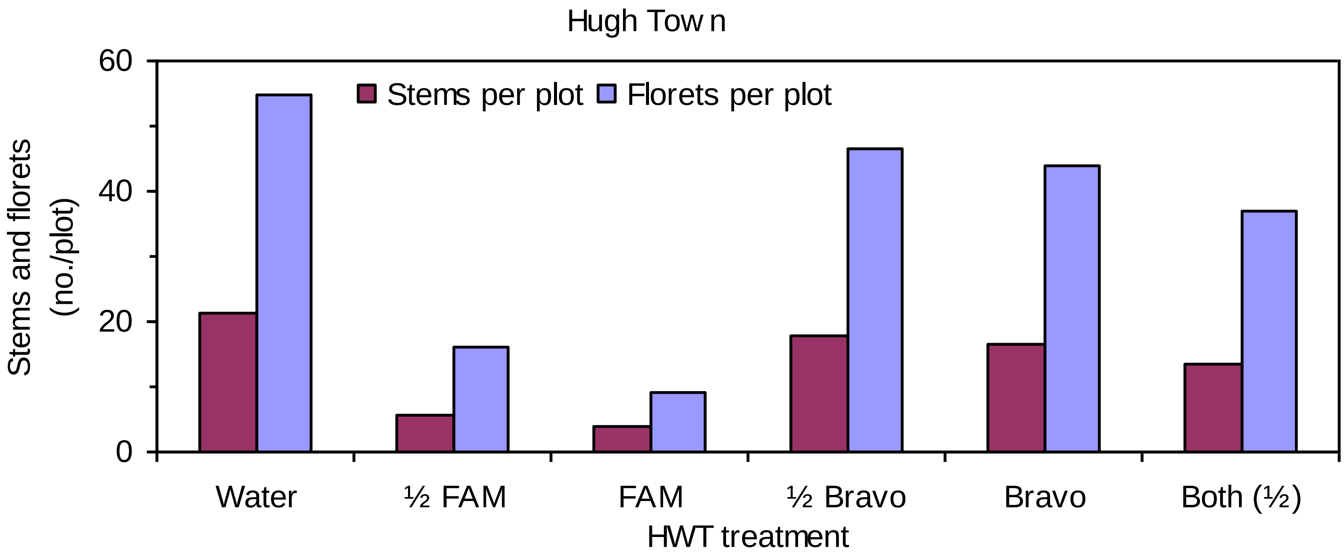
b) 'Carlton': only the 'Bravo 500' treatments improved stem yields compared with the control, 'FAM 30' treatments appearing to be ineffective in this base rot-susceptible cultivar.



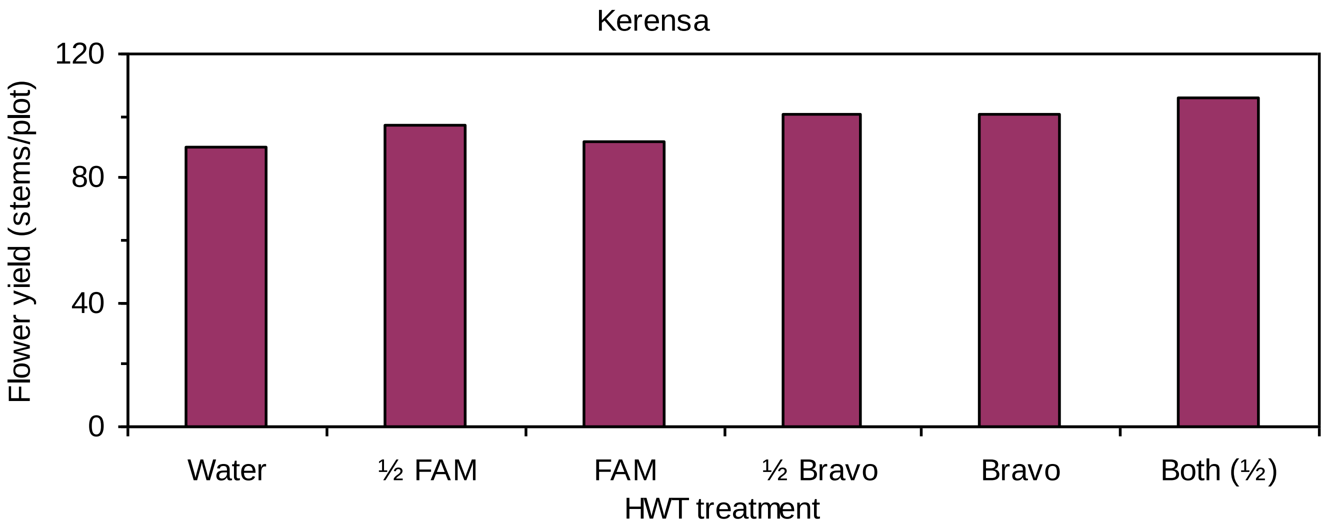
c) 'Dutch Master': compared with some other cultivars, stem yield appeared relatively consistent across treatments, though closer examination shows that all treatments increased stem yield (and mostly significantly) above that of the control.



