FINAL REPORT

To:
Horticultural Development Company
Agriculture & Horticulture Development Board
Stoneleigh Park
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HDC Project BOF 61b
Final Report (April 2012)

Daffodils: Developing alternatives to formalin

The effects of HWT with an iodophore biocide and chlorothalonil fungicide on crop growth and yield

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April 2012

Commercial - In Confidence

Grower Summary

BOF 61b

Daffodils: Developing alternatives to formalin
The effects of HWT with an iodophore biocide and chlorothalonil fungicide on crop growth and yield

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Project title:	**Daffodils: Developing alternatives to formalin** The effects of HWT with an iodophore biocide and chlorothalonil fungicide on crop growth and yield
HDC project number:	**BOF 61b**
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Report:	Final Report (April 2012)
Previous reports:	Annual Report (November 2010)
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Date commenced:	24 August 2009
Date completion due:	29 February 2012 (extended from 31 December 2011 by agreement)
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

Signed:…..…………………………………………. Date: …………………………….

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Contents

Grower Summary

Headline

► 'Bravo 500' can be used as a crop-safe alternative to thiabendazole-based fungicides in the hot-water treatment of daffodil bulbs.

► 'FAM 30' can be used as a crop-safe alternative to formaldehyde-based biocides in the hot-water treatment of daffodil bulbs.

► Both products can safely be used together in HWT if appropriate concentrations are used (0.5L of 'Bravo 500' + 4.0L of 'FAM 30' per 1000L of water).

Background

Stem nematode (*Ditylenchus dipsaci*) is potentially the most devastating pest of daffodil crops worldwide, but has been managed for decades by hot-water treatment (HWT) of planting stocks, usually adding formalin to the dip to augment the effect of hot water (HW) itself. Although biocides (disinfectants) other than formalin have been evaluated for this purpose from time to time, for various reasons none replaced formalin. But in 2008 the agricultural/horticultural approvals for formalin were revoked within the EU at short notice. Shortly after, HDC Project BOF 61 was set up to reconsider the question of finding an alternative or alternatives to replace formalin-HWT of daffodil bulbs.

Fusarium rots (base rot and neck rot caused by *Fusarium oxysporum f.sp. narcissi*) continue to cause concern to UK growers, and although formalin had given some control of *Fusarium* rots when added to the HWT dip, a fungicide was often added as well to enhance the effect, usually (in recent years) a thiabendazole-based fungicide. Also in 2008, this use of thiabendazole fungicides was restricted by legislation in terms of (a) the maximum permitted concentration, (b) the number of treatments allowed per year, and (c) by banning its use in the Isles of Scilly. Clearly, alternative fungicides, as well as alternatives to formalin, were required by the industry.

As a result of initial tests in HDC Project BOF 61a, an iodophore 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. Following the finding that these chemicals controlled stem nematode and *F. oxysporum f.sp. narcissi*, it was necessary to evaluate these novel treatments to ensure both were crop-safe under commercial conditions. Project BOF 61b was set-up to field-test HWT with 'FAM 30' and (or) 'Bravo 500' with 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:

1. None (control) – HWT with no biocide or fungicide added
2. Iodophore biocide at half-rate – 4L 'FAM 30'/1000L water
3. Iodophore biocide at full-rate – 8L 'FAM 30'/1000L water
4. Chlorothalonil at half-rate – 0.5L 'Bravo 500'/1000L water
5. Chlorothalonil at full-rate – 1L 'Bravo 500'/1000L water
6. Iodophore biocide ('FAM 30') + chlorothalonil ('Bravo 500'), each at half-rate.

All dips included a non-ionic wetter and an anti-foam preparation used at standard rates. HWT was carried out over 9 to 10 September 2009, using a 5-tonne front-loading tank of standard design. The treated bulb lots were planted in a light silt soil on a bulb farm in south Lincolnshire and grown for two years employing typical, commercial husbandry. The trial was fully replicated and randomised, with a structure of eight cultivars, six HW treatments and six replicate blocks, making 288 plots in all.

The crop was checked for pests, diseases and defects regularly and growth stages (GS) were recorded. Flowering dates, flower yields, flower quality, and stem and leaf heights at flowering were recorded. Three of the six replicate blocks were grown 'one-year-down' and harvested in July 2010, and the yield of bulbs recorded after the normal drying, cleaning and grading. The remaining three blocks were lifted and assessed in 2011 after growing for the typical two-year period.

In the first crop-year, with one exception, there were no visually obvious differences in growth and development between plots of any cultivar that had received the different HW treatments. In the year after HWT, this process typically results in HWT-induced damage consisting of roughened, mottled leaf tips and flowers that are small, 'starry' and sometimes had split coronas (trumpets or cups). Leaf damage was seen throughout the plots, but was mild and not atypical of HWT-damage. Only very low numbers of damaged flowers occurred, and these were unrelated to specific HW treatments. Exceptionally, plots of 'Actaea' from the control HW treatment had many fewer flowers than the other treatments, probably due to a high level of base rot in the stock.

The crops developed normally, within the expected commercial parameters, though again with one exception. To achieve a wide range of daffodil types in the trial, one of the cultivars chosen was the tazetta cultivar 'Hugh Town', a type not normally grown in the east of England: tazetta daffodil respond differently to the low temperature of winter, and the plants of 'Hugh Town' emerged as early as November, following which they suffered damage as a result of the unusually cold winter. Although producing reasonable flowers over a wide season, 'Hugh Town' did not thrive in this situation. There was one further varietal issue with 'Great Leap', which frequently produced stems with dead buds (like 'drumsticks') following the failure of the spathe to split normally, though this is common in double daffodil cultivars.

In the second crop-year these trends continued. There was generally no visual evidence that the different HW treatments had affected crop growth and development in any significant way. The plots of 'Actaea' continued to show relatively weak growth, the plots of 'Hugh Town' continued to demonstrate its unsuitability for growing in the region, and the plots of 'Great Leap' continued to produce many dead buds.

In this type of trial the difference between the mean values of a measurement for each plot will be due to a combination of 'error' (biological variation and experimental error) and true effects of the imposed factors. The analysis of variance (AoV) enables these effects to be apportioned. In this case the measurements were flower number, leaf height, etc., there were 288 plots in the trial, and the imposed factors were cultivar, HW treatment and the interaction between them (the cultivar x HW treatment interaction). Analysis showed that most of the statistically significant differences between plots were due to the effects of cultivar, with some differences due to the effects of HW treatment and fewer differences due to the effects of the interaction between cultivar and HWT.

<u>The following varied from cultivar to cultivar, but were unaffected by the HW treatment:</u>

► *<u>Growth and development to flowering, flowering date and leaf and stem height.</u>* In year 1, for each of the cultivars, the pattern of development (including cropping date and the growth of shoots, leaves and flower stems) was identical across the six HW treatments. In the second crop-year GS and shoot/leaf and stem heights were recorded weekly up to flowering and confirmed these results.

► *<u>Leaf and stem height at flowering.</u>* The HW treatments did not significantly affect either stem or leaf height at flowering.

► *<u>Number of florets (in multi-headed varieties).</u>* 'Hugh Town' and 'Yellow Cheerfulness' are multi-headed, and there was no statistically significant effect of HW treatment on the number of florets per stem.

- ► *Numbers of unmarketable flowers.* These comprised dead, distorted or damaged buds or flowers, and only very low numbers of these occurred in either year. However, some varieties are known to be prone to problems with flower opening in certain circumstances, and in this trial nearly 5% of the stems of 'Great Leap' produced dead buds; these occurred equally across all HW treatments.
- ► *Smoulder and physiological rust symptoms.* In the second crop-year, when foliar symptoms were more developed, measurable levels of smoulder lesions were recorded on four cultivars, and of physiological rust on three. It was shown that, within a cultivar, the incidence and severity of the disorders were uniform, with no significant effects due to HW treatment.
- ► *Bulb yields (by numbers).* There were no statistically significant effects of HW treatments on the total numbers of bulbs lifted in either year. This may mean that the treatments were not causing a significant shift in rates of growth or bulb-splitting.
- ► *The number of rotted bulbs discarded at grading* was low in all cases, the more so for the second crop-year, and was also unaffected by HW treatment.

The following varied from cultivar to cultivar and were affected by the HW treatment and the cultivar x HW treatment interaction:

- ► *Flower yields* showed significant effects due to HW treatment as well as the expected varietal differences. In the first crop-year, higher flower yields were obtained from bulbs treated with half-rate 'FAM 30', full-rate 'Bravo 500' and the half-rate of both chemicals together, and there were lower yields in the control and where full-rate 'FAM 30' had been used (half-rate 'Bravo 500' gave intermediate yields). These finding were backed up by the second crop-year, where the highest flower yield followed treatment with the half-rate of 'FAM 30' and 'Bravo 500' together (158 stems/plot) and the lowest following use of full-rate 'FAM 30' (142 stems/plot). In both years the interaction between cultivar and HW treatment was also significant, indicating that different cultivars may be responding differently to the HW treatments, some responding better to one 'FAM 30' or 'Bravo 500' treatment, and others to another, though these differences were generally small and probably not of commercial significance. The safest conclusion was that, in general, HWT that included 'Bravo 500' (at either rate) gave higher flower yields than those treatments that did not.

The following varied from cultivar to cultivar and were affected by the HW treatment in the first crop-year only:

- ► *Bulb yields (by weight).* In the first year there were small, though significant, differences due to HW treatments, with the highest total yield (for half-rate 'Bravo 500') significantly greater than the lowest (for full-rate 'FAM 30'), and there was a slight detrimental effect of using full-rate 'FAM 30'. The cultivar x HW treatment interaction was not significant. By the second year, however, there was no longer a significant effect of HW treatment, though the results were *suggestive* of lower yields in the control and full-rate 'FAM 30' treatment, with superior yields in all other treatments where 'Bravo 500' or half-rate 'FAM 30' were included.
- ► *Yield of the larger, saleable grades of bulbs*. In the first year there was a small effect of HW treatments, with the full-rate 'FAM 30' treatment resulting in a greater yield of saleable bulbs, perhaps because fewer bulbs grew to the larger grades. The cultivar x HW treatment interaction was not significant. By the second year's harvest, the effect of HW treatment was no longer significant. Considering the distribution of bulb weight to grades showed that, between years I and 2, the proportion of bulbs in the largest and smallest grades had fallen (a natural consequence of the large bulbs splitting and the small bulbs growing to saleable sizes), so there was a more equable distribution of yield to the larger, saleable grades.

Financial benefits

Loss of control of stem nematode or base rot could be devastating to UK daffodil bulb and cut-flower production, an industry with an annual output value of around £45million. As no alternative to HWT as a method of control can be identified in the short-term, the finding in this project that 'FAM 30' and 'Bravo 500' can be integrated into the HWT process without phytotoxic or growth-reducing side-effects should enable the industry to move forward after some uncertainty following the loss of formalin. The project showed that optimising biocide and fungicide use in HWT could boost bulb output alone by 12%; with a similar likely figure for cut-flower output, this would represent an increase in production worth in excess of £5million annually (or in excess of £1k/ha). This would not involve other changes in bulb handling and growing, would use existing HWT facilities, and, while 'FAM 30' is more expensive than formalin, chlorothalonil-based fungicides are less expensive than thiabendazole fungicides.

Action points for growers

► An HWT regime of 3 hours at 44.4°C should continue to be regarded as the standard, as this is expected to control most or all stem nematodes

► Add 'FAM 30' to HWT dips at a concentration of 4L/1000L water to enhance the management of stem nematodes and base rot and to improve general hygiene

► In addition to 'FAM 30', add 'Bravo 500' to HWT dips at a concentration of 0.5L/1000L water, or, where base rot is of special concern, at 1.0L/1000L water

► Where base rot is of special concern, alternate the use of a thiabendazole-based product ('Tezate 220 SL' or 'Storite Clear Liquid') with 'Bravo 500', for example (1) by using a thiabendazole fungicide as a post-lifting bulb spray treatment and 'Bravo 500' in HWT, and (2) by alternating the use of these two fungicides in HWT each time a stock is lifted and treated (remembering that thiabendazole fungicides may not be used on a stock more than once each year).

Science Section

Introduction

Stem nematode (*Ditylenchus dipsaci*) of daffodils (*Narcissus* cultivars) is a 'quarantine pest' in the EU, the only quarantine pest or disease affecting the crop. Potentially the most devastating pest of daffodil crops worldwide, stem nematode has been managed for decades by the hot-water treatment (HWT) of bulb stocks. It has been long-standing practice to include a suitable level of the biocide (disinfectant) formalin (a.i., formaldehyde) in the HWT dip to 'augment' the kill of stem nematode. Formalin has routinely been used as a biocide in bulb dipping, which includes both HWT and ambient-temperature bulb dipping ('cold-dipping'), and this was also considered a core practice for the management of fungal pathogens and particularly of *Fusarium oxysporum f.sp. narcissi*, the causal organism of *Fusarium* bulb rots (base rot and most neck rot) and, by general industry assent, the most serious daffodil disease.

Both stem nematode and *Fusarium* rots are of special concern to UK growers because of the contemporary practice of growing daffodils on a cycle of two or more 'years down', meaning bulb stocks no longer receive HWT with formalin (HWTF) every year, as was previously the case for many decades of commercial daffodil growing. While few if any doubts had been raised about the effectiveness of HWTF in managing stem nematode, *Fusarium* rots have proved much more difficult to manage consistently, and, consequently, much of UK strategic and applied research on the crop has been targeted at base rot. Most applied research has involved defining optimal HWTF regimes and which fungicides should be added to bulb dips in addition to formalin. The management of stem nematode and *Fusarium* rots has also been studied in other producer countries, notably the Netherlands and the USA. The management of stem nematode and *Fusarium* in daffodil has been fully reviewed in standard texts in the light of the R&D conducted (Lane, 1984; Moore et al., 1979; Gratwick & Southey, 1986; Chastagner & Byther, 1985; Hanks, 1993, 2002). In addition, advice has been given in HDC-funded reviews and factsheets (projects BOF 31 and 68 and factsheet 13/04).

In 2008 agricultural/horticultural approvals for formalin in the EU were revoked at short notice, apparently following its re-classification as carcinogen. In the same year the HDC funded Projects BOF 61 and 61a to study alternatives to the use of formalin in HWT tanks. The main aspects and findings of these projects were:

- *A literature review* that concluded there were no practical, physical alternatives to HWT for the control of stem nematode and *Fusarium* spores, though:
  - A number of biocides, nematicides and fungicides were identified that merited small-scale testing as potential alternatives for formalin
  - The time-temperature regime used for HWT needed re-evaluation
- *Laboratory-based tests* that:
  - Confirmed the value of using 3 hours at 44.4°C as the preferred HWT regime
  - Demonstrated that an iodophore disinfectant ('FAM 30') and a chlorothalonil-based fungicide ('Bravo 500') were effective additives for HWT tanks
- ***A field trial***, set up to compare the effects of formalin, 'FAM 30' and 'Bravo 500' as HWT additives on an infested daffodil stock, showed that these materials caused no phytotoxic effects on the crop one year later, as evidenced by unimpaired bulb survival, flower yields, and flower and leaf lengths and quality.

Following the completion of this above work a project extension (BOF 61b) was set up in August 2009 to field-test HWT on a farm-scale with 'FAM 30' and (or) 'Bravo 500' on a range of daffodil varieties and specifically to study any effects on phytotoxicity and bulb yields (the effectiveness of 'FAM 30' and 'Bravo 500' in managing stem nematode and *Fusarium* rots having been confirmed by earlier work). The specific objectives of Project BOF 61b were:

- 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.

The previous annual report (December 2010) described the first year's results from the trial. These results indicated there were no adverse effects due to using 'FAM 30' or 'Bravo 500' in the first year of the crop. With the second year of the trial the project has now been completed and the findings can be fully reported.[1]

[1] The field trial was limited to one, two-year-down crop at a single location, and the biological nature of the work means that different circumstances and conditions could produce different results: therefore care should be taken when interpreting the results

Materials and methods[2]

Bulbs

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 that had not received HWT after lifting, and they were used as supplied, without any further sorting. From receipt the bulbs were stored in 25kg net bags at ambient conditions in a typical large agricultural shed with good air movement.

For each cultivar, 36 lots of 6.35kg (±0.05kg) were weighed out and labelled for allocation to six replicates of each of six treatments. As the bulbs were to be planted in netting (to assist full bulb recovery when harvesting) 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 0.5t of bulbs each) ready for HWT, and were stored in the same ambient conditions as before until HWT.

Hot-water treatment

HWT was carried out over 9 and 10 September 2009 in a 5t-capacity HWT tank of conventional 'front-loading' design (Secker Welding Ltd, Holbeach, PE12 8NG). Prior to each treatment, the tank was washed out and filled to the 7500L mark with mains water, 'FAM 30' and 'Bravo 500' were added (see below), and the tank brought to the required temperature. There were six biocide or fungicide HW treatments:

1. None (control) – HWT with no biocide or fungicide added
2. Iodophore biocide at half-rate – 4L 'FAM 30'/1000L water
3. Iodophore biocide at full-rate – 8L 'FAM 30'/1000L water
4. Chlorothalonil fungicide at half-rate – 0.5L 'Bravo 500'/1000L water
5. Chlorothalonil fungicide at full-rate – 1L 'Bravo 500'/1000L water
6. Tank mix of Iodophore biocide ('FAM 30') + chlorothalonil ('Bravo 500') each 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). All dips included non-ionic 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).