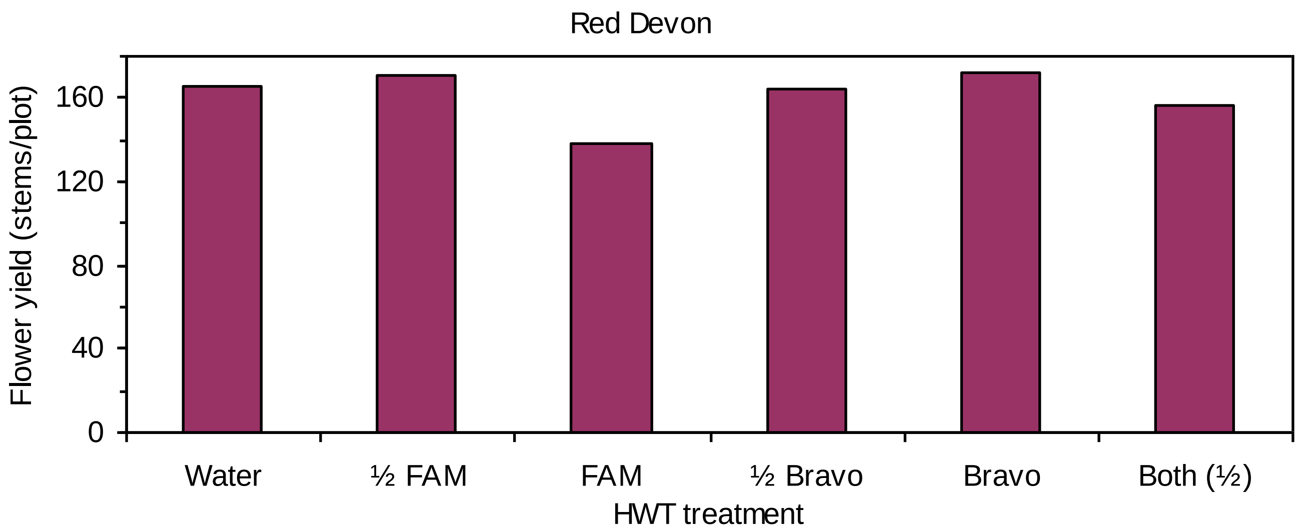
d) 'Great Leap': in this trial the cultivar produced many blind stems, though these seemed reasonably consistent in number across all HWT treatments, suggesting a stock problem or a varietal response to low winter temperatures. 'Great Leap' was atypical in showing an apparent adverse response to HWT with full-rate 'FAM 30' (though using half-rate 'FAM 30' increased yields above control levels).



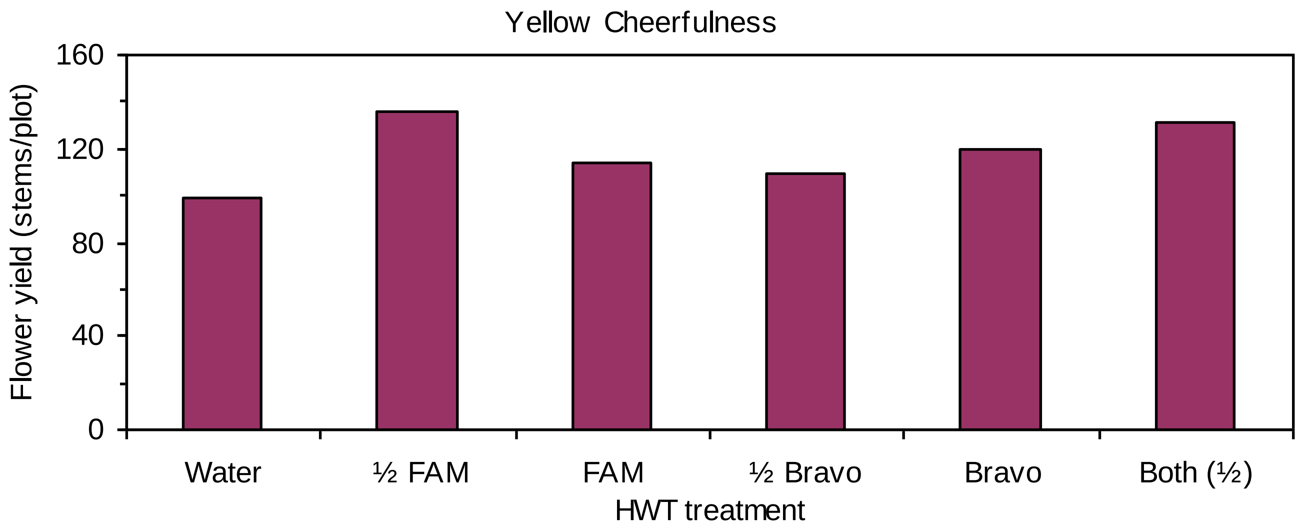
e) ‘Hugh Town’: so few stems were produced by this cultivar that the first-year results are probably unreliable, and next year’s results should be awaited: nevertheless, the apparent adverse effect of ‘FAM 30’ (at either rate) on stem numbers - and on total floret numbers – suggests this treatment may be unsuitable for the variety.



f) ‘Kerensa’: all treatments produced a modest, though significant, increase in stem yield compared with the control.



g) 'Red Devon': in this high-yielding cultivar treatment with full-rate 'FAM 30' reduced stem yields to below the level of the control, while half-rate 'FAM 30' and full-rate 'Bravo 500' significantly increased yields.



h) 'Yellow Cheerfulness': all treatments increased stem yield compared with the control, but half-rate FAM 30, and half-rate of both additives particularly so.

Flower quality

When marketable (undamaged) flowers/buds were counted, any dead or distorted/damaged buds/flowers were recorded separately. With the exception of dead buds in ‘Great Leap’, very few dead flowers, and even fewer distorted flowers (very occasional ‘starry’ flowers and split trumpets, typical of HWT damage) were seen. With such a low incidence, statistical analysis would be of dubious value, so simple tables of means are given as Tables 1 and 2. Apart from the exception mentioned, there was no evidence for cultivar or treatment effects. There was no indication that any of the HW treatments increased the number of flowers lost or damaged.