Each HWT was for 3 hours at 44.4°C, with the 3-hour period timed from when the target temperature of the circulating water had been reacquired 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 5 days later.

Planting and husbandry

The field trial site was located in south Lincolnshire on a light silt soil. The previous crop was vining peas, giving a N index of 1. Standard 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 ready for planting the trial.

[2] For accurate reporting materials may be referred to by the names of commercial products. No endorsement of the products mentioned is intended, nor criticism of products not mentioned

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 (in such a way that three blocks could be lifted after one year without driving over the adjacent, two-year-down blocks). The positions 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. Nitrogen fertiliser was top-dressed on 3 March 2010 (155kg/ha of Nitro Chalk containing 27%N). The trial received the grower's standard commercial husbandry, including fungicide and herbicide spray programmes (see Appendix 1). To allow full assessment of flower development and quality, flowers were not picked.

Records taken in the growing seasons

In the first (2009-2010) growing season detailed records were made only for the three replicate blocks being lifted in 2010. In all cases obvious off-types, clearly uneven plants at the ends of plots, and the short, late-flowering stems produced from lateral bulb units were ignored at recording. The term 'stem' is usually used to mean the whole 'cut-flower', so 'stem heights' are the total height from soil level to the top-most part of the bud or flower, while 'stem numbers' usually refers to the yield of marketable 'stems' (cut-flowers).

As a tazetta (Division 8) daffodil, 'Hugh Town' does not have the usual requirement for a cold period before stem growth, and its foliage emerged in November. In winter/spring 2009/2010 particularly these plants were damaged by unusually cold winter, as a result producing relatively sparse, chlorotic foliage with blackened leaf tips; because of this damage and poor growth, some records were not taken as they would have been considered atypical.

The following records were made:

- ► Each growing season the crop growth stage (GS; see Table 1) was recorded weekly (since GS were modified for the second growing season, the GS already presented in the annual report for 2010 have been updated in the present report)
- ► At the time of recording GS, any significant HWT damage, pest or disease symptoms, or indications of failures of flower development were noted
- ► In the second growing season (2010-2011) shoot or (later in the season) leaf heights were measured at weekly intervals up to flowering, and stem height was measured at weekly intervals close to flowering (only once the stem height could be measured without damaging the emerging shoot)
- ► One-off measurements of foliage and stem heights were made at ten fixed points along each plot at a convenient date for each cultivar during its flowering period (in year 1 the heights of the tallest and shortest stems in each plot were also recorded). (These heights were measured at a convenient, appropriate stage for each cultivar, and so were 'snapshots' and did not necessarily relate to stem length at a particular cropping stage.)

Foliage and stem heights were always measured as the height of the leaf tip or the uppermost part of the bud or flower above ground level.

When a cultivar was flowering the following were recorded:

- ► 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' and 'Yellow Cheerfulness' the number of florets per stem was recorded
- ► Any stems with damaged or necrotic buds or flowers, including 'drumsticks'.

In 2010 these records were made on 11 April for 'Dutch Master' and 'Carlton', 18 April for 'Kerensa', 'Red Devon' and 'Yellow Cheerfulness', and 26 April for 'Actaea' and 'Great Leap'.

In 2011 the dates were 10 March for 'Dutch Master', 17 March for 'Hugh Town', 24 March for 'Carlton', 29 March for 'Kerensa' and 'Red Devon', 18 April for 'Actaea' and 27 April for 'Great Leap' and 'Yellow Cheerfulness'.

Foliar symptoms of disease were assessed in mid-May 2011. Where there were substantial disease levels, incidence and severity were scored for each plot. In these cases incidence was scored from 1 to 10 on a semi-logarithmic scale (up to 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000 leaves per plot affected), and severity as the most usual extent of lesions, again using a 1 to 10 score (from 1, meaning one isolated lesion per leaf or stem, up to 10, meaning that most of leaves or stems were dying-down or grossly disfigured and up to 100% of their green area was affected).

Bulb lifting and recording

The three first-year blocks were dug out manually on 15 July 2010 and the second-year blocks on 4 July 2011, the foliage having been flailed off a few days' earlier in each case. On lifting, each net of bulbs was placed in a wooden bulb tray and the trays stacked under a lean-to roof to air-dry (taking about 2 weeks). The bulbs from each plot were then recovered from the netting and roughly cleaned, separated and sorted manually.

Net integrity and bulb recovery were deemed good in both years. In spring 2011 a total of 66 bulbs sprouted from the combined sites of the previously lifted one-year-down plots, indicating a bulb recovery rate better than 99.5% (based on planting *ca*. 100 bulbs per plot), and the bulk of these 'groundkeepers' produced thin-leaved plants typical of small offset bulbs.

Following further air-drying at ambient conditions in a typical large agricultural shed with good air movement (*ca.* 4 weeks) the plots were graded into <10, 10-12, 12-14, 14-16 and >16cm sizes using a conventional daffodil bulb-grading machine with slotted riddles (2010) or manually (2011). During bulb grading any grossly rotted and damaged bulbs were counted and discarded, and the number and weight of sound (marketable) bulbs were recorded grade-by-grade. Storage of the graded bulbs was continued under the same ambient conditions as before.

At bulb grading in 2011 substantial numbers of bulbs were seen with damaged base plates, a finding seen elsewhere in commercial daffodils in 2011 (industry representatives, personal communications). This damage appeared due to large narcissus fly larvae infesting the bulbs in the previous year, often resulting in grossly damaged bulbs. Since formalin has been reported under some circumstances to cause base plate damage in the form of a 'corkiness' of texture (Briggs, 1988), the possibility that other HWT additives might cause internal bulb damage was checked. Fifty-bulb samples were taken at random from the middle grades (10-12, 12-14 and 14-16cm) of plots each HW treatment of four varieties ('Carlton', 'Dutch Master', 'Kerensa' and 'Yellow Cheerfulness') and examined for internal quality after lengthwise bisection and further cutting as necessary. The bulbs were examined to determine:

- Whether the *current* year's base plate appeared normal (i.e. normal colour and texture, root initials developing normally, and no discolouration, breaks or erosion extending internally)
- Whether the developing bulb scales and shoots appeared normal (turgid, healthy and normal in colour)
- The extent of damage due to the presence of large narcissus fly larvae (characteristically extensive damage with a single large larva, copious frass and damage from the tunnelling through the base plate), earlier large narcissus fly larvae (usually extensive, with granular frass, blackened, dried bulb scales and damage from tunnelling), base rot (typically dark brown and moist and either in the basal plate or clearly extending up and out from the base plate) and neck rot (typically dark brown and moist and clearly spreading downwards from the neck of the bulb). Mechanical damage, invariably in this case caused by implements when lifting the bulbs manually, was ignored

Where abnormalities in the current year's base plate was not assignable to any specific category, it usually took the form of somewhat darker areas spreading in from the outside edge or was entirely internal, referred to here as 'base plate darkening' (BPD), though it is by no means clear whether this putative 'damage' was simply part of the normal range of appearance of the base plate, a reaction to minor mechanical damage, or a result of enzymic activity on the cut surface. The number of affected bulbs was recorded and the severity of damage was scored as 1, confined to a small area of the base plate; 2, over a larger area of the base plate; 3, spreading into the bulb scales; 4, affecting up to 50% of the area of the bulb scales, and 5, most or all of the bulb scales affected.

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. In the second crop year, data for two plots were missing owing to vandalism. After preliminary data analysis, where considered worthwhile, each year's data were investigated using the factorial analysis of variance (AoV) tool within 'Microsoft Office Excel'. Following standard practice, where appropriate data were also analysed following transformation. In some cases data were so sparse (e.g. the number of stems with dead or unmarketable buds/flowers) or so uniform (e.g. smoulder incidence and severity scores) as to make formal analysis inappropriate.

The main findings are described under 'Results', and more detailed tables of results and AoV are given in Appendix 2. In this type of trial the differences between the mean values of the different 'variates' for each plot will be due to a combination of 'error' (biological variation and experimental error) and true effects of the imposed 'factors'. AoV enables these effects to be apportioned; in this case the variates were flower number, leaf height, etc., there were 288 plots in the trial, and the imposed factors were cultivar, HW treatment and the interaction between cultivar and HW treatment. Where data were subjected to AoV, the effects (e.g. of HW treatment on flower yield) are described conventionally as 'not significant' (NS, $P>0.05$), 'significant' (*, $P\leq0.05$), 'highly significant' (**, $P\leq0.01$) or 'very highly significant' (***, $P\leq0.001$).

Table 1
A proposed scale of Growth Stages (GS) for daffodils[1]

Period	*GS*	*Description*	*Notes*
Unplanted bulb (GS 0)	0.1	'Dormant' bulb in storage	
	0.2	Root initial development evident close to the surface of the bulb	Bulbs would normally be planted at GS 0.1 or 0.2
	0.3	Shoot and/or roots emerging from stored bulb	Applies only to stored bulbs
	0.4	Bulb becoming desiccated with loss of skin, emerging roots or shoots becoming moribund	Applies only to stored bulbs
	0.5	Bulb shrivelled, light in weight, or rotted	Applies only to stored bulbs
Planted bulb (GS 1)	1.1	No clear emergence of shoot or roots from bulb	
	1.2	Roots and/or shoot emerging, <1cm in length	
	1.3	Roots and shoot elongating	
	1.4	Shoot tip close to soil surface	
Emergence (GS 2)	2.1	First shoots starting to emerge	Foliage height nominally 0
	2.2	Many shoots emerging, or shoots beginning to elongate but no buds obviously visible	Record maximum foliage height[2]
	2.3	Shoots elongating, tips of flower buds visible without pulling shoots apart	Record maximum foliage height
	2.4	Full length of flower buds visible, buds 'upright pencils'	Record maximum foliage and stem heights[2]
Anthesis (GS 3)	3.1	Flower buds still 'upright pencils' with no colour showing, but becoming clear of the foliage; flower cropping could begin if a very tight stage is required and stem length is adequate	Record maximum foliage and stem heights
	3.2	Flower buds are 'fat pencils' with no colour showing, flower cropping should begin	Record maximum stem height
	3.3	Pedicels bending and/or spathes splitting, colour may be showing; a very late picking stage	Record maximum stem height
	3.4	Pedicels fully 'goose-necked' but flowers not open	This stage may pass quickly and variably
	3.5	Flowers (or florets) starting to open	
	3.6	Flowers fully open	Applies to 50% of florets for multi-headed types
	3.7	Flowers starting to senesce (petal tips dying)	As above
	3.8	Flowers (or florets) fully senescent, leaves still fully green and upright	As above
Post-flowering (GS 4)	4.1	Leaves still fully green, but at least some leaves starting to bend to ground	
	4.2	As 4.1, but some leaves bending conspicuously and at least some leaves with senescent (yellowing and dying) tips	
	4.3	Most leaves almost flat, with general incidence of senescence at the leaf ends	
	4.4	Some 50% of leaf area senescent	
	4.5	Less than 10% leaf area remaining green	
	4.6	None (or a trace) of leaf area remaining green	
'Summer dormancy' (GS 5)	5.1	Small amounts of green foliage remaining attached to bulbs	
	5.2	Any foliage attached to the bulbs now dead	
	5.3	Dead foliage lost or removed	
Lifted bulb (GS 6)	6.1	Bulb surface damp and/or not cleaned	
	6.2	'First stage' drying (surface drying) complete	
	6.3	'Second stage' drying complete	
	6.4	Bulbs cleaned (and graded if appropriate)	

[1] Avoid the following when recording: plot or row ends; obvious rogues, off-types and atypically damaged/diseased plants; late flowers from lateral bulbs; and the most advanced plants if these are about 1% or less of the total

[2] Record shoot height from the point of emergence from the soil to the uppermost tip of foliage, and stem height from the point of emergence from the soil to the topmost tip if the bud, spathe or flower

Results

General observations

- ► With the exception of 'Actaea', there were no differences in overall growth and development between the various HW treatments or plots of any given cultivar in year 1. However, compared with the other five treatments, control plots of 'Actaea' had obviously fewer flowers in year 1. This difference was less obvious by year 2.

- ► With the exception of 'Hugh Town', crop development was considered normal and within expected commercial parameters. However, 'Hugh Town', a tazetta (Division 8) daffodil, produced foliage that emerged in November 2009 and was subsequently damaged by the unusually cold winter, producing relatively sparse, chlorotic foliage with damaged, blackened leaf tips. In winter 2010-2011 there was similar but milder damage.

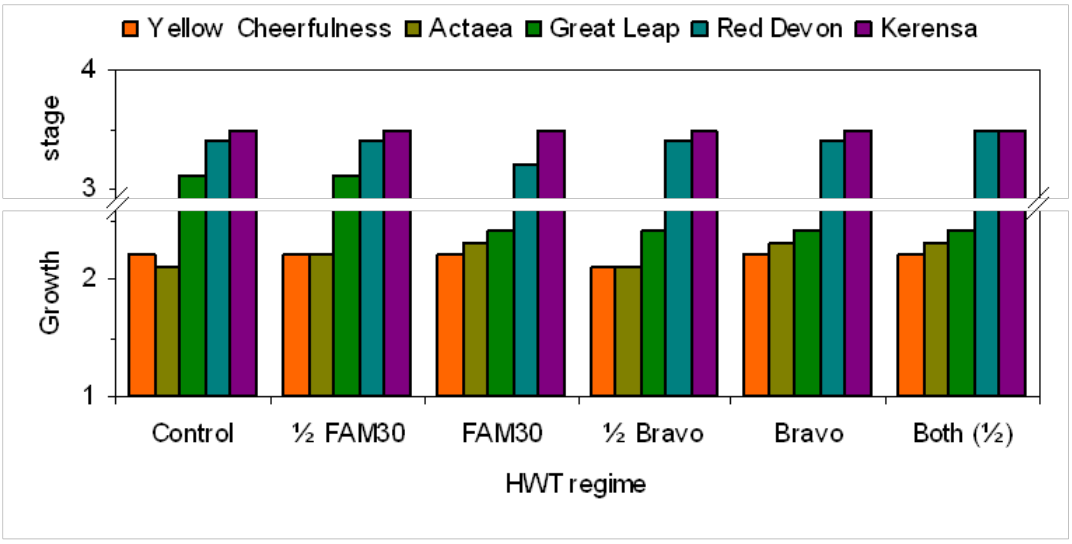
- ► The expected foliar symptoms of HWT-related damage were seen across the trial in the first year, and were considered mild and not abnormal, with roughened, mottled leaf tips. This was particularly noticeable in 'Carlton' and 'Great Leap'.

- ► There were no significant pest or disease problems in either year. In 2010, along with the usual occasional leaf lesions, smoulder was evident as white patches on buds and petals, though this was very sporadic and not localised to particular treatments. Very small numbers of plants significantly affected by base rot (yellowing foliage, early die-down) or bulb-scale mite (twisted, damaged leaves with notched edges) were seen in either year, and were not confined to particular treatments. As expected, smoulder symptoms were more obvious in the second year and occurred across most varieties. Rust was seen in some varieties in Year 2. Occasional virus symptoms were seen (yellow patches or stripes on the leaves).

Year 1: Development up to flowering

Within cultivars, the rate of progress towards flowering did not differ substantially between HW treatments. Figure 1 illustrates this for the five later-flowering cultivars, showing the general uniformity of growth stages (GS; see Table 1) across treatments within cultivars. Possibly, there were small differences between some treatments in the case of 'Great Leap'.

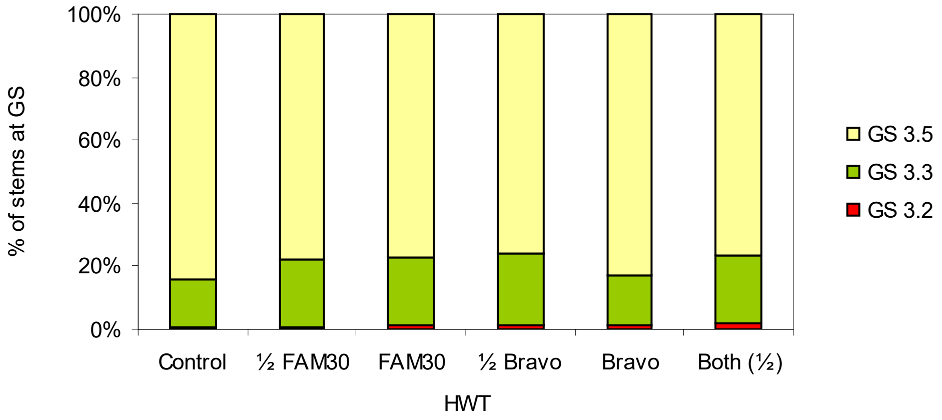
Figure 1
GS of five cultivars from six treatments in year 1 (assessed 3 April 2010)



The uniformity of the onset of flowering was also checked by recording the percentage of flowers at different stages (pencil, spathe-splitting/goose-neck and open flower) during the cropping phase of each cultivar, illustrated in Figure 2. AoV of the $\log_{10}$-transformed percentage of flowers at the open-flower stage showed the effect of HW treatment was not significant (see Appendix 2, Appendix Table 1).