Table 1. Mean number of dead flowers or buds per plot, recorded at flowering time in year 1

Cultivar	**HWT chemicals**						**Cultivar means**
	Control (water)	***FAM 30***		***Bravo 500***		**Both at half-rate**	
		Half-rate	**Full-rate**	**Half-rate**	**Full-rate**		
Actaea	2	3	3	4	4	1	3
Carlton	0	1	0	1	1	0	1
Dutch Master	1	0	1	1	1	0	1
Great Leap	33	32	29	43	41	36	36
Hugh Town	1	0	1	3	1	1	1
Kerensa	0	0	0	0	0	0	0
Red Devon	2	2	0	1	3	1	1
Yellow Cheerfulness	1	0	0	0	0	0	0
HWT means	5	5	4	7	6	5	

Table 2. Mean number of damaged or distorted flowers or buds per plot, recorded at flowering time in year 1

Cultivar	**HWT chemicals**						**Cultivar means**
	Control (water)	***FAM 30***		***Bravo 500***		**Both at half-rate**	
		Half-rate	**Full-rate**	**Half-rate**	**Full-rate**		
Actaea	0.0	0.7	0.0	0.0	0.7	0.0	0.2
Carlton	0.3	0.0	0.0	0.7	0.3	0.7	0.3
Dutch Master	0.7	0.7	0.3	0.0	0.3	0.3	0.4
Great Leap	0.7	0.7	0.0	0.0	0.0	0.7	0.3
Hugh Town	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kerensa	0.0	0.0	0.0	0.0	0.0	0.3	0.1
Red Devon	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yellow Cheerfulness	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HWT means	0.2	0.3	0.0	0.1	0.2	0.3	

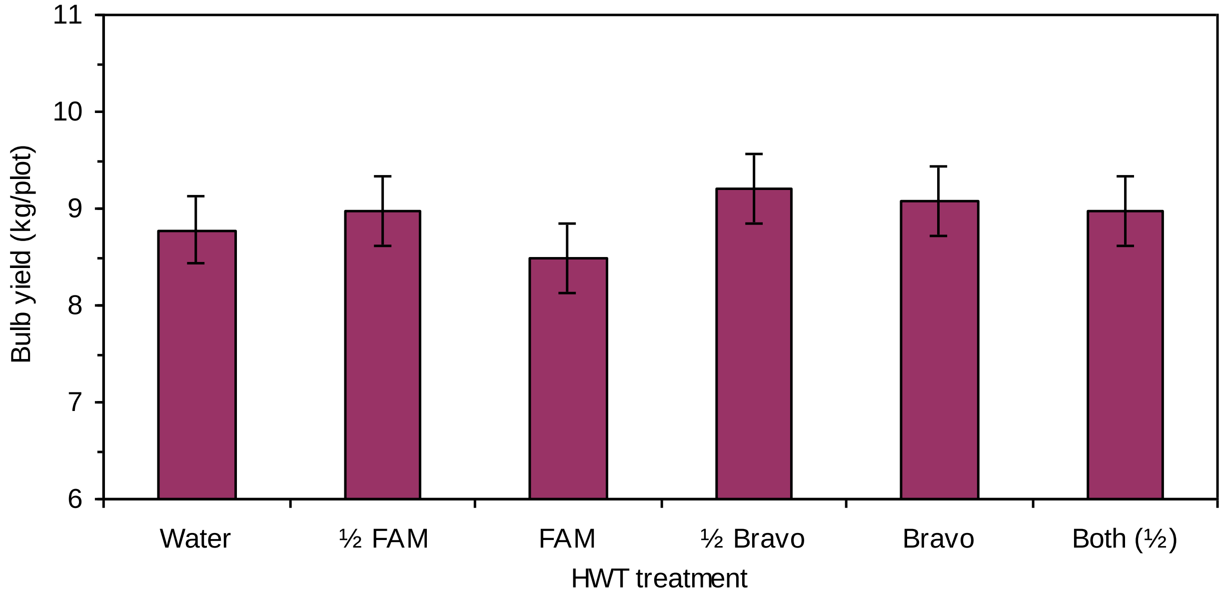
Stem length is an important attribute of crop quality. It was recorded by measuring a sample of stems from each plot during each cultivar's flowering period, and also (more simply) by taking the height of the tallest and shortest stems and averaging them. Not unexpectedly, there were significant differences between cultivars, but stem length, irrespective of how assessed, was not significantly affected by either HW treatments or the interaction between cultivar and HWT (Table A4). Figure 3 (see above under 'Foliage height') illustrates how little average stem height varied between treatments.

Note that stem/flower heights were measured at an appropriate stage for each cultivar, and so represent a 'snapshot' at one time in each case; therefore these measurements do not necessarily relate to stem length at the usual cropping stage. Due to weather damage, these data were not available for 'Hugh Town'.

Bulb yields (weights)

As equalised weights of bulbs had been planted in each plot, bulb yields are expressed as the simple weight or number of bulbs lifted for plots. The results and analysis of variance for the total weight of bulbs lifted are given in Table A5, which shows that the bulk of the variation found was due to cultivar differences, with a small component due to HWT differences.

- ► Not unexpectedly, 'Carlton' showed the heaviest yields. The yields of 'Actaea' were very poor, with little mass added since planting, so in some analyses the 'Actaea' results have been excluded. Other cultivars had intermediate yields.
- ► The effects of the different HWT chemicals were small, though the highest total yield (for ½-rate 'Bravo 500' treatment) was significantly more than the lowest (for full-rate 'FAM 30'), as shown in Figure 6. This could mean that the HWT process itself was sufficient for bulb treatment, with added fungicide or biocide having little additional effect on total yield. There appeared to be a slight detrimental effect of using full-rate 'FAM 30', but overall the reduction in bulb yield was small.
- ► The interaction between cultivar and HWT was not significant, indicating that all cultivars responded to the HWT chemicals in the same way. The experimental error – the variation between replicates of the same treatment – was fairly high, as is often found in daffodil trials of this type.