Figure 2

The percentage of stems at pencil (GS 3.2), split-spathe/goose-neck (GS 3.3/3.4) and open flower (GS 3.5) stages assessed during flowering in year 1 (values are marginal means for cultivars)

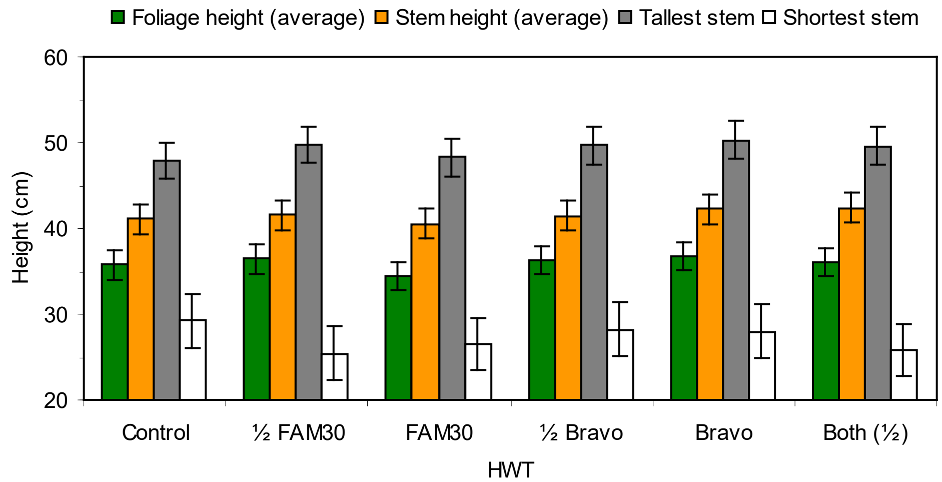


Year 1: Flowering

With the exceptions of the HWT and weather-related damage to the foliage, noted above, leaf growth appeared normal throughout the trial, with no signs of stunted or weak growth. Height measurements of foliage and stems at flowering showed that, while there were some significant (and expected) differences in leaf and stem heights between cultivars, neither HW treatment, nor the cultivar x treatment interaction exerted statistically significant effects (Figure 3, Appendix Table 2). Due to the early emergence of the foliage of ‘Hugh Town’ and consequent damage, foliage height was not measured for this cultivar.

Figure 3

Foliage and stem heights assessed at flowering in year 1 (figures are marginal means for HWT across seven varieties, ‘Hugh Town’ being omitted (see text); vertical bars are 5% LSDs)



As would be expected with such a range of cultivars, there was considerable variation in flower yield. Excluding ‘Hugh Town’ (which yielded an average of only 13 undamaged stems per plot), yields ranged from 61 for ‘Great Leap’ to 161 stems per plot for ‘Red Devon’ (Figure 4).

Although cultivar differences accounted for the bulk of the variance in these data, the effects of HW treatment and the cultivar x treatment interaction were also highly significant (see Appendix Table 3). The findings are described below. Average yields fell into two groups of HW 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’ was used; half-rate ‘Bravo 500’ gave an intermediate yield (Figure 4).

There were marked differences in yield between cultivars (Figure 5). The main findings are listed below.

- *‘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 HW treatment (half-rate ‘FAM 30’, full-rate ‘Bravo 500’ and half-rate of both chemicals) resulted in reasonable yields of stems. This effect of HW treatment was very highly significant (P<0.001).
- *‘Carlton’*: only the ‘Bravo 500’ HW treatments improved stem yields compared with the control, with ‘FAM 30’ treatments appearing to be ineffective in this base rot-susceptible cultivar. This effect of HWT was highly significant (P<0.01).
- *‘Dutch Master’*: compared with some other cultivars, stem yield appeared relatively consistent across HW treatments. Although there is a suggestion of yield reduction in the control and full-rate ‘FAM 30’ treatment, this effect of HW treatment was not statistically significant.
- *‘Great Leap’*: there was an adverse response to HWT when full-rate ‘FAM 30’ was used, with fewer stems being produced, though using half-rate ‘FAM 30’ was effective and increased yields above control levels. This effect of HW treatment was highly significant (P<0.01). In this trial ‘Great Leap’ produced many blind stems, though these were reasonably consistent in numbers across all treatments and there was no statistically significant effect, suggesting a stock problem or a varietal response to HWT or low winter temperatures.
- *‘Hugh Town’*: due to the weather damage already mentioned, few flower stems were produced in this variety. Nevertheless, there was a significant effect (P<0.05) of HW treatments on stem numbers, treatment with ‘FAM 30’ at either rate markedly reducing yields (but apparently mitigated when combined with half-rate ‘Bravo 500’. Despite the very high variance of total floret number data, there was a similar significant effect (P<0.05) on the total number of florets produced.
- *‘Kerensa’*: the number of stems produced was similar in all HW treatments, with no statistically significant effect. Even so, it is tempting to point out that the lowest flower yields resulted from the control and full-rate ‘FAM 30’ treatments.
- *‘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. This effect was significant at P<0.05.
- *‘Yellow Cheerfulness’*: all HW treatments increased stem yield compared with the control, but half-rate ‘FAM 30’, and half-rate of both additives, particularly so. The effect was significant at P<0.05.

Figure 4
The effects of HW treatment on stem yield per plot after one year (values are marginal means across all cultivars, stems with damaged flowers being excluded; vertical bars are 5% LSDs)

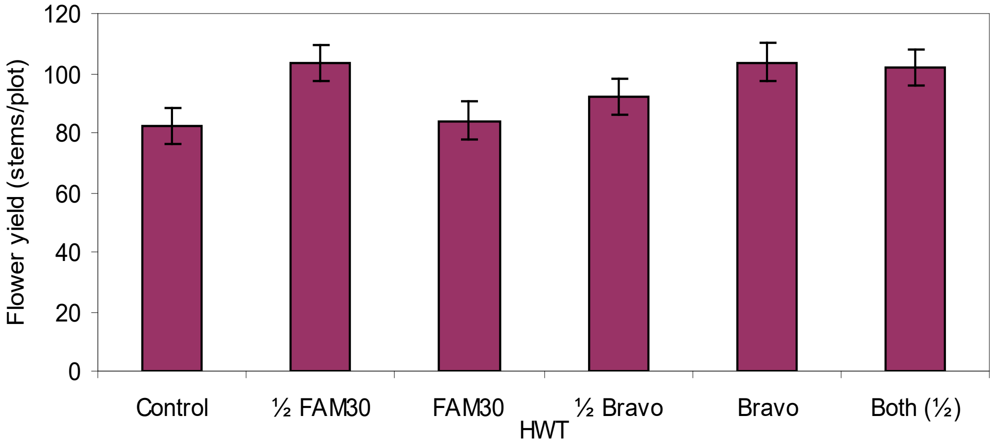
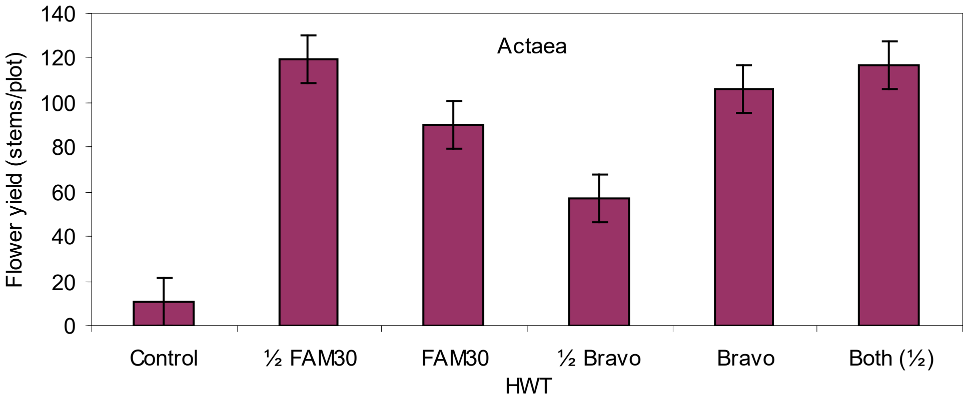
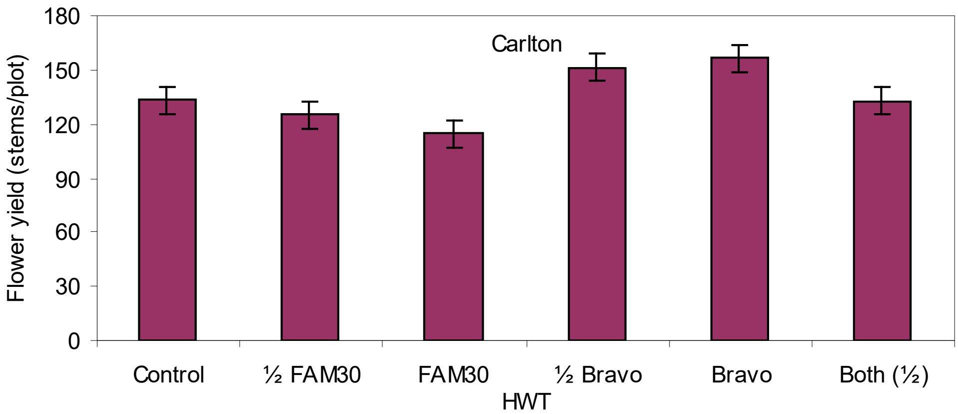
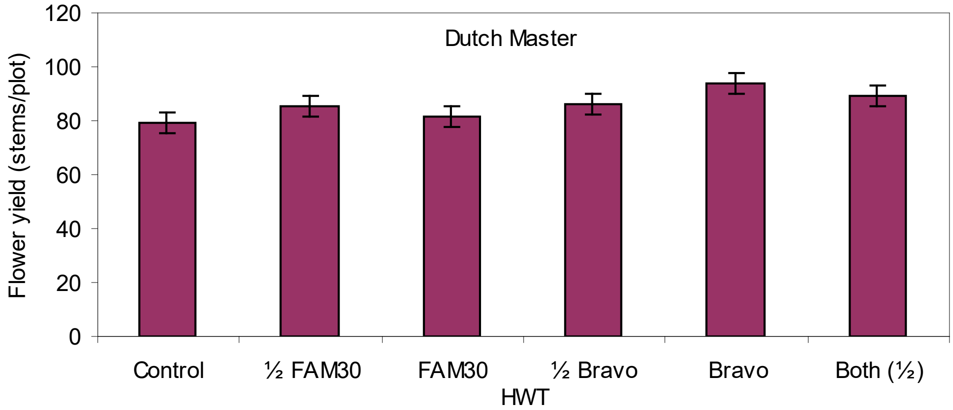
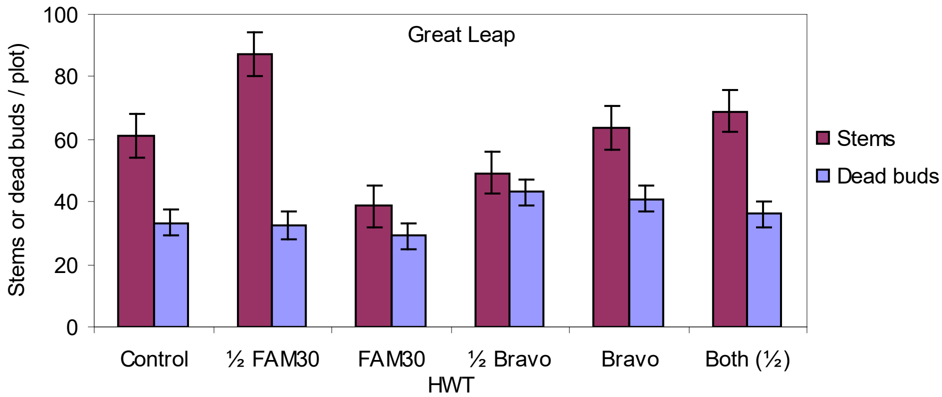


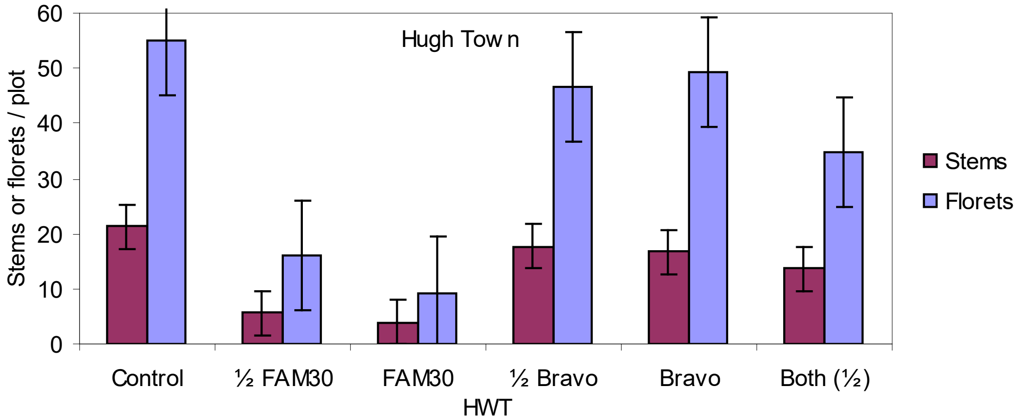
Figure 5
The effect of HW treatment on stem yield per plot after one year for eight cultivars shown individually, all stems with damaged flowers being excluded; for 'Great Leap' the number of blind stems is also shown, and for 'Hugh Town' the number of florets (vertical bars are 5% LSDs for within-cultivar comparisons)

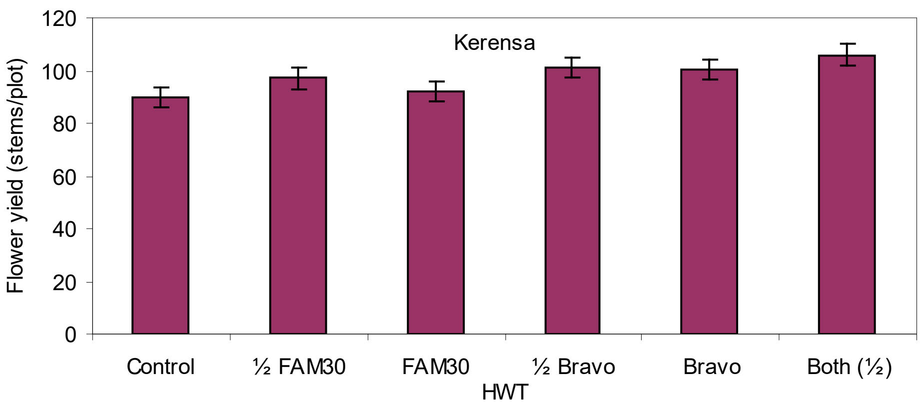


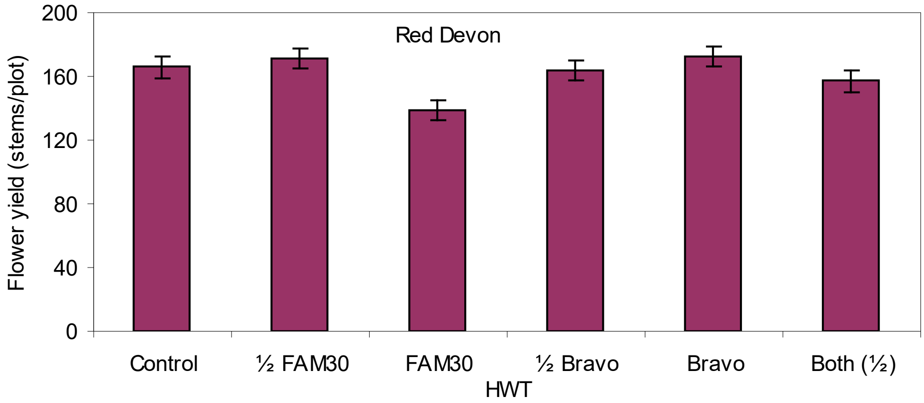


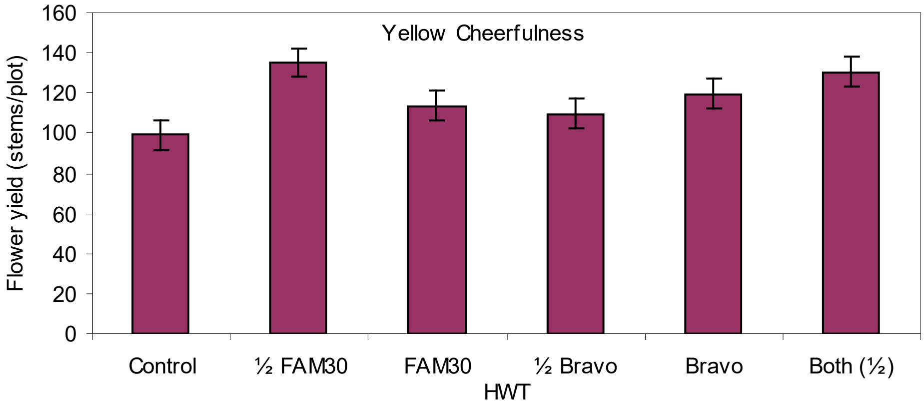

Dutch Master
Flower yield (stems/plot)
120
100
80
60
40
20
0
Control
½ FAM30
FAM30
½ Bravo
Bravo
Both (½)
HWT


Great Leap
Stems or dead buds / plot)
100
80
60
40
20
0
Control
½ FAM30
FAM30
½ Bravo
Bravo
Both (½)
HWT
Stems
Dead buds


Hugh Tow n
Stems or florets / plot
60
50
40
30
20
10
0
Control
½ FAM30
FAM30
½ Bravo
Bravo
Both (½)
HWT
Stems
Florets


Kerensa
Flower yield (stems/plot)
120
100
80
60
40
20
0
Control
½ FAM30
FAM30
½ Bravo
Bravo
Both (½)
HWT





Year 1: Flower quality

When marketable (undamaged) stems were counted, any with dead, distorted or damaged buds or flowers were recorded separately. With the exception of dead buds in 'Great Leap', mentioned above, very few dead flowers and even fewer distorted flowers were seen. Distorted flowers took the form of 'starry' flowers and split trumpets, typical of HWT damage. With such a low incidence, statistical analysis would be of dubious value, so simple tables of means are given as Tables 2 (dead flowers or buds) and 3 (damaged flowers or buds). Apart from 'Great Leap' 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 2
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 3
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	

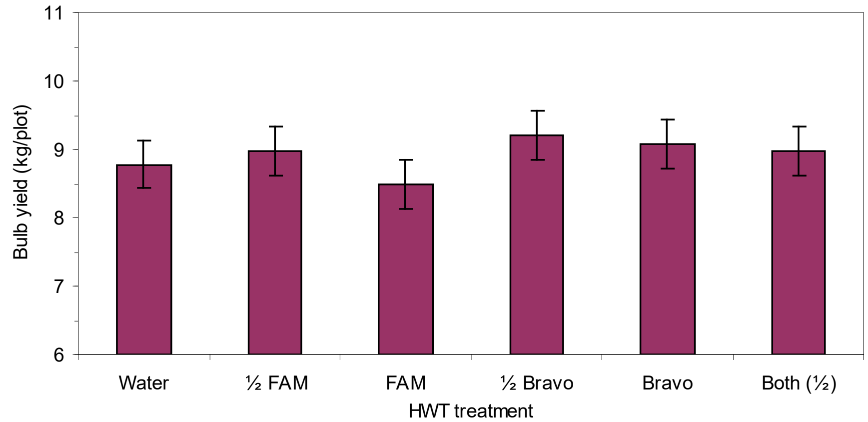
Stem length is an important attribute of crop quality. It was recorded by measuring a sample of stems from each plot during each cultivar's flowering period, and more simply by recording the height of the tallest and shortest stems. Figure 3 (see above under 'Foliage height') illustrates how little average stem height varied between HW treatments. Not unexpectedly, there were significant differences between cultivars, but stem length, irrespective of how assessed, was not significantly affected by either HW treatment or the cultivar x treatment interaction (Appendix Table 4).