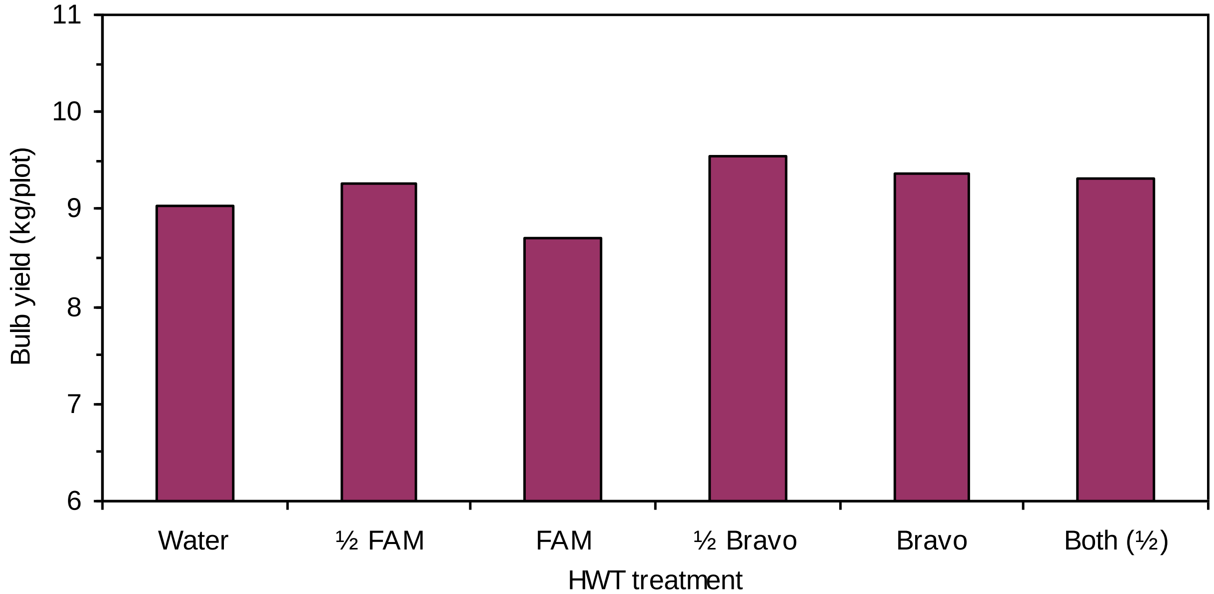


Figure 6. The effects of HWT chemicals on weight of bulbs lifted after one year.

Top: marginal means across all cultivars (vertical bars are LSD values at the 5% level);

Bottom: the results with 'Actaea' excluded

Bulb yields (numbers)

Table A6 summarises the total bulb yield as numbers. The results showed the expected differences between cultivars, the extremes being the large-bulbed 'Hugh Town' and the small-bulbed 'Actaea'. There were no effects of HWT chemicals on total bulb numbers, demonstrating that the treatments do not cause a significant shift in growth rates or bulb-splitting.

Saleable bulb yields

Bulb yields can also be expressed as the yield of saleable bulbs, taken as the yield in grades from 10 to 14cm (10-16cm for 'Hugh Town', a large-bulbed variety) (Table A7). This showed the bulk of the variation found was due to cultivar differences, with a small component due to HWT differences.

- ► With its large bulb size, 'Hugh Town' showed the greatest proportion of lifted bulbs (77%) in the saleable grades. 'Carlton', 'Dutch Master' and 'Kerensa' had only 50% of the lifted bulbs in the saleable grades, while in the other cultivars it was intermediate at 60 to 65%.
- ► The effects of the different HWT chemicals were small, though the full-rate 'FAM 30' treatment resulted in a greater yield of saleable bulbs than the other treatments (Figure 7); this appeared to be due to reduced growth, with fewer bulbs growing to the larger (>14cm) sizes (Figure 8).
- ► The interaction between cultivar and HWT was not significant.
- ► These conclusions were confirmed by analysis of the $\log_{10}$-transformed data.

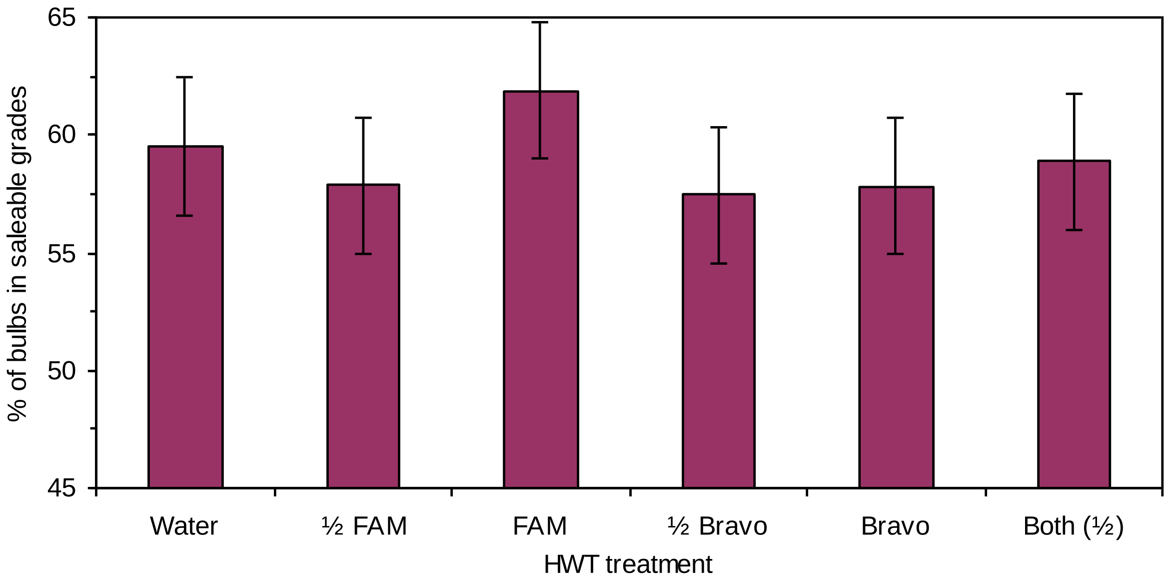


Figure 7. The effects of HWT chemicals on the percentage of bulb yield (after one year) in saleable grades (10-14cm, or 10-16cm for 'Hugh Town')
(vertical bars are LSD values at the 5% level)