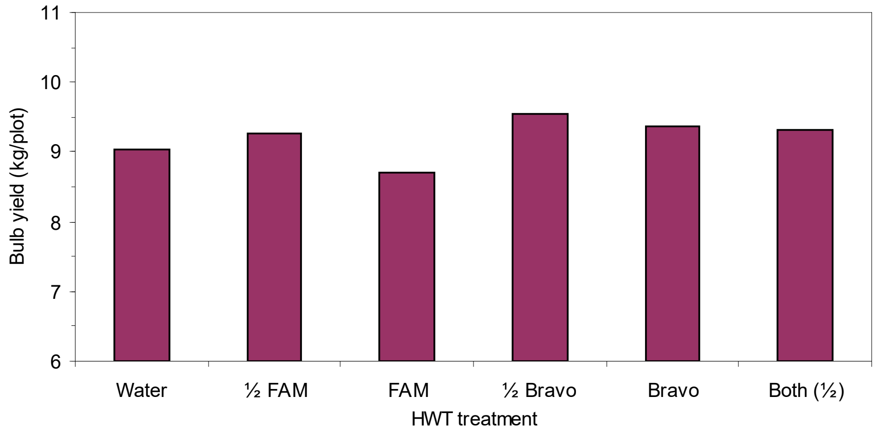
Year 1: Bulb yields (weights)

As equalised weights of bulbs had been planted in each plot, bulb yields were expressed as the simple weight or number of bulbs lifted per plot. The results and AoV for the total weight of bulbs lifted are given in Appendix Table 5, which shows that the bulk of the variation found was due to cultivar differences, with a small component due to HW treatment.

- ► 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.
- ► 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 HW treatment 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 often found in daffodil field trials.

Figure 6
The effects of HW treatment on weight of bulbs lifted after one year. Top: marginal means across all cultivars; bottom, the results with 'Actaea' excluded (vertical bars are 5% LSDs)





Year 1: Bulb yields (numbers)

Appendix Table 6 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 HW treatment on total bulb numbers, demonstrating the treatments did not cause a significant shift in growth rates or bulb-splitting.

Year 1: Saleable bulb yields

Bulb yields were also be expressed as the yield of the larger, saleable bulbs in grades from 10 to 14cm (or 12 to 16cm for 'Hugh Town', a large-bulbed variety) (see Appendix Table 7). This showed the bulk of the variation found was due to cultivar differences, with a small component due to HW treatments.

► With its large bulb size, 'Hugh Town' showed the greatest proportion of lifted bulbs in these grades (77%). 'Carlton', 'Dutch Master' and 'Kerensa' had only 50% of the lifted bulbs in these 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 the larger, saleable bulbs than the other treatments (Figure 7); this may have been due to less vigorous growth, with fewer bulbs growing to the larger (>14cm) sizes (Figure 8).
► The interaction between cultivar and HW treatment was not significant.
► These conclusions were confirmed by analysis of the log_{10}-transformed data.

Figure 7
The effects of HW treatment on the percentage of bulb yield (after 1 year) in the larger, saleable grades (10-14cm, or 12-16cm for 'Hugh Town') (marginal means across all cultivars, vertical bars are 5% LSDs)

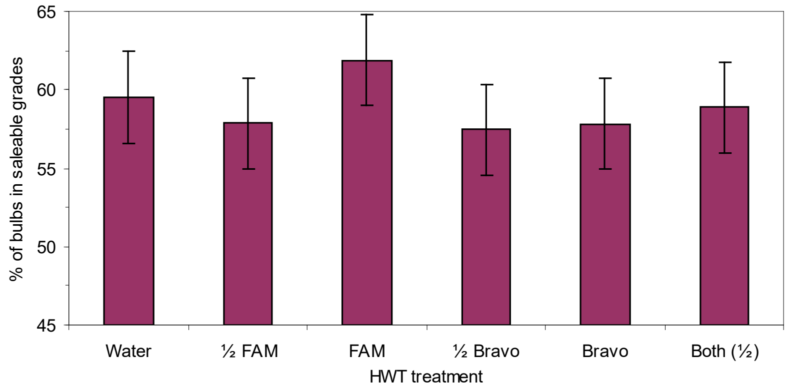
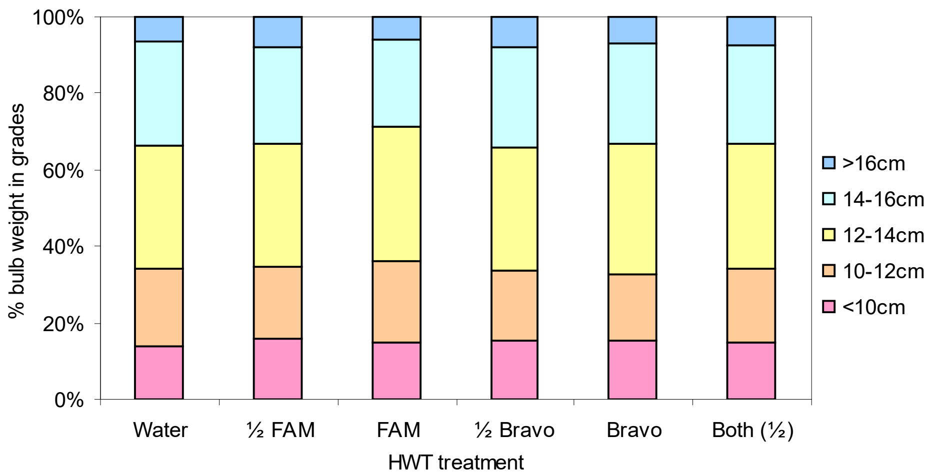


Figure 8
The effects of HW treatments on the percentage of bulb yield in size grades after 1 year (marginal means across all cultivars

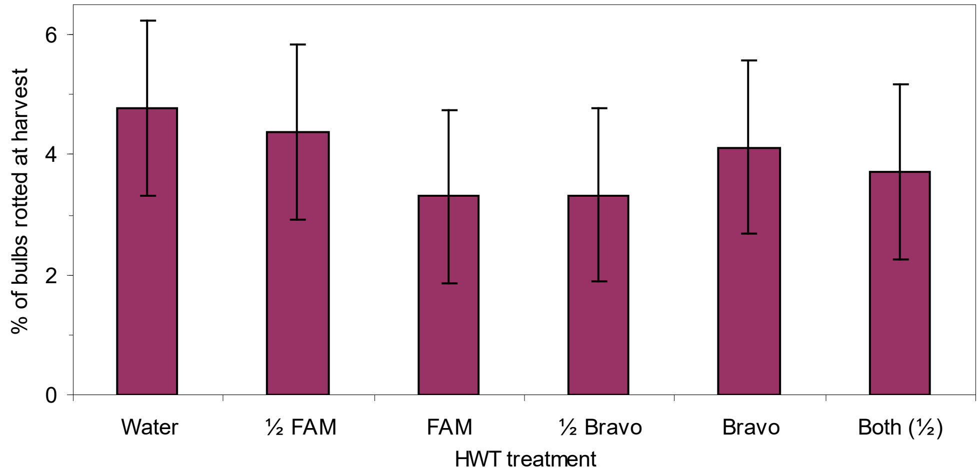


Year 1: Unmarketable bulbs

Overall, although bulb yields in this trial were not exceptional, very few bulbs were rejected at grading due to rotting or damage (see Appendix Table 8). 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 HW treatment or the interaction between cultivars and treatment.

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

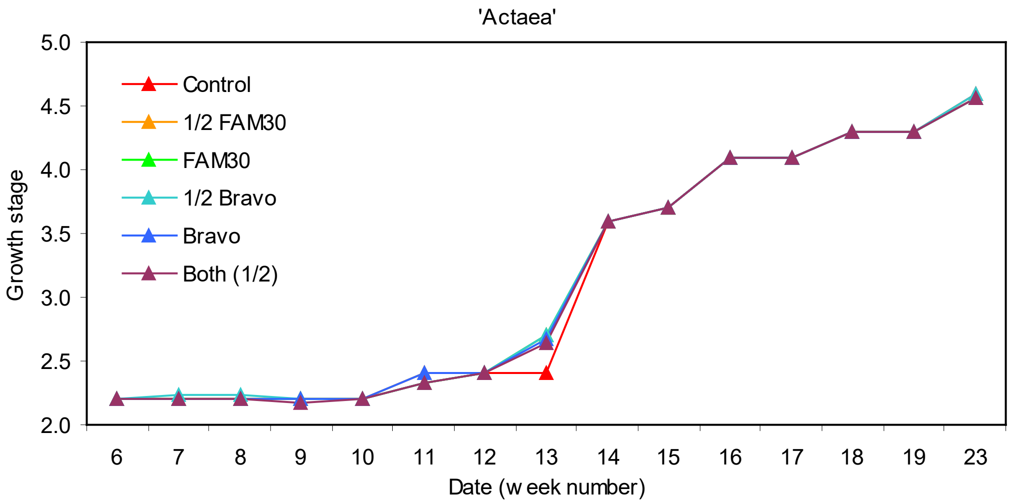
Figure 9
The effects of HW treatments on the percentage of bulbs rotted or damaged at grading in year 1 (marginal means across all cultivars, vertical bars are 5% LSDs)

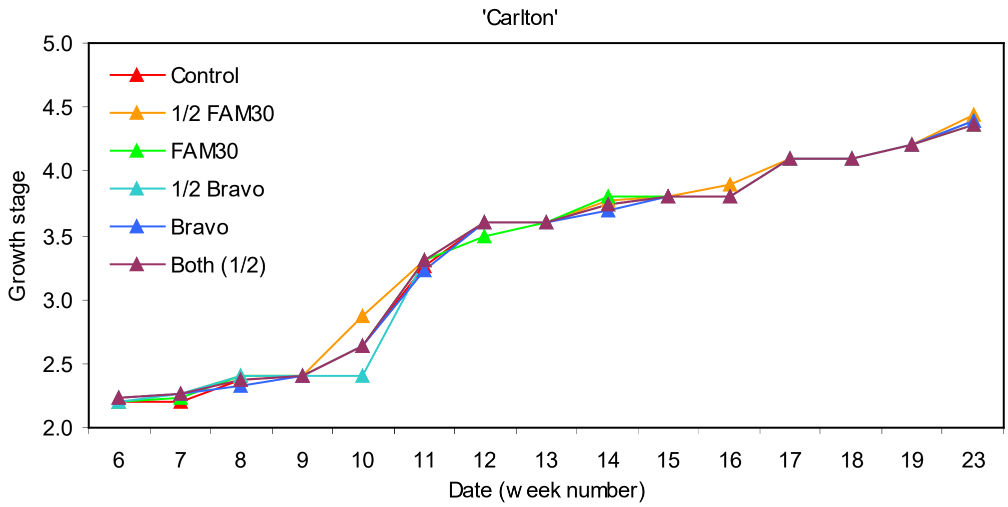


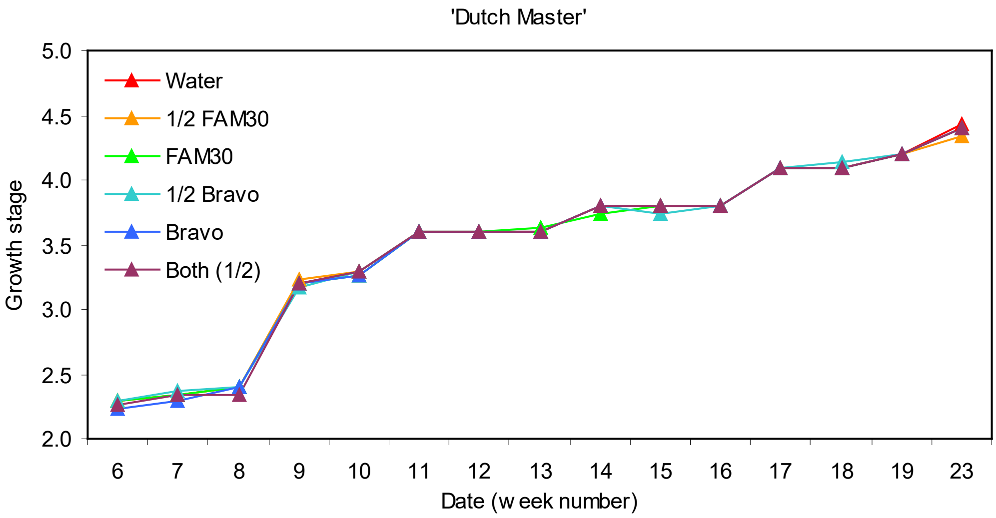
Year 2: Crop development

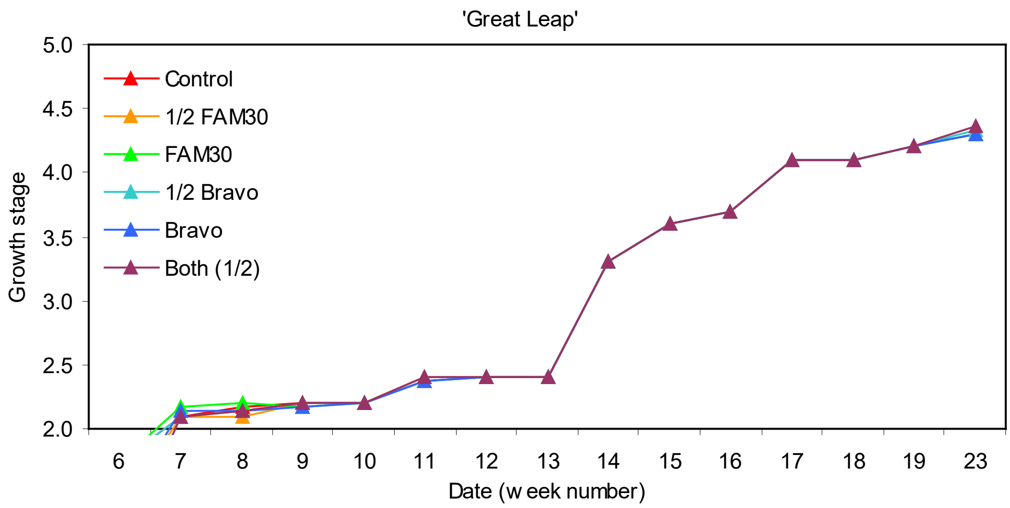
The development of crops in the second growing season (2011) is shown as the weekly GS, shoot/leaf height and stem height in Figures 10 to 12, respectively. For each of the eight cultivars in the trial there were no, or only minimal, differences in the rate of development due to HW treatment. Leaf height was a highly variable measurement, and this is obvious in Figure 11 where, however, it was also clear that there were no consistent differences in shoot/leaf height due to the treatments given. As has already been seen above, the growth pattern of 'Hugh Town' was atypical and only representative leaf height measurements were made; these too showed no consistent differences due to HW treatments. Stem heights measured near flowering also indicated there were no consistent differences between treatments.