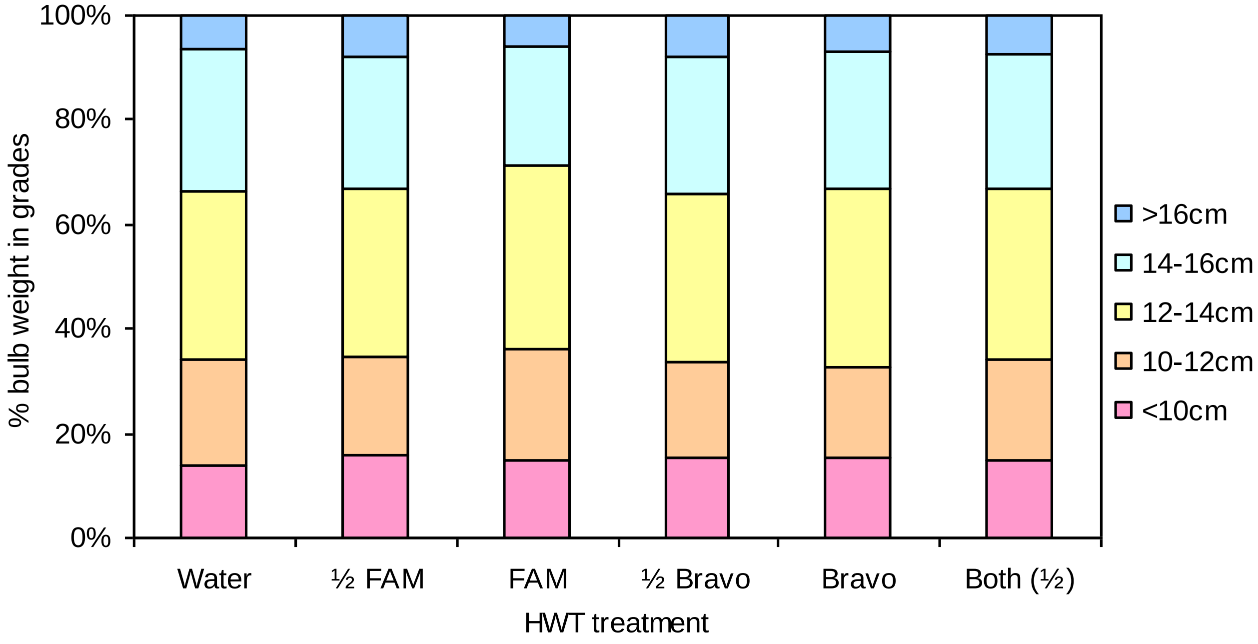


Figure 8. The effects of HWT chemicals on the percentage of bulb yield in size grades (after one year)

Unmarketable bulbs

Overall, although bulb yields in this trial were not exceptional, very few bulbs were rejected at grading due to rotting or damage (Table A8). It is likely that most bulb losses occurred in the period after planting, so that no remains were present at harvest. Statistically, cultivar had a significant effect on the percentage of unmarketable bulbs, while there were no significant effects due to HWT or the interaction between cultivars and HWT.

- ► The extremes were 6% rotted/damaged bulbs in 'Kerensa' and 2.5% in 'Hugh Town' and 'Red Devon'.
- ► Three treatments, full-rate 'FAM 30', ½-rate 'Bravo 500' and both additives at ½-rate, appeared to result in fewer bulbs being rejected as rotted/damaged, compared with the other treatments, though this effect was shown to be not significant (Figure 9).
- ► These conclusions were confirmed by analysis of the log_{10}-transformed data.

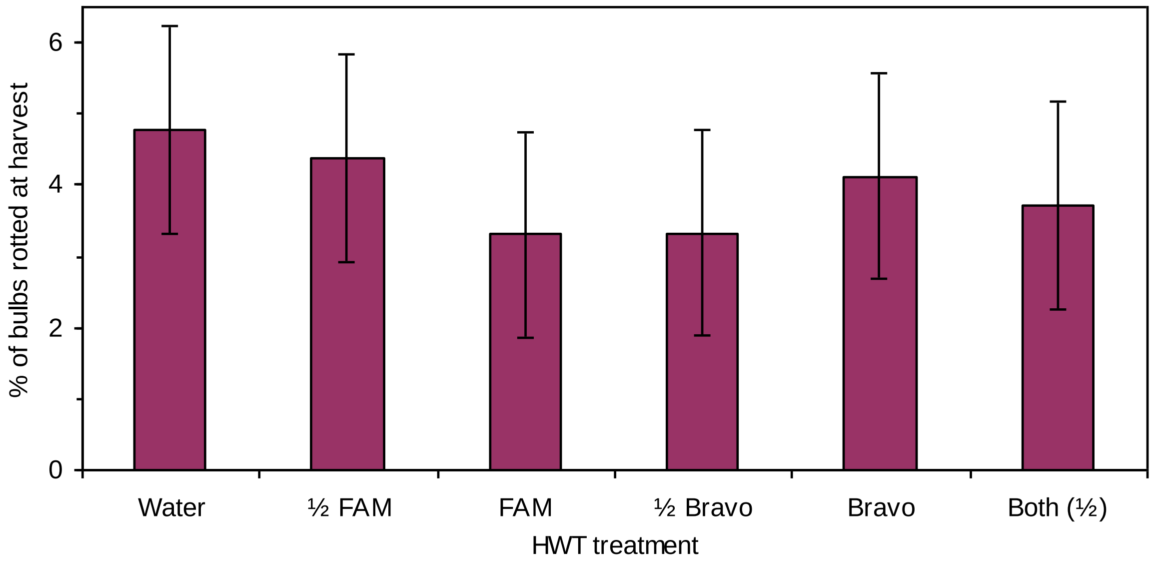


Figure 9. The effects of HWT chemicals on the percentage of bulbs rotted or damaged at grading in year 1
(vertical bars are LSD values at the 5% level)

Discussion

Summary of results

From these results (and those from the earlier field trial in BOF 61a) it was clear that 'FAM 30' and 'Bravo 500' were, as used here and based only on first-year growth, either beneficial, innocuous or had only mild detrimental effects on daffodil growth and development.

There were no statistically significant effects of the HW treatments (and generally no or only weak interactions between HW treatments and cultivar) on:

- ► Progress to flowering or flowering date
- ► Leaf length at flowering
- ► Stem length at flowering
- ► Incidence of flower losses or defects
- ► Numerical yield of bulbs
- ► Numbers of rotted bulbs removed at bulb grading.

Some mild damage was seen on leaves (roughened and mottled leaves) and flowers (‘starry’ flowers, deformed coronas and ‘drumsticks’), this was typical of the damage caused by the normal process of HWT, and was not linked to particular HW treatments.

There were some significant effects of HW treatments on flower and bulb yields.

Overall, HWT with half-rate ‘FAM 30’, full-rate ‘Bravo 500’ or half-rate of both additives resulted in higher ***flower yields***, while the control and full-rate ‘FAM 30’ gave lower yields. In most cultivars all treatments improved yields over that of the controls. However, so far in this trial:

- ‘FAM 30’ was ineffective in improving yields in ‘Carlton’, a cultivar susceptible to base rot and which benefited especially from using ‘Bravo 500’
- None of the treatments benefited flower yield in ‘Actaea’ or ‘Great Leap’, both of which appeared to have stock problems (base rot in ‘Actaea’, possibly sensitivity to HWT in ‘Great Leap’)
- ‘FAM 30’ appeared slightly detrimental to yields used at full rate in ‘Great Leap’ and ‘Hugh Town’, though this needs to be checked in the second crop year when it is hoped the performance of these cultivars will have improved.

None of the HW treatments were significantly detrimental to ***bulb yields*** (by weight), compared with the control; overall, half-rate ‘Bravo 500’ gave the highest bulb yields, and full-rate ‘FAM 30’ the lowest, so again there is a slight note of caution over the use of full-rate ‘FAM 30’. Using the full-rate ‘FAM 30’ treatment slightly increased the yield of bulbs in the saleable (usually 10-14cm) grades through reducing the yield of larger bulbs. In daffodil trials of this type it is not unusual for different treatments to affect different aspects of yield (e.g. total yield, saleable yield, yield by weight or by number) in subtly different ways; sometimes different benefits will have to be weighed up to obtain the best overall result.

Implications for growers

Previous HDC-funded projects suggested ‘FAM 30’ as a likely replacement for formalin in HWT, and ‘Bravo 500’ as an alternative to ‘Storite Clear Liquid’. The present trial confirmed that these treatments were without significant phytotoxic effects – at least in the first year following planting, and so should be used with caution until further results have been gathered in 2011 following completion of the two-year-down trial. A few other comments should be made.

► HWT itself, without any effects of added chemicals, is well known to be mildly damaging to daffodils, reducing vigour and resulting in various types of crop damage as seen here (such as mottled leaves, dead buds and distorted flowers). Some of the pesticides used in bulb dipping, such as thiabendazole fungicides (e.g. 'Storite Clear Liquid') are also known to depress crop growth in the year following treatment, though yields recover following a further year's growth.[9] Slight, transient damage due to a chemical treatment might therefore also be acceptable.

► The results showed a small but consistent advantage to crop growth of using half-rate 'FAM 30' treatment over full-rate. This suggests a rate of 4 or perhaps 6L of 'FAM 30' per 1000L water should be used. Also, until more information is available, the full-rate of 'FAM 30' should not be used with non-standard cultivars. There seemed no such disadvantage to using the full-rate 'Bravo 500' treatment, or to using both chemicals together at half-rate of each.

► While all safety notices regarding pesticides and other chemicals should always be complied with, no ***specific*** operator hazards were identified to using 'FAM 30' in this way. Currently, biocides used in agriculture/horticulture for hygiene, rather than for specific control of pests and pathogens, fall outside pesticides legislation, but extant biocides are presently being reviewed by the EU under its Biocidal Products Directive (BPD). No definite guidance is available from the HDC at this point, nor is it clear whether Evans Vanodine International PLC will be supporting iodophore biocides for the relevant 'Product Type' through the BPD review. The finding of ***one*** alternative biocide to formalin should not be taken to mean that there is no need to consider further alternatives, as iodophore biocides may not complete the EU review successfully, or in any case might be withdrawn from the market for a variety of reasons.

► This use of 'Bravo 500' (with MAPP 10518 or 14548) is permitted under SOLA 2009/2491 (expiring 31 August 2011) and SOLA 2009/1824 (expiring 28 February 2016), respectively. As always, growers must adhere to guidance provided on the product label and the use of dust-proof goggles when handling 'Bravo 500' concentrate would sensibly be extended to their use when in close proximity to bulbs that have been dipped in the fungicide. In managing *Fusarium*-susceptible daffodil stocks, the use of chlorothalonil- and thiabendazole-based products should be alternated, and should still be combined with appropriate non-chemical means of pest and disease control.

► ► This use of 'Bravo 500' (with MAPP 10518 or 14548) is permitted under SOLA 2009/2491 (expiring 31 August 2011) and SOLA 2011/0943 (expiring 3.March 2015) , respectively. As always, growers must adhere to guidance provided on the product label and the use of dust-proof goggles when handling 'Bravo 500' concentrate would sensibly

[9] Hanks, GR (1996). Control of *Fusarium oxysporum* f.sp. *narcissi*, the cause of narcissus basal rot,

be extended to their use when in close proximity to bulbs that have been dipped in the fungicide. In managing Fusarium-susceptible daffodil stocks, the use of chlorothalonil- and thiabendazole-based products should be alternated, and should still be combined with appropriate non-chemical means of pest and disease control.

- Further information on the use of ‘FAM 30’ and ‘Bravo 500’ in bulb dipping – stability, topping-up, measuring concentrations, etc. - will becoming available from HDC-funded project BOF 70 later in 2010.

Acknowledgements

The HDC and the author thank Richard and Jon Barlow and their staff at F Dring & Sons Ltd for their skill and care carrying out this trial. We thank F Dring & Sons Ltd, Grampian Growers Ltd and Winchester Growers Ltd for providing bulb stocks.

---

with thiabendazole and other fungicides. *Crop Protection*, **15**, 549-558.