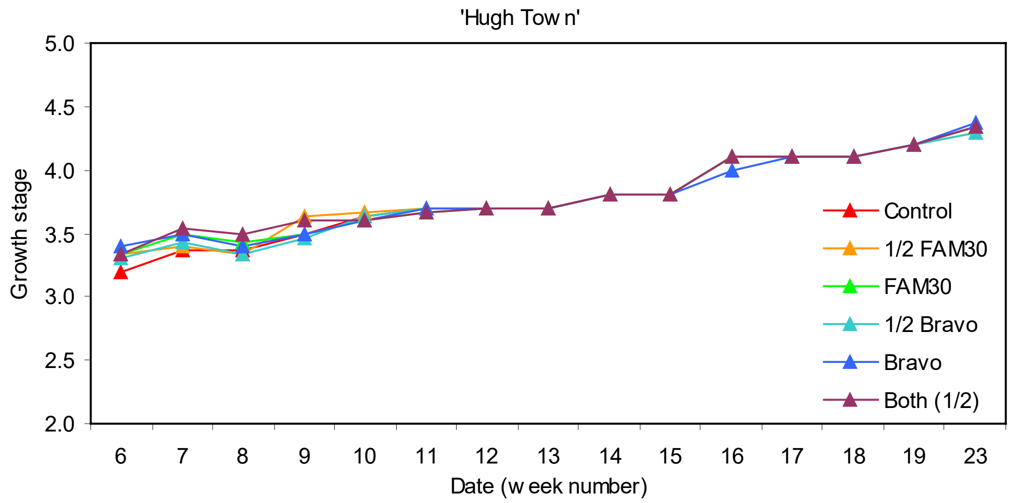
Figure 10
Progress through GS for eight cultivars in the second growing season (2011) following six HW treatments in 2009; for explanation of GS, see Table 1

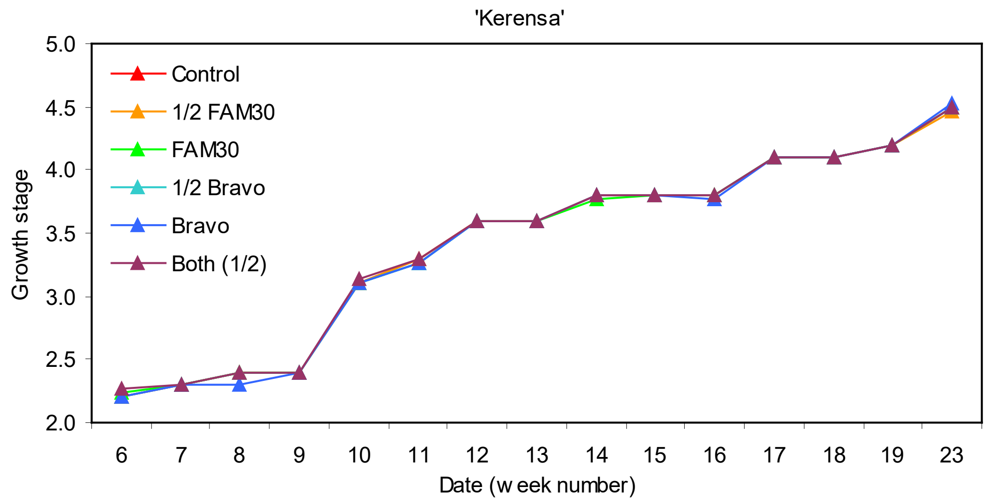


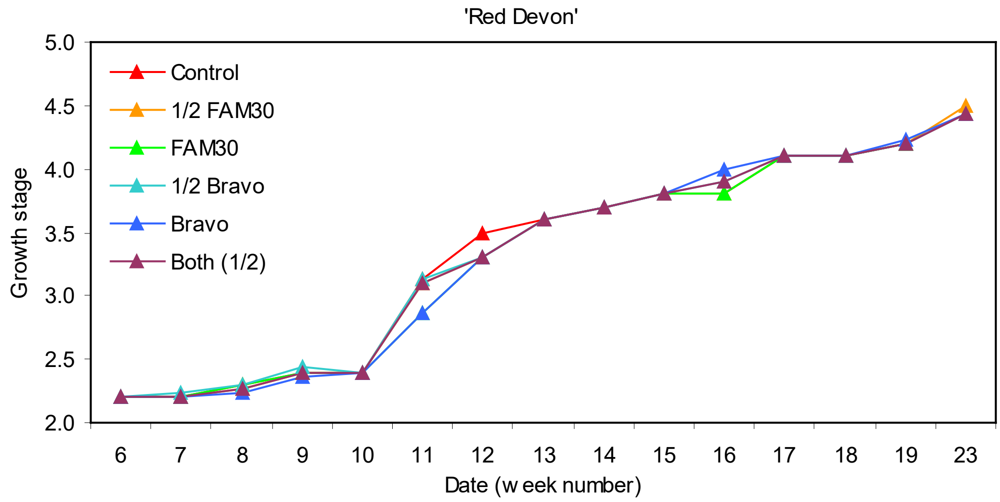

'Carlton'
Growth stage
Date (w eek number)
Control
1/2 FAM30
FAM30
1/2 Bravo
Bravo
Both (1/2)


'Dutch Master'
Growth stage
Date (w eek number)
Water
1/2 FAM30
FAM30
1/2 Bravo
Bravo
Both (1/2)


'Great Leap'
Growth stage
Date (w eek number)
Control
1/2 FAM30
FAM30
1/2 Bravo
Bravo
Both (1/2)


'Hugh Tow n'
Growth stage
5.0
4.5
4.0
3.5
3.0
2.5
2.0
6
7
8
9
10
11
12
13
14
15
16
17
18
19
23
Date (w eek number)
Control
1/2 FAM30
FAM30
1/2 Bravo
Bravo
Both (1/2)


'Kerensa'
Growth stage
5.0
4.5
4.0
3.5
3.0
2.5
2.0
6
7
8
9
10
11
12
13
14
15
16
17
18
19
23
Date (w eek number)
Control
1/2 FAM30
FAM30
1/2 Bravo
Bravo
Both (1/2)


'Red Devon'
Growth stage
5.0
4.5
4.0
3.5
3.0
2.5
2.0
6
7
8
9
10
11
12
13
14
15
16
17
18
19
23
Date (w eek number)
Control
1/2 FAM30
FAM30
1/2 Bravo
Bravo
Both (1/2)

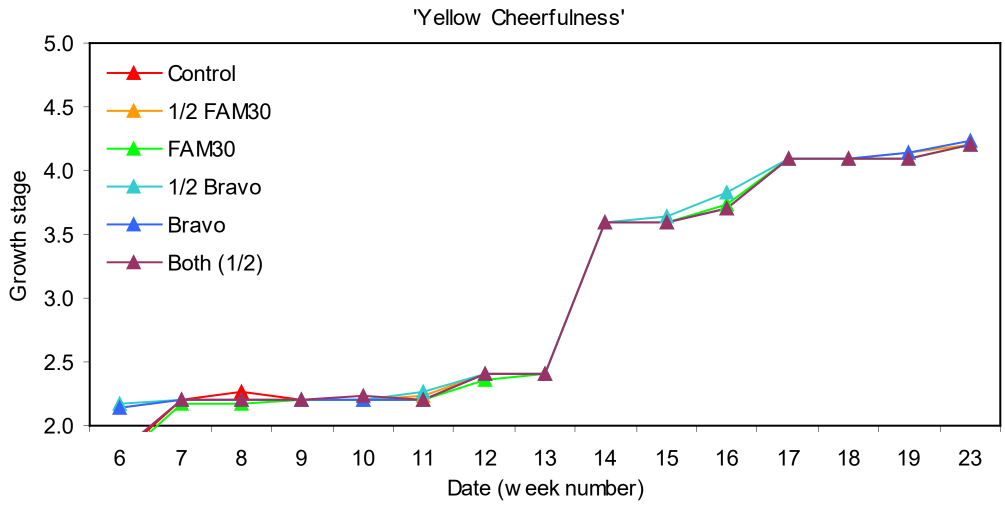
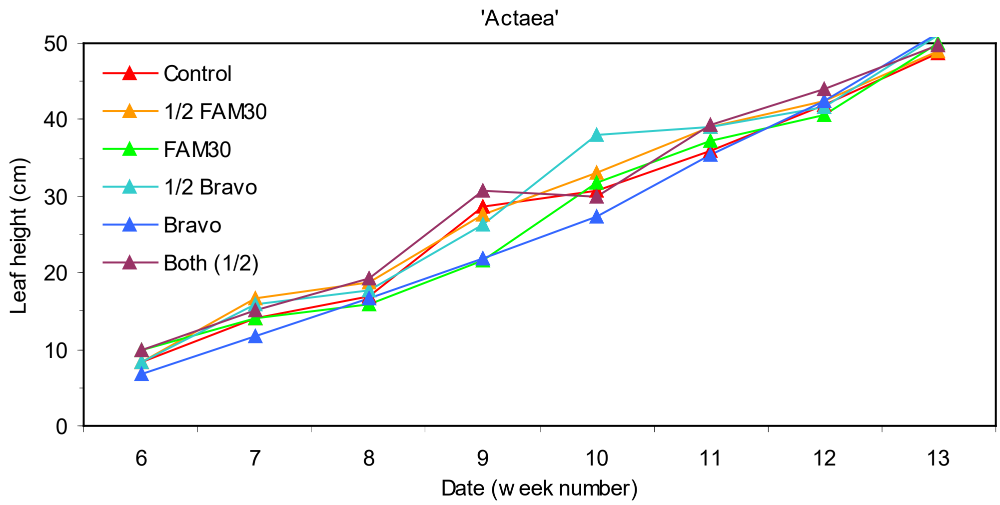
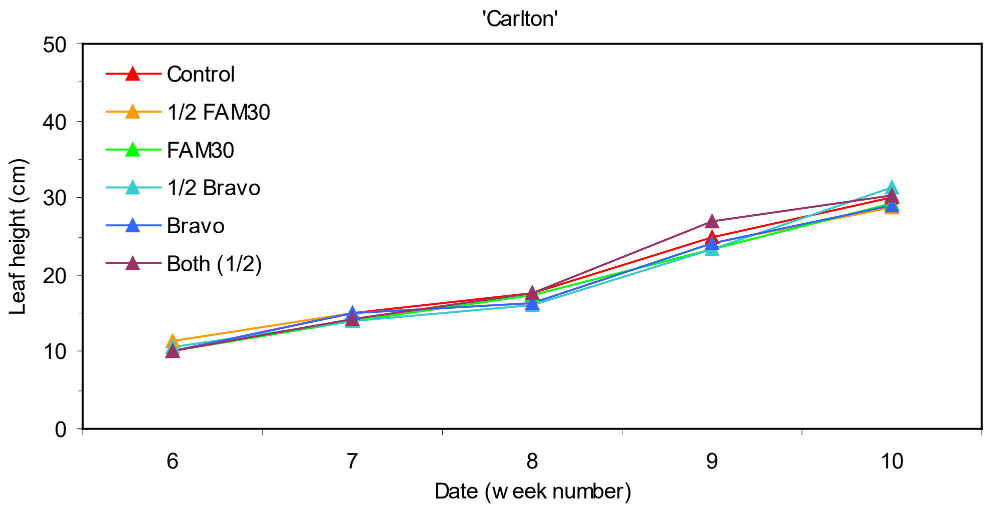
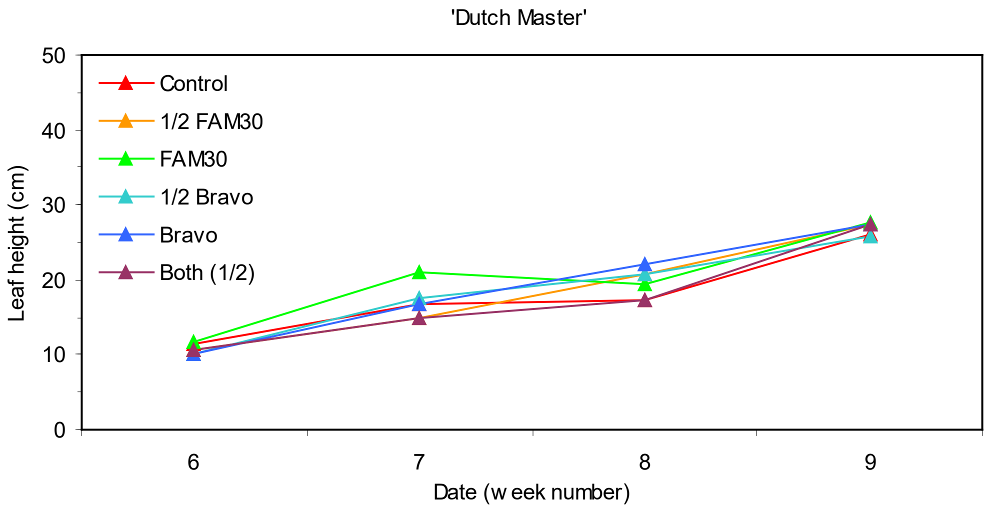
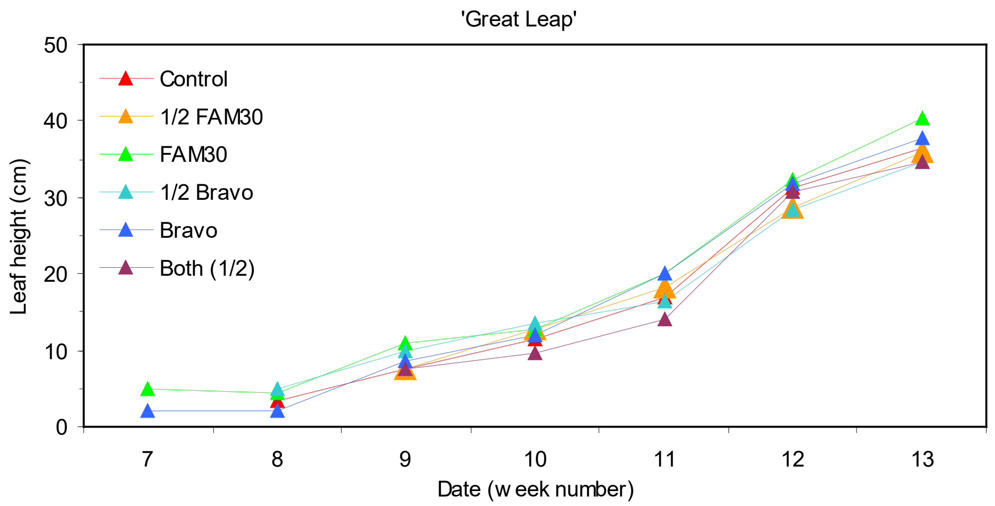


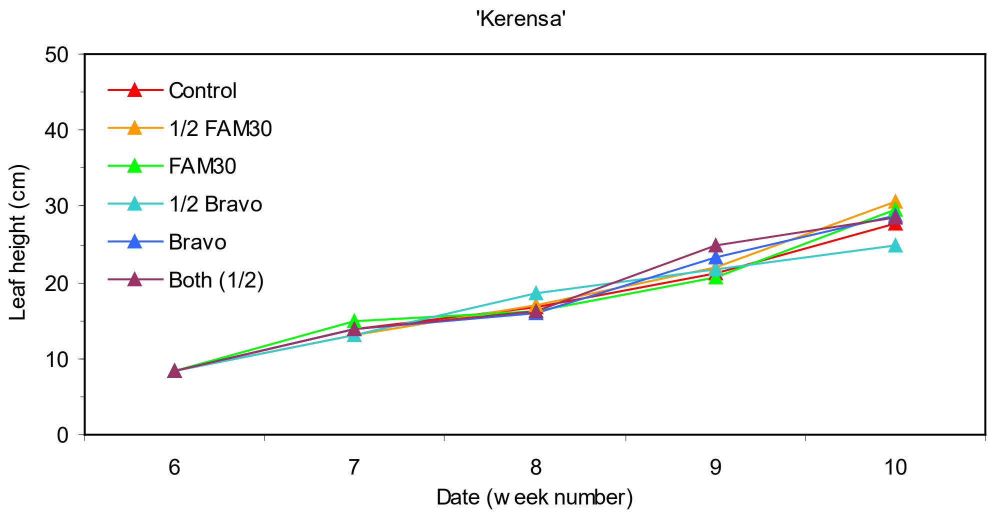
Figure 11
Shoot/leaf height for seven cultivars in the second growing season (2011) following six HW treatments in 2009 (for 'Hugh Town', see text)

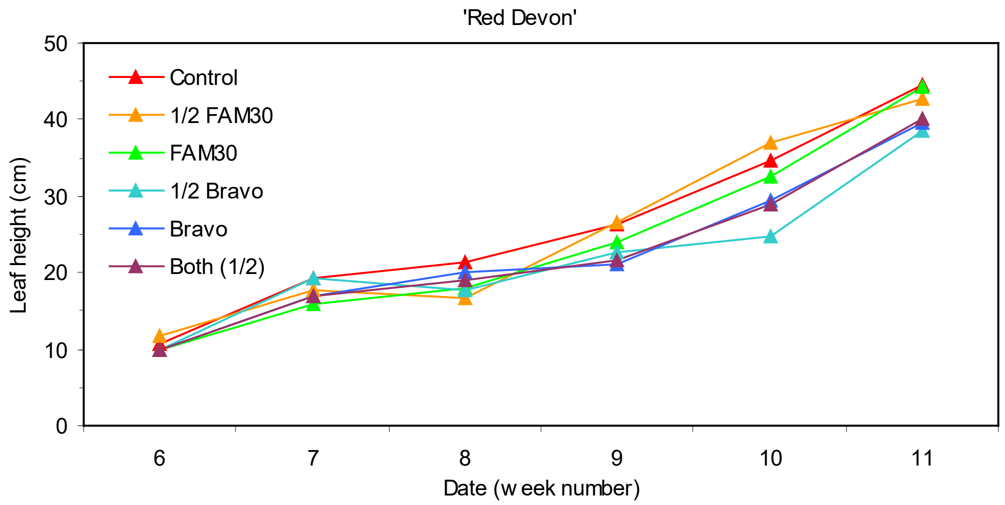





'Dutch Master'
Leaf height (cm)
50
40
30
20
10
0
Control
1/2 FAM30
FAM30
1/2 Bravo
Bravo
Both (1/2)
6
7
8
9
Date (w eek number)