Appendix: Tables of results

Table A1
Means and LSD values (above) and analysis of variance (below) for the percentage of stems with open flowers recorded at one stage in the flowering period in year 1 (log_{10}-transformed data) (see footnotes for explanation)

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*FAM 30*		*Bravo 500*		*Both at half-rate*		
		Half-rate	*Full-rate*	*Half-rate*	*Full-rate*			
Actaea	1.78	1.83	1.86	1.83	1.91	1.83	1.84	
Carlton	1.90	1.77	1.80	1.70	1.84	1.81	1.80	
Dutch Master	1.97	1.95	1.93	1.92	1.94	1.94	1.94	
Great Leap	2.00	1.99	1.99	2.00	2.00	2.00	2.00	*LSD (5%) = 0.042*
Kerensa	1.99	1.99	1.98	1.99	1.99	1.99	1.99	
Red Devon	1.89	1.87	1.82	1.88	1.90	1.85	1.87	
Yellow Cheerfulness	1.96	1.97	1.94	1.95	1.95	1.95	1.95	
	LSD (5%) = 0.017							
HWT means	1.93	1.91	1.91	1.90	1.93	1.91		
	LSD (5%) = 0.049							

Analysis of variance

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	0.6138	6	0.1023	56.3435	<0.001	***
HWT	0.0206	5	0.0041	2.2689	0.055	NS
Interaction	0.0921	30	0.0031	1.6905	0.032	*
Residual	0.1525	84	0.0018			
Total	0.8791	125				

Least significant differences (LSD) for the 5% level of probability are given for the 'treatment means' (the main body of the table) and the 'marginal means' (i.e. for cultivar and for HWT), and can be used to indicate whether the differences between individual pairs of means are significantly different from each other. Where analysis of variance shows that not all factors (cultivar, HWT and the interaction between them) had significant effects on the results, the non-significant part is shown in grey (in this case, HWT).

The analysis of variance tables indicate the overall significance of cultivar and HWT effects and of the interaction between them, with NS = not significant and *, ** and *** meaning significant at the 5, 1 and 0.1% levels of probability, respectively. The level of probability indicates how often a result may have occurred by chance: 5, 1 and 0.1% levels of probability indicate that the result could arise by chance once in 20, once in 100, or once in 1,000 times, respectively.

Table A2
Means and LSD values (above) and analysis of variance (below) for leaf height (cm) at flowering in year 1 (see footnotes to Table A1 for explanation)

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*FAM 30*		*Bravo 500*		*Both at half-rate*		
		Half-rate	*Full-rate*	*Half-rate*	*Full-rate*			
Actaea	35.0	36.7	35.7	37.6	37.3	36.8	36.5	*LSD (5%) = 3.05*
Carlton	35.9	36.6	34.5	39.6	39.1	34.7	36.7	
Dutch Master	37.1	34.9	32.7	34.2	35.3	34.4	34.8	
Great Leap	38.6	39.7	35.2	38.3	39.7	38.7	38.3	
Kerensa	33.7	33.5	33.4	32.9	34.8	33.2	33.6	
Red Devon	37.9	39.6	34.8	39.3	35.7	38.8	37.7	
Yellow Cheerfulness	31.6	33.9	34.0	32.3	36.0	35.7	33.9	
	LSD (5%) = 1.24							
HWT means	35.7	36.4	34.3	36.3	36.8	36.0		
	LSD (5%) = 3.29							

Analysis of variance

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	372.59	6	62.10	7.65	<0.001	***
HWT	80.22	5	16.04	1.98	0.091	NS
Interaction	190.05	30	6.34	0.78	0.776	NS
Residual	682.10	84	8.12			
Total	1324.96	125				

Table A3
Means and LSD values (above) and analysis of variance (below) for flower yield (number of stems with undamaged flowers/plot) in year 1 (see footnotes to Table A1 for explanation)

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*FAM 30*		*Bravo 500*		*Both at half-rate*		
		Half-rate	*Full-rate*	*Half-rate*	*Full-rate*			
Actaea	10.3	119.7	90.3	57.3	106.0	117.0	83.4	
Carlton	133.3	125.0	114.7	151.3	156.7	132.7	135.6	
Dutch Master	79.0	85.7	81.3	86.3	94.0	89.3	85.9	
Great Leap	61.0	87.3	38.7	49.3	63.7	69.0	61.5	*LSD (5%) = 10.73*
Hugh Town	21.3	5.7	4.0	17.7	16.7	13.7	13.2	
Kerensa	89.7	97.0	92.0	101.0	100.3	106.0	97.7	
Red Devon	165.7	171.3	138.3	164.0	172.3	157.0	161.4	
Yellow Cheerfulness	99.0	135.3	113.7	109.7	119.7	130.7	118.0	
	LSD (5%) = 4.38							
HWT means	82.4	103.4	84.1	92.1	103.7	101.9		
	LSD (5%) = 12.39							

Analysis of variance

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	263401.53	7	37628.79	323.51	<0.001	***
HWT	11453.56	5	2290.71	19.69	<0.001	***
Interaction	30403.56	35	868.67	7.47	<0.001	***
Residual	11166.00	96	116.31			
Total	316424.64	143				

Table A4
Means and LSD values (above) and analysis of variance (below) for stem/flower height (cm) at flowering in year 1 (see footnotes to Table A1 for explanation)

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*FAM 30*		*Bravo 500*		*Both at half-rate*		
		Half-rate	*Full-rate*	*Half-rate*	*Full-rate*			
Actaea	38.3	41.7	40.1	41.2	42.2	39.6	40.5	
Carlton	40.5	41.8	40.9	45.4	45.2	42.2	42.7	
Dutch Master	44.2	39.9	39.3	38.3	41.0	41.6	40.7	*LSD (5%) = 3.24*
Great Leap	43.7	41.6	41.5	43.8	43.7	47.6	43.6	
Kerensa	40.8	41.6	42.2	40.8	42.5	41.2	41.5	
Red Devon	44.3	45.1	41.5	45.1	43.6	45.3	44.2	
Yellow Cheerfulness	35.9	39.1	38.5	36.0	37.9	39.6	37.8	
			LSD (5%) = 1.32					
HWT means	41.1	41.5	40.6	41.5	42.3	42.4		
			LSD (5%) = 3.49					