'Great Leap'
Leaf height (cm)
50
40
30
20
10
0
Control
1/2 FAM30
FAM30
1/2 Bravo
Bravo
Both (1/2)
7
8
9
10
11
12
13
Date (w eek number)


'Kerensa'
Leaf height (cm)
50
40
30
20
10
0
Control
1/2 FAM30
FAM30
1/2 Bravo
Bravo
Both (1/2)
6
7
8
9
10
Date (w eek number)



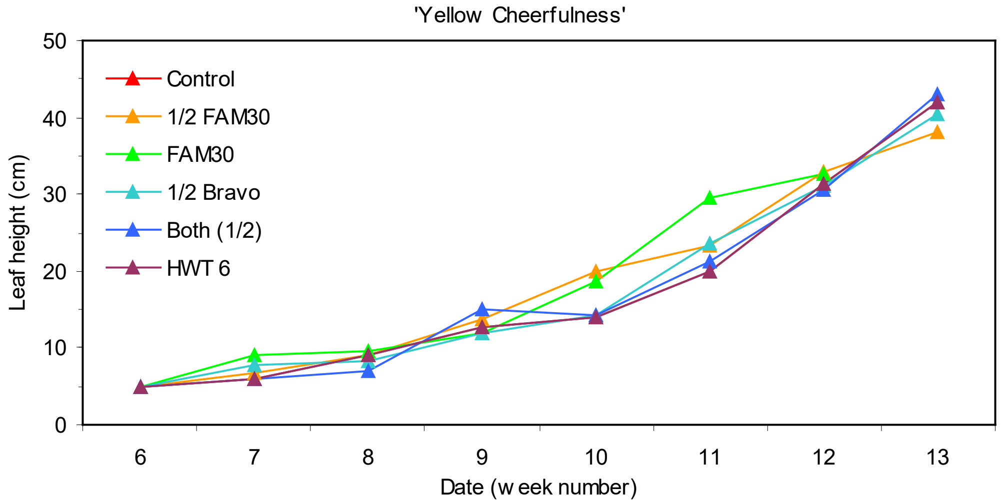
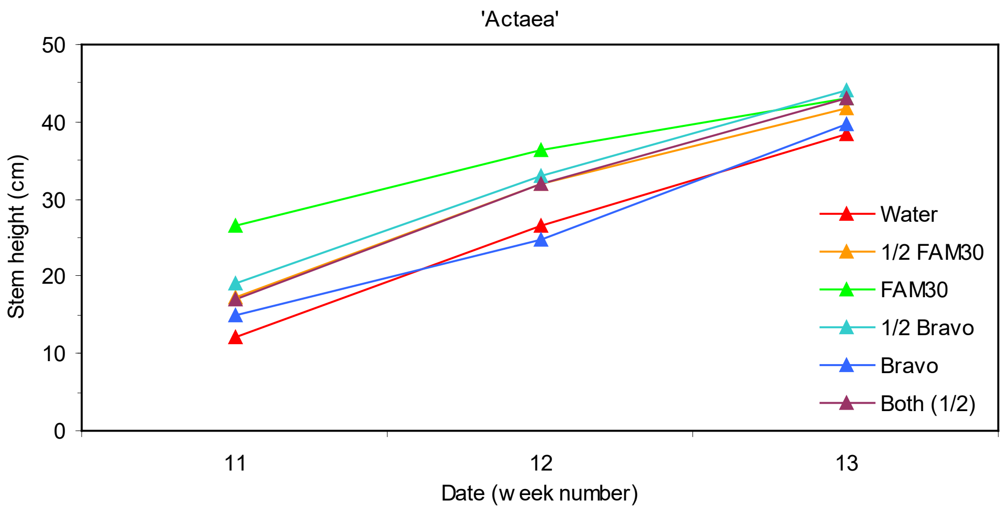
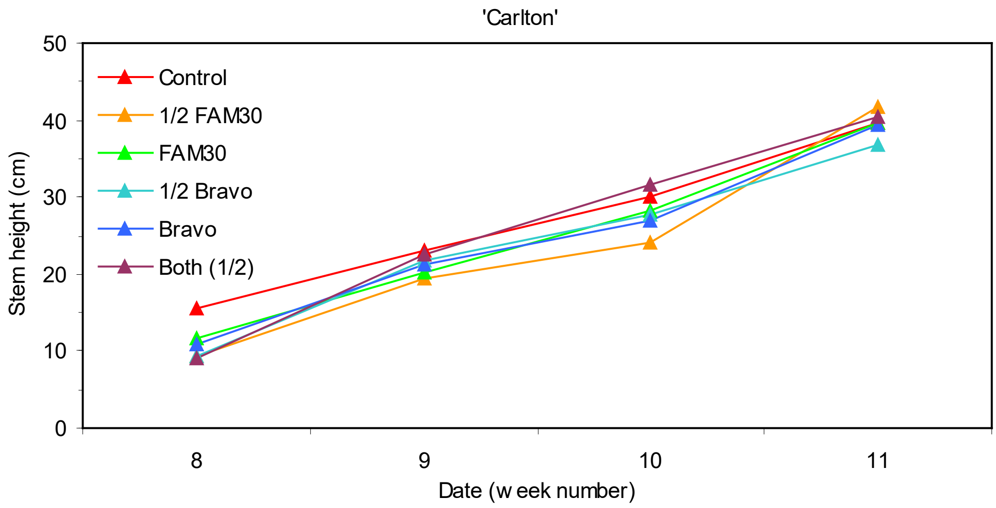
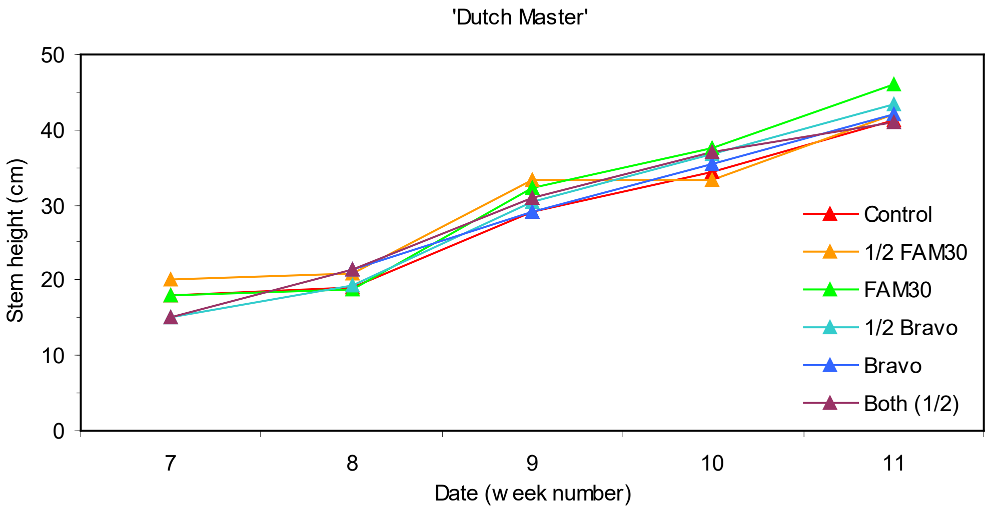
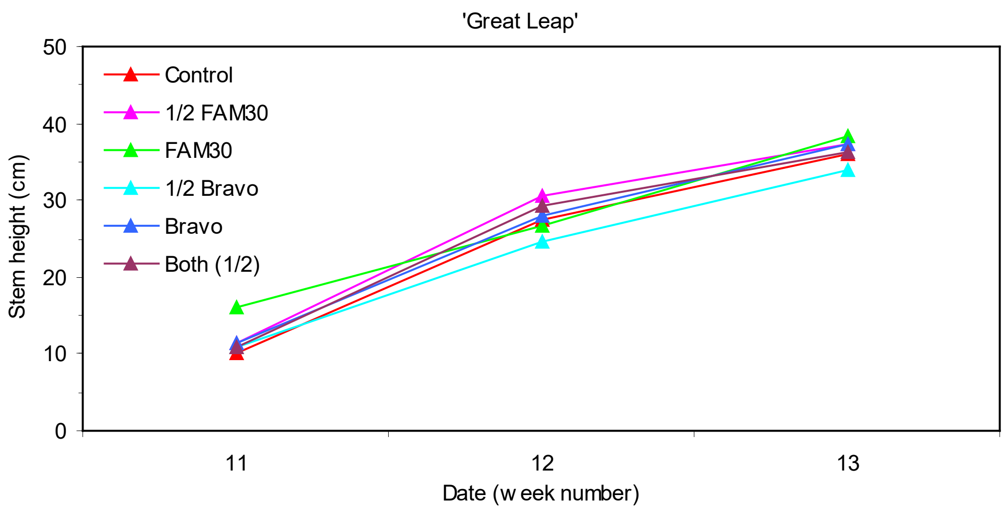


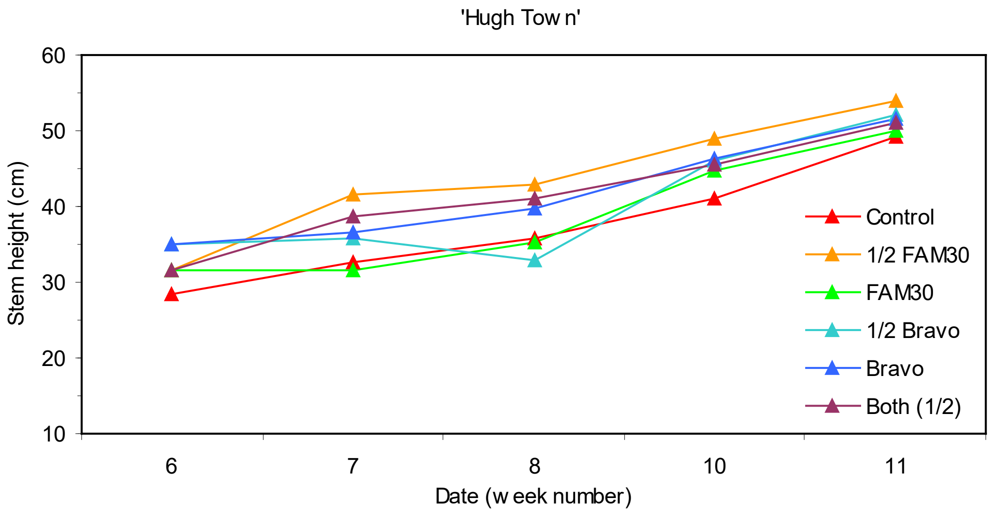
Figure 12
Stem height for eight cultivars in the second growing season (2011) following six HW treatments in 2009

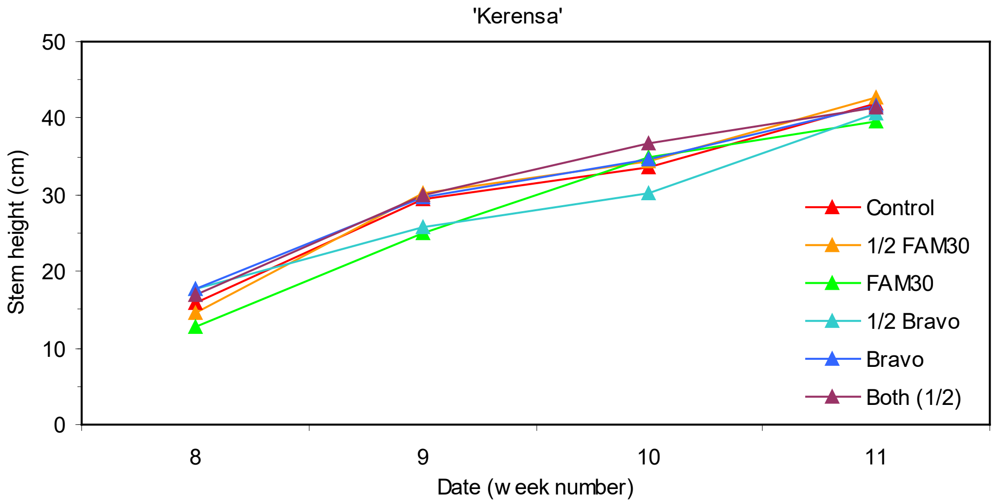


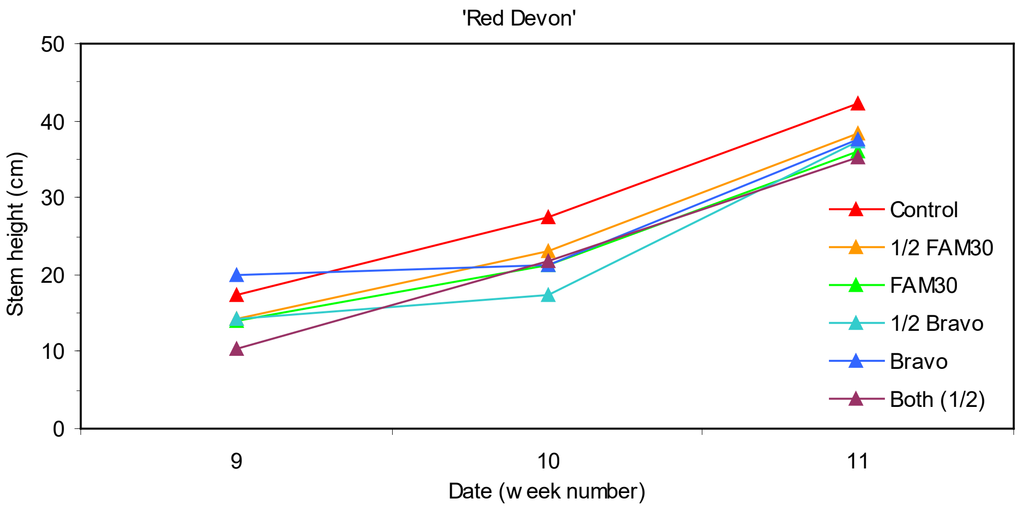

'Carlton'
Stem height (cm)
50
40
30
20
10
0
Control
1/2 FAM30
FAM30
1/2 Bravo
Bravo
Both (1/2)
8
9
10
11
Date (w eek number)

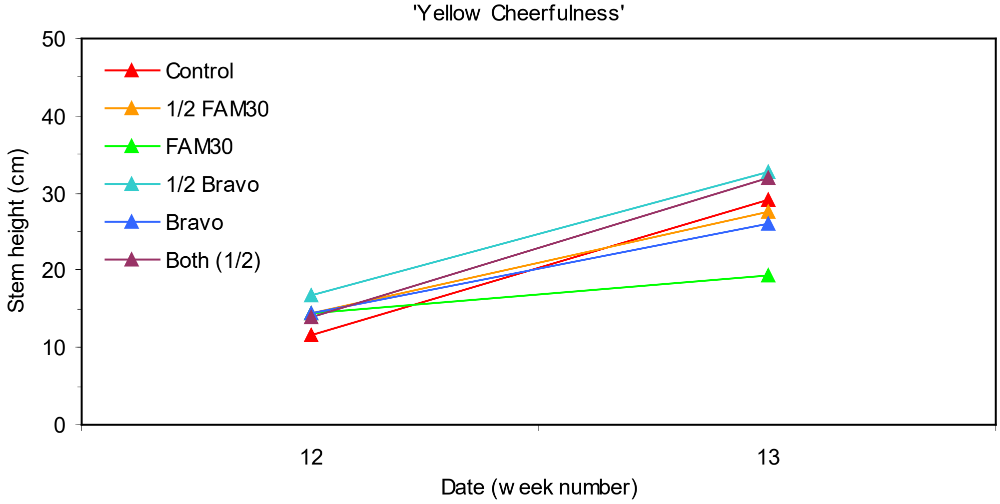

'Dutch Master'
Stem height (cm)
50
40
30
20
10
0
Control
1/2 FAM30
FAM30
1/2 Bravo
Bravo
Both (1/2)
7
8
9
10
11
Date (w eek number)


'Great Leap'
Stem height (cm)
50
40
30
20
10
0
Control
1/2 FAM30
FAM30
1/2 Bravo
Bravo
Both (1/2)
11
12
13
Date (w eek number)


'Hugh Tow n'
Stem height (cm)
60
50
40
30
20
10
6
7
8
10
11
Date (w eek number)
Control
1/2 FAM30
FAM30
1/2 Bravo
Bravo
Both (1/2)


'Kerensa'
Stem height (cm)
50
40
30
20
10
0
8
9
10
11
Date (w eek number)
Control
1/2 FAM30
FAM30
1/2 Bravo
Bravo
Both (1/2)


'Red Devon'
Stem height (cm)
50
40
30
20
10
0
9
10
11
Date (w eek number)
Control
1/2 FAM30
FAM30
1/2 Bravo
Bravo
Both (1/2)



Year 2: Flower yield and quality

Appendix Table 9 details the number of marketable stems (the numbers of stems at cropping time appearing free of defects). The main factor affecting stem numbers was cultivar (P<0.001), with an overall mean of only 51 stems per plot for ‘Hugh Town’ and between 111 (‘Dutch Master’) and 222 (‘Yellow Cheerfulness’) stems per plot for the other cultivars. There was a significant but weaker effect of HWT on stem numbers (P<0.05), the highest yield being 158 per plot following HWT with ‘FAM 30’ + ‘Bravo 500’ combined, and the lowest 142 where full-rate ‘FAM 30’ had been used. However, the interaction between cultivar and HWT was also significant (P<0.01), indicating that the different cultivars may be responding differently to HWT regimes, but the safest conclusion may be that, in general, HWT that included ‘Bravo 500’ (at either rate) gave better results than those that did not.

Because of the atypical growth of ‘Hugh Town’, flower yields were also analysed with the ‘Hugh Town’ data excluded (Appendix Table 10), though this only backed up the conclusions already drawn.

‘Hugh Town’ and ‘Yellow Cheerfulness’ are multi-headed, so the numbers of florets per stem were also examined (Appendix Table 11). ‘Hugh Town’ produced twice as many florets as ‘Yellow Cheerfulness’ (P<0.001), but both the effects of HWT and the interaction between cultivar and HWT were not statistically significant.

In addition to marketable stems, a very few additional stems were considered unmarketable because of defects, and the percentage of these is shown in Table 4. No statistical analysis was attempted because of the paucity of data. In all but one cultivar, the proportion of stems with unmarketable flowers was less than 0.5%, but in nearly 5% of the stems of ‘Great Leap’ the flower buds dried following the failure of the spathe to split normally. These dead buds appeared to occur across all HW treatments. In addition to the cultivars in Table 4, there were several ‘drumsticks’ across the plots of ‘Hugh Town’, and these probably represented the effects of the poor growing conditions for this cultivar and the effects of low temperatures.

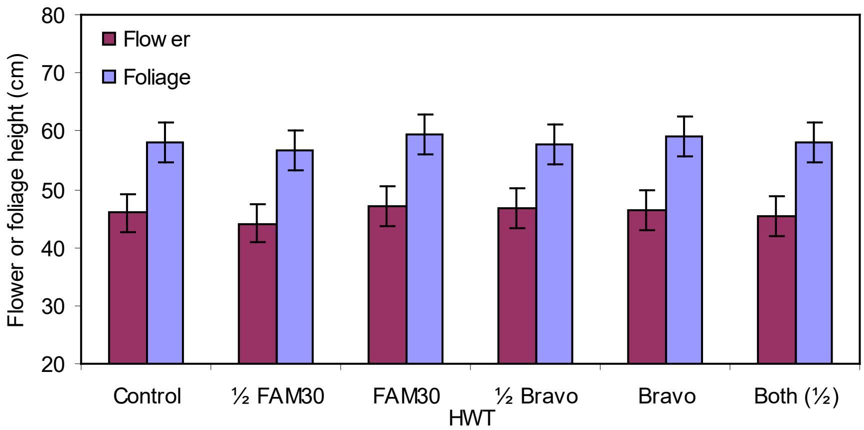
Table 4
The percentage of stems with defects in plots of daffodil cultivars from different HW treatments (for 'Hugh Town', see text)

Cultivar	HWT treatment							Defect
	Control	*'FAM 30' (½)*	*'FAM 30'*	*'Bravo 500' (½)*	*'Bravo 500'*	*Both (½)*	*Mean*	
Actaea	0	0	0	0	0	0	0	-
Carlton	0	0.2	0	0	0	0	0.03	White spotting on buds
Dutch Master	0.3	1.0	0	0.3	0	0	0.26	Marks from smoulder primaries
Great Leap	3.4	4.4	5.3	4.3	5.9	2.7	4.33	'Drumsticks', non-splitting spathes
Kerensa	0	0	0	0	0	0	0	-
Red Devon	0.0	0.4	0.2	0.0	0.6	0.2	0.24	'Drumsticks', non-splitting spathes
Yellow Cheerfulness	0.2	0.1	1.1	0.3	0.1	0.0	0.30	'Drumsticks', non-splitting spathes
Mean	0.55	0.86	0.94	0.69	0.96	0.41		

Year 2: Flower and foliage height

As an overall measure of 'vigour', average flower and foliage heights were determined for each cultivar during flowering. Figure 13 shows that, as for in the previous year, there were the expected statistically significant differences between cultivars, but not between the six HW treatments (see also Appendix Tables 12 and 13).

Figure 13
Flower and foliage heights during the flowering period of year 2 for daffodils from 6 HW treatments. Flower heights are marginal means across the eight cultivars, foliage heights across seven cultivars ('Hugh Town' was excluded); vertical bars are 5% LSDs



Year 2: Pest and disease levels

Smoulder As expected, smoulder occurred generally across the field at a low level in year 2, and particularly in plots of 'Carlton', 'Dutch Master', 'Great Leap' and 'Yellow Cheerfulness' where the average incidence and severity scores (on scales of 1 to 10) were 6 and 7, respectively. Within a cultivar the infection appeared uniform and there were no HW treatment-related effects.

Physiological rust Rust symptoms were seen on leaves and stems of 'Carlton', 'Dutch Master' and 'Great Leap'. 'Dutch Master' was worst affected, with incidence and severity scores averaging 7 and 6 and bordering commercial significance. 'Carlton' was less seriously affected, and lesions were late to develop. In 'Great Leap' the average scores were low, 3 and 2. As with smoulder, within a cultivar the infection was uniform and there were no treatment-related effects.

White mould Some white mould-like lesions were seen on the foliage of 'Great Leap' in late-May, but did not develop to the characteristic appearance of sporulating lesions.

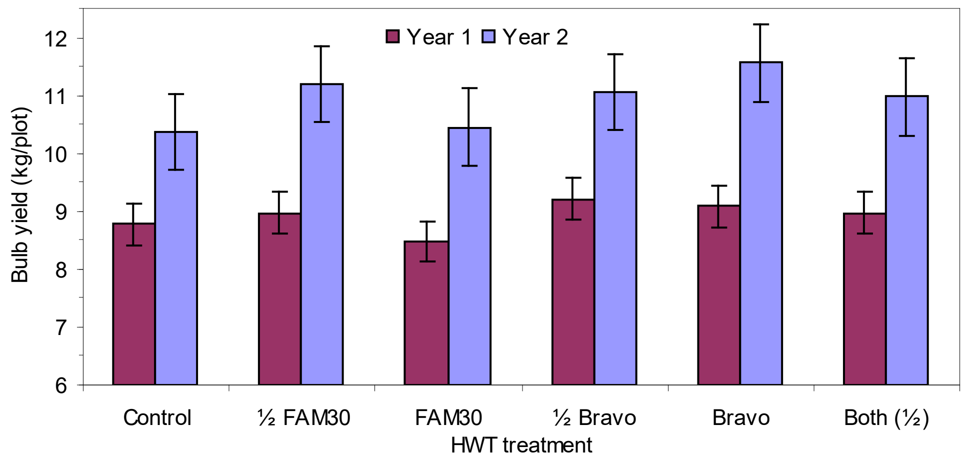
Year 2: Bulb yields (by bulb weight)

Figure 14 shows the total yield of sound bulbs after lifting in year 2, alongside the equivalent figures for year 1. AoV showed that, as for year 1, cultivar had the overwhelming influence on yields ($P<0.001$; see Appendix Table 14). The effect of HWT seen in the first year, however, was no longer significant, though, nevertheless, the results emphasised the lower yields in the control and full-rate 'FAM 30' treatment, and the superior yields in all other treatments where 'Bravo 500' or half-rate 'FAM 30' were included in the HWT tank.

As expected from experience and the previous year's findings, 'Carlton' had the highest overall yield, equivalent to a 106% weight increase from planting (6.35kg planted, 13.07kg lifted). The substantial base rot infection in the 'Actaea' stock resulted in the expected poor yields, with only a 27% weight increase from planting, and yields were also poor (45% increase) in 'Great Leap'. Amongst the other five cultivars, the percentage weight increase ranged from 73 to 96%. Overall, these yields were poor, but reflected the typically low yields found in commercial crops in 2011, probably due to low rainfall through most of the growing season.

It is encouraging to note, however, the increase in percentage weight increase found in all eight cultivars when the optimum HWT chemicals for each cultivar were chosen. Comparing the average percentage weight increase for each cultivar, with the percentage weight increase for each cultivar when the optimum HWT additive or additives were used, gave a commercially significant average improvement of 12%, ranging from 6 to 7% for 'Dutch Master', 'Hugh Town' and 'Kerensa', to 22% for 'Carlton'.

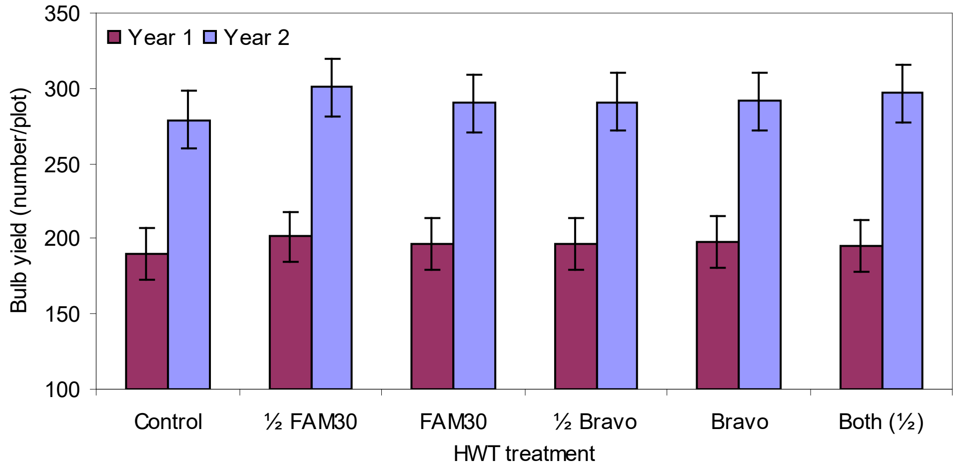
Figure 14
The effects of HW treatments on weight of sound bulbs lifted after 1 and 2 years (values are marginal means across all cultivars, vertical bars are 5% LSDs for comparisons within years)



Year 2: Bulb yields (by bulb number)

Figure 15 shows the total numbers of sound bulbs obtained after 1 and 2 years. AoV (see Appendix Table 15) showed the same response in year 2 as in year 1, that is a significant effect of cultivar on bulb numbers ($P<0.001$) but no significant effect due to HW treatment or the cultivar x treatment interaction. Again, there were the expected differences between cultivars, with extremes of the large-bulbed 'Hugh Town' and the small-bulbed 'Actaea'. The overall mean for the control was 279 bulbs/plot, but where any HWT additive was used bulb numbers were higher and remarkably consistent – the yields ranged only between 290 and 301 bulbs/plot. None of the HW treatments caused any significant shift in the rate of bulb-splitting.

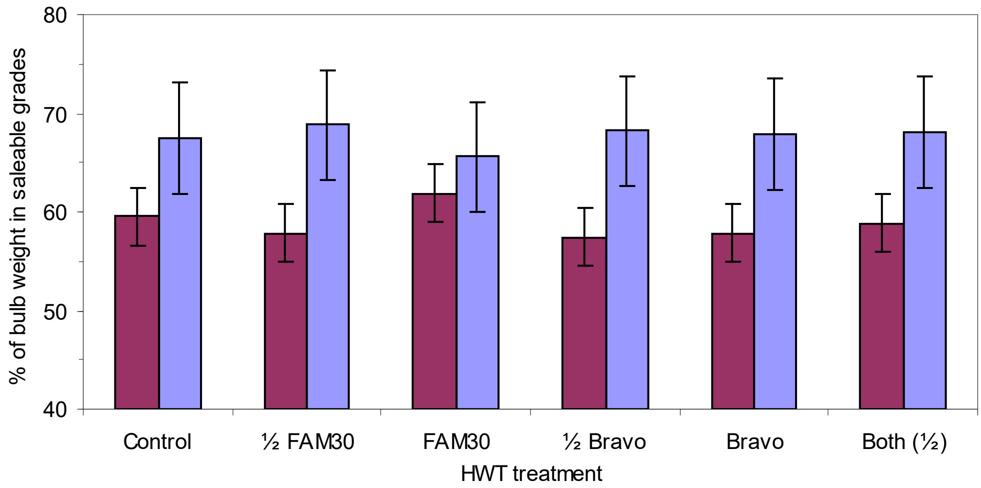
Figure 15
The effects of HW treatments on number of sound bulbs lifted after 1 and 2 years (values are marginal means across all cultivars, vertical bars are 5% LSDs for comparisons within years)



Year 2: Saleable bulb yields

As in the first year, bulb yields were also expressed as the percentage of harvested bulbs falling within the larger, saleable grades (10-14cm except for 'Hugh Town' where grade 12-16cm was used). Analysis confirmed that, as in year 1, the bulk of the variation found was due to cultivar (P<0.001; see Appendix Table 16), the small effect of HWT observed in year 1 having by now become insignificant. The slightly increased percentage in these grades seen with bulbs treated with full-rate 'FAM 30' did not persist into the second year's growth. Figure 16 shows these bulb yields for both years. In year 2 'Hugh Town' continued to have the largest proportion of bulbs in these grades (80%). 'Kerensa' had the lowest percentage of these grades, 56%, but there was little difference between the percentages across the other six cultivars, which all fell in the range of 60 to 74%.

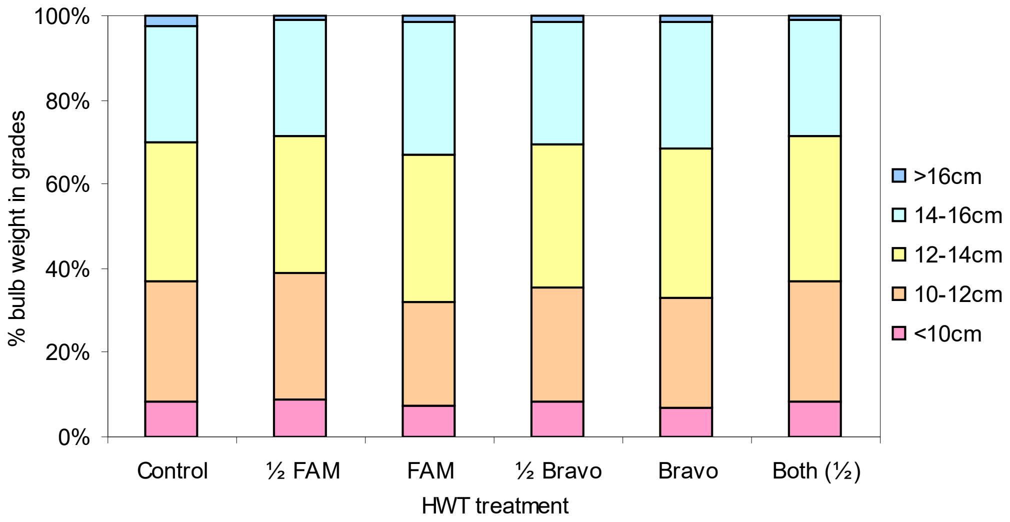
Figure 16
The effects of HW treatments on the percentage of bulb yield in the larger, saleable grades after 1 and 2 years (values are marginal means across all cultivars, vertical bars are 5% LSDs for comparisons within years)



Year 2: Distribution of bulb yield to grades

The distribution of bulb yield (by weight) to grades is shown in Figure 17. Compared with the results from the first year (Figure 8), it can be seen that the proportion of bulbs in the largest and smallest grades have fallen, a consequence of the large bulbs splitting and the small bulbs growing to saleable sizes, so there was a more equable distribution of yield to the three saleable grades (10-12, 12-14 and 14-16cm). Little effect of HW treatment can be seen, though the smaller percentage of bulbs in the 14-16cm grade in year 1, observed as a result of full-rate 'FAM 30' treatment, has now been corrected.

Figure 17
The effects of HWT chemicals on the percentage of bulb yield in size grades after 2 years (values are marginal means across all cultivars)

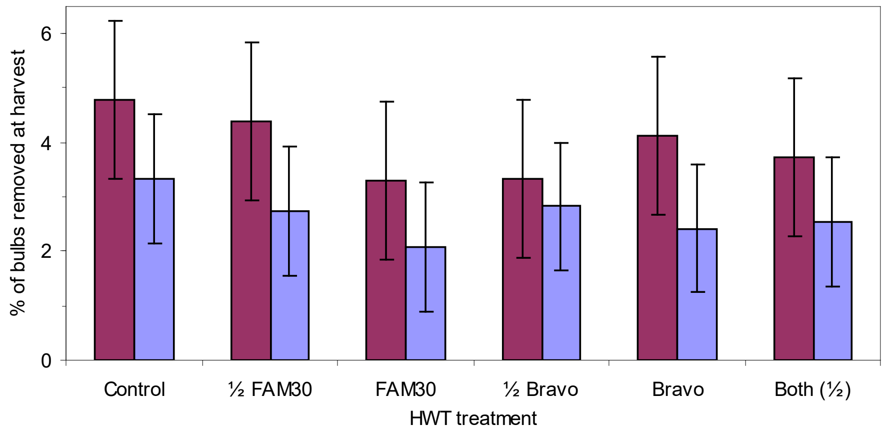


Year 2: Unmarketable bulbs

Although bulb yields in this trial were not exceptional, few bulbs were unmarketable (removed at grading due to rotting or damage). Figure 18 shows the percentage of bulbs removed each year, numbers having fallen from year 1 to year 2. The AoV showed that in year 2, as in year 1, the cultivar had a significant effect on the percentage of unmarketable bulbs, while there were no significant effects due to HWT or the cultivar x HWT interaction (see Appendix Table 17). As in the first year, 'Hugh Town' and 'Kerensa' were the cultivars with the extreme percentages of unmarketable bulbs, though their relative positions had reversed – 'Hugh Town' now had 5% of bulbs affected and 'Kerensa' less than 2%. The other cultivars had 2 to 3% of unmarketable bulbs. These data were highly variable, as shown by the large LSD values, but the conclusions were confirmed by the analysis of log-transformed data.