Analysis of variance

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	504.59	6	84.10	9.18	<0.001	***
HWT	52.55	5	10.51	1.15	0.342	NS
Interaction	263.20	30	8.77	0.96	0.537	NS
Residual	769.33	84	9.16			
Total	1589.67	125				

Table A5
Means and LSD values (above) and analysis of variance (below) for total marketable bulb yield (kg/plot) after 1 year's growth (see footnotes of Table A1 for explanation)

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*FAM 30*		*Bravo 500*		*Both at half-rate*		
		Half-rate	*Full-rate*	*Half-rate*	*Full-rate*			
Actaea	6.90	6.91	6.83	6.90	7.15	6.63	6.89	
Carlton	9.54	10.42	9.32	10.12	10.54	10.13	10.01	
Dutch Master	8.28	8.91	7.94	9.21	9.21	9.61	8.86	
Great Leap	7.95	8.53	8.19	8.59	8.58	8.07	8.32	*LSD (5%) = 0.614*
Hugh Town	10.55	9.54	9.17	10.01	9.59	9.88	9.79	
Kerensa	8.36	8.48	8.26	9.31	9.19	8.66	8.71	
Red Devon	9.04	9.03	8.28	9.16	8.91	8.73	8.86	
Yellow Cheerfulness	9.60	9.91	9.85	10.38	9.49	10.05	9.88	
			LSD (5%) = 0.236					
HWT means	8.78	8.97	8.48	9.21	9.08	8.97		
			LSD (5%) = 0.709					

Analysis of variance

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	133.63	7	19.09	50.09	<0.001	***
HWT	7.90	5	1.58	4.14	0.002	**
Interaction	12.57	35	0.36	0.94	0.566	NS
Residual	36.58	96	0.38			
Total	190.68	143				

Table A6
Means and LSD values (above) and analysis of variance (below) for total number of marketable bulbs lifted per plot after 1 year's growth (see footnotes to Table A1 for explanation)

Cultivar	*HWT chemicals*						*Cultivar means*	
		FAM 30		*Bravo 500*				
	Control (water)	*Half-rate*	*Full-rate*	*Half-rate*	*Full-rate*	*Both at half-rate*		
Actaea	289	298	292	279	294	289	290	
Carlton	174	196	194	195	192	181	189	
Dutch Master	169	169	159	170	167	175	168	
Great Leap	181	200	186	191	191	168	186	*LSD (5%) = 14.8*
Hugh Town	141	136	140	131	135	137	137	
Kerensa	163	172	161	165	163	156	163	
Red Devon	202	215	214	211	225	209	213	
Yellow Cheerfulness	202	223	230	230	214	245	224	
	LSD (5%) = 6.0							
HWT means	190	201	197	197	198	195		
	LSD (5%) = 17.0							

Analysis of variance

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	277901.31	7	39700.19	180.52	<0.001	***
HWT	1659.56	5	331.91	1.51	0.194	NS
Interaction	7211.11	35	206.03	0.94	0.575	NS
Residual	21112.00	96	219.92			
Total	307883.97	143				

Table A7
Means and LSD values (above) and analysis of variance (below) for the percentage of marketable bulb weight in saleable grades (10-14cm, except 10-16cm for 'Hugh Town') after 1 year's growth (see footnotes to Table A1 for explanation)

Cultivar	*HWT chemicals*						*Cultivar means*	
		FAM 30		*Bravo 500*				
	Control (water)	*Half-rate*	*Full-rate*	*Half-rate*	*Full-rate*	*Both at half-rate*		
Actaea	63.4	59.4	58.6	59.5	54.0	58.3	58.9	
Carlton	51.1	46.2	53.9	47.9	45.3	52.0	49.4	
Dutch Master	48.7	52.3	62.0	46.7	48.8	47.8	51.1	
Great Leap	66.3	62.4	63.1	68.0	65.9	67.4	65.5	*LSD (5%) = 5.04*
Hugh Town	80.2	76.3	79.6	72.8	76.8	74.5	76.8	
Kerensa	47.9	51.1	56.0	41.9	49.3	47.1	48.9	
Red Devon	59.4	58.5	62.9	59.5	61.5	58.6	60.1	
Yellow Cheerfulness	59.2	56.2	58.9	63.5	60.8	65.3	60.6	
	LSD (5%) = 2.03							
HWT means	59.5	57.9	61.9	57.5	57.8	58.9		
	LSD (5%) = 5.81							

Analysis of variance

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	11156.28	7	1593.75	62.22	<0.001	***
HWT	326.51	5	65.30	2.55	0.033	*
Interaction	1208.98	35	34.54	1.35	0.129	NS
Residual	2458.93	96	25.61			
Total	15150.70	143				

Table A8
Means and LSD values (above) and analysis of variance (below) for the percentage of bulbs rotted or damaged at grading in year 1 (see footnotes to Table A1 for explanation)

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*FAM 30*		*Bravo 500*		*Both at half-rate*		
		Half-rate	*Full-rate*	*Half-rate*	*Full-rate*			
Actaea	2.37	4.72	3.10	4.40	3.69	6.36	4.11	
Carlton	6.34	2.14	3.45	2.22	3.13	2.96	3.38	
Dutch Master	6.23	4.65	3.80	5.03	5.92	4.06	4.95	
Great Leap	5.41	4.66	3.01	2.79	2.44	7.02	4.22	*LSD (5%) = 2.514*
Hugh Town	0.25	4.65	0.24	2.54	3.18	2.98	2.31	
Kerensa	7.40	7.34	7.72	5.07	5.81	2.78	6.02	
Red Devon	3.31	0.91	2.98	2.95	2.78	1.91	2.47	
Yellow Cheerfulness	6.95	5.94	2.13	1.60	6.07	1.71	4.07	
				LSD (5%) = 1.026				
HWT means	4.78	4.38	3.30	3.33	4.13	3.72		
				LSD (5%) = 2.903				

Analysis of variance

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	190.82	7	27.26	4.27	<0.001	***
HWT	42.35	5	8.47	1.33	0.259	NS
Interaction	290.63	35	8.30	1.30	0.159	NS
Residual	612.94	96	6.38			
Total	1136.74	143				