Figure 18

The effects of HW treatments on the percentage of unmarketable bulbs in years 1 and 2 (values are marginal means across all cultivars; vertical bars are 5% LSDs for comparisons within years.

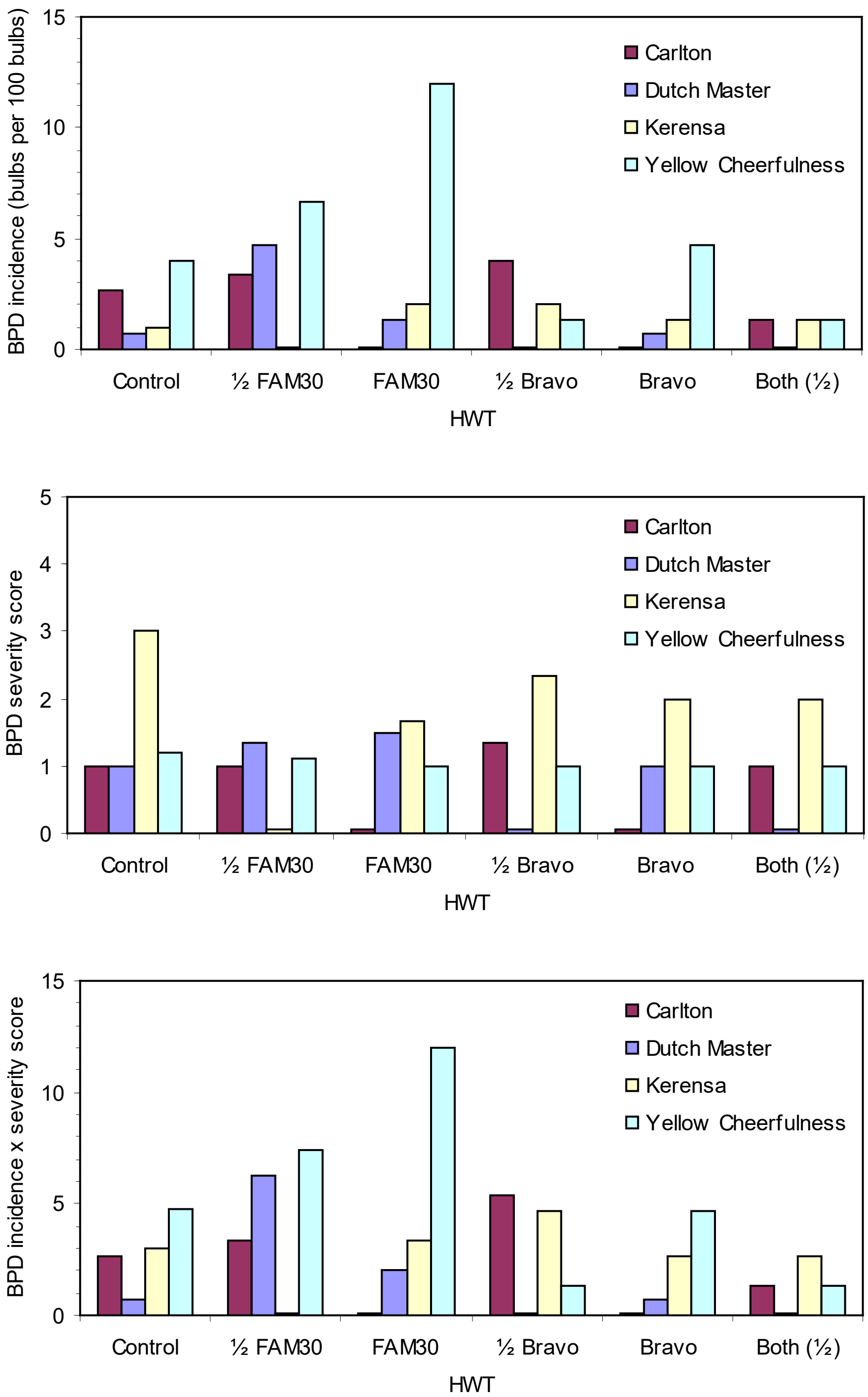


Year 2: Bulb internal quality

Bulbs were cut through and examined for identifiable damage (i.e. caused by large narcissus fly larva, base rot or neck rot) or any unidentified damage. The *current year's* base plate was examined specifically for any damage, and was considered normal if its colour and texture were typical, its root initials developing normally, and with no discolouration or erosion extending internally. The only putative 'damage' found consisted of infrequent, small, darker patches within the base plate, either spreading in from the outside edge, or entirely internal, referred to here as 'base plate darkening' (BPD). Such 'damage' as was found was minor, was unlike the symptoms of formalin damage, and in all cases the bulb scales and new shoots of affected bulbs appeared turgid, healthy and of normal colour.

Figure 19 shows the incidence and severity of BPD, and the AoV is in Appendix Table 18. The overall incidence of BPD was 2.3%, and it was only in 'Yellow Cheerfulness' that its incidence exceeded 5% (and then not in all HW treatments): most variation was due to cultivar ($P<0.001$) and the cultivar x HWT interaction ($P<0.01$), with a small effect from HWT ($P<0.05$). Severity scores were generally low, hence the similarity of the analysis for incidence and the incidence x severity score. 'Kerensa' had some higher severity scores than the other varieties.

Figure 19
The effects of HW treatments on the incidence (top), severity (middle) and 'incidence x severity score' (bottom) for BPD in four cultivars examined after lifting in year 2



The incidence of old and new large narcissus fly damage and of base rot were shown by AoV to be due to cultivar effects (P<0.001, 0.05 and 0.01, respectively), the effects of HW treatment being non-significant (see Appendix Tables 19 to 21). Overall, old fly damage was found in 0.9% of the bulbs, and was more frequent in 'Yellow Cheerfulness' (1.9%), while new fly damage was found on average in 2.7% of bulbs and was more likely to occur in 'Dutch Master' (3.2%) and 'Kerensa' (3.1%). Overall, base rot was found in 1.1% of bulbs and was most frequent in 'Carlton' (2.3%); neck rot occurred in only 0.2% of bulbs, mainly in 'Dutch Master' (0.6%).

Discussion

The main findings

It was shown in HDC projects BOF 61 and 61a that, used as additives to the HWT tank, the iodophore biocide 'FAM 30' and the chlorothalonil-based fungicide 'Bravo 500' have useful effects in controlling stem nematode and *Fusarium* rot of daffodils. The main aim of the present project was to determine whether these materials, used separately or together in HWT, have phytotoxic or other adverse effects on two-year-down crops of a range of daffodil cultivars. Adverse effects sometimes reported for other pesticides include alterations to crop timing, development and appearance, reductions to yields and quality, and stunting. The results showed that most aspects of crop growth and development were not affected by any of the HW treatments, though there were two important exceptions (Table 5).

First, bulb yields were reduced in a first year harvest where full-rate 'FAM 30' had been used in HWT. In the first year there were small, though significant, differences in the total weight of bulbs harvested due to HW treatments, with the highest total yield (for half-rate 'Bravo 500') significantly greater than the lowest (for full-rate 'FAM 30'), and there was a slight detrimental effect of using full-rate 'FAM 30'. However, it is unusual for daffodils to be grown on a one-year-down basis, and it is known that they are able to compensate for poor growth in the first crop-year by making up for lost growth in the second year. This compensation has been recorded where a thiabendazole fungicide used in HWT depresses yield in the year after HWT, or when the bulbs are damaged through too long or too hot HWT. By the second year, however, there was no longer a significant effect of HW treatment, though the results were nevertheless *suggestive* of lower yields in the control and full-rate 'FAM 30' treatment, and superior yields in all other treatments where 'Bravo 500' or half-rate 'FAM 30' were included in the tank.

In the first year there was a also small effect of HW treatments on the yield of *saleable grades*, with the full-rate 'FAM 30' treatment resulting in a greater yield, perhaps because fewer bulbs grew to the larger grades. By the second year's harvest, however, the effect of HW treatment was no longer statistically significant. Considering the distribution of bulb weight to grades showed that, between years I and 2, the proportion of bulbs in the largest and smallest grades had fallen, a natural consequence of the large bulbs splitting and the small bulbs growing to saleable sizes.

Secondly, flower yields were depressed where full-rate 'FAM 30' had been used, and, more seriously, this effect persisted to the flower yield in the second year of the crop when a high flower yield would be expected. In the first crop-year, higher flower yields were obtained from bulbs treated with half-rate 'FAM 30', full-rate 'Bravo 500' and the half-rate of both chemicals together, and there were lower yields in the control and where full-rate 'FAM 30' had been used. In the second crop-year, the highest yield followed treatment with the half-rate of 'FAM 30' and 'Bravo 500' together and the lowest following use of full-rate 'FAM 30'. In both years the interaction between cultivar and HW treatment was also significant, indicating that different cultivars may respond differently to different HW treatments, some responding better to one 'FAM 30' or 'Bravo 500' treatment, and others to another (though these differences were generally small and probably not of any commercial significance). The safest conclusion may be that, in general, HWT which included 'Bravo 500' (at either rate) gave higher flower yields than those treatments that did not. The trial did not include recording the numbers of flowers produced in the year following lifting, so it cannot be ruled out that the poorer treatment combinations may have led to slightly fewer flowers being produced in the subsequent year, had the bulbs been used for forcing.

In some circumstances the use of formalin in HWT has resulted in 'corkiness' in the base plate. In the present trial there was no evidence for any significant damage to the base plate as a result of 'FAM 30' or 'Bravo 500' use. Although a low incidence and severity of 'base plate darkening' was found and, for completeness, recorded, it is not known whether this should be regarded as a disorder.

Table 5
Summary of the significant effects of HW treatments on various crop attributes. All attributes were significantly affected by cultivar differences.

Not affected by HW treatment in years 1 or 2	HWT-related damage to the leaves and flower Pattern of growth and development Cropping/flowering date Leaf and stem height pre-flowering and at flowering Number of florets (in multi-headed varieties) Numbers of unmarketable buds/flowers Smoulder and physiological rust incidence/severity Bulb yields (by numbers) Number of rotted bulbs at grading
Affected by HW treatment in year 1 only (with no effect of interaction)	Total bulb yields (by weight) Saleable bulb yields (by weight)
Affected by HW treatment (and by the HW treatment x variety interaction) in years 1 and 2	Flower yield

Benefits

Half- or full-rate 'Bravo 500', half-rate 'FAM 30', and the mix of 'FAM 30' and 'Bravo 500' each at half-rate, consistently gave the best overall results. It is suggested that the half-rate mix is adopted for general use, perhaps increasing the 'Bravo 500' to a three-quarter concentration (0.75L/1000L water) or to the full-rate where base rot is a special issue. If 'Bravo 500' is not being used, the 'FAM 30' concentration might be increased too 6L/1000L water. Fungicide resistance strategies should be considered, especially where there is a problem of base rot. Fungicide types could be alternated, for example, by using a thiabendazole product as a post-lifting bulb spray and chlorothalonil in HWT, or by alternating the two fungicides in successive HWT (which could be two or more years apart).

It was encouraging to note, however, the increase in percentage weight increase found in all eight cultivars when the HWT chemicals were optimised for each cultivar. Comparing the average percentage weight increase for each cultivar, with the percentage weight increase for each cultivar when the optimum HWT additive or additives were used, gave a commercially significant average improvement of 12%, ranging from 6 to 7% for 'Dutch Master', 'Hugh Town' and 'Kerensa', to 22% for 'Carlton'.

Application

In order to optimise the effect of high temperatures on stem nematode control, the current standard HWT regime of 3 hours at 44.4 ± 0.1°C should be maintained. Some results of a recent HDC-funded project (BOF 61a) raised questions about the necessity of including a biocide for this purpose, appearing to confirm the earlier view that high temperatures alone were sufficient to kill stem nematode. However, some doubts remain about the wisdom of omitting a biocide from the dip, because of (1) doubts over the appropriateness of arguing from laboratory-scale tests to a farm-scale level, and (2) some uncertainties over the effects of HWT on nematode wool (a highly resistant stage of the nematode) obtained from different sources. Additionally, other recent HDC projects, BOF 61c and 70, have shown the value of a biocide in HWT in controlling bioload and maintaining general hygiene in the tanks.

At the time of writing 'Bravo 500' and two thiabendazole-based products, 'Tezate 220 SL' and 'Storite Clear Liquid', are approved under 'Extension of Authorisation for minor use in the UK' (formerly SOLAs) for use in daffodil bulb dipping (which includes HWT) for the control of basal or neck rot.[3] There do not appear to be any issues at present over the use of biocides in bulb

[3] 'Bravo 500', authorisation no. 20110943 expiring 3 March 2015; 'Storite Clear Liquid', no. 20070924 and 'Tezate 220SL', no. 20091180, both expiring 31 December 2015

dipping, though this is subject to the EC's on-going review under the Biocidal Products Directive (BPD) (Viv Powell, HDC, personal communication). Despite this, and bearing in mind bulb growers' experiences in 2008 following the loss of formalin and the restrictions imposed on the use of thiabendazole fungicides in bulb dipping, it is inadvisable for the industry to rely on a single biocide or just one or two fungicides for use in HWT. A new HDC project (BOF 74) is addressing the question of alternative fungicides, though no further work is at present being considered regarding the suitability of other biocides. Before using any of these products, pesticides or biocides, the latest information should, of course, always be obtained.

While these results confirmed the crop safety of 'FAM 30' and 'Bravo 500' on daffodil crops, and UK growers have been using these materials since 2009 without any concerns becoming evident, in adopting any alternative HWT additives it is important to understand issues such as the stability of additives in the HWT system and the potential for corrosion as a result of their use (some formulations are acidic). HDC project BOF 61c addressed the question of the stability of 'FAM 30' and 'Bravo 500' in HWT conditions – the former was fairly rapidly lost and the latter needed to be topped up to counter loss due to sedimentation. Regarding corrosion monitoring, this does not appear to have been addressed in any systematic way in HWT systems, though it could be monitored easily and routinely by using a 'corrosion coupon' system.

Conclusions

The loss of control of stem nematode or base rot would be devastating to UK daffodil bulb and cut-flower production, an industry with an annual output value of around £45million.[4] As no alternative to HWT as a method of control can be identified in the short-term, and attempts to breed disease resistance into improved commercial daffodil cultivars have not progressed, the finding in this project that 'FAM 30' and 'Bravo 500' can be integrated into the HWT process without apparent phytotoxic or growth-reducing side-effects should enable the industry to move forward after a period of some uncertainty following the loss of formalin and restrictions on thiabendazole use. The project showed that even optimising biocide and fungicide use in HWT could boost bulb output alone by 12%; together with a similar likely figure for cut-flower output, this would represent an increase in production worth in excess of £5million annually (or in excess of £1k/ha). This would not involve any other changes in bulb handling and growing, would use existing HWT facilities, and, while 'FAM 30' is more expensive than formalin, chlorothalonil-based fungicides are less expensive than thiabendazole fungicides. The following is suggested:

- ► An HWT regime of 3 hours at 44.4°C should continue to be regarded as the standard, as this is expected to control most or all stem nematodes
- ► Add 'FAM 30' to HWT dips at a concentration of 4L/1000L water to enhance the management of stem nematodes and base rot and to improve general hygiene
- ► In addition to 'FAM 30', add 'Bravo 500' to HWT dips at a concentration of 0.5L/1000L water, or, where base rot is of special concern, at 1.0L/1000L water
- ► Where base rot is of special concern, alternate the use of a thiabendazole-based product ('Tezate 220 SL' or 'Storite Clear Liquid') with 'Bravo 500', for example (1) by using a

[4] Because of the way agricultural statistics are now collected in the UK, it is only possible to quote an approximate value for the UK daffodil industry. Defra statistics for the UK for 2010 give annual values of £38million for "flowers and bulbs in the open… including forced flower bulbs" [*sic*], and of £26million for exports of "bulbs" and "cut flowers" (*Agriculture in the United Kingdom 2010* published by Defra and others, available on-line at: http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-crosscutting-auk-auk2010-110525.pdf). It is likely that daffodils make up much of both these values, though the first figure – for product values - should include non-daffodil bulb and non-bulb crops "in the open", as well as non-daffodil bulbs forced (under protection), and much will depend on whether protected lilies are regarded as "forced flower bulbs"; consequently this figure is difficult to interpret. The second figure – for exports – may be more useful, as few bulbs and bulb cut-flowers other than daffodils are exported by the UK; on the basis of industry estimates that some 50% of UK daffodil bulbs and some 60% of UK daffodil cut-flowers are exported, it is likely that the total annual value of UK daffodil production is around £45million (26x(100/55)).

thiabendazole fungicide as a post-lifting bulb spray treatment and ‘Bravo 500’ in HWT, or (2) by alternating the use of these two fungicides in HWT each time a stock is lifted (remembering that thiabendazole fungicides may not be used on a stock more than once each year).

Technology Transfer

- *What can growers use in bulb dips as an alternative to formalin?*, open afternoon at BOF 61b trial site, Moulton, 29 April 2010
- *Daffodil growing without formalin*, talk at South Holland Growers Club meeting, Whaplode, 24 January 2011
- *Life after formalin*, talk at HDC/South Holland Growers Club Narcissus Technical Seminar ‘Maintaining bulb quality’, Spalding, 14 April 2011 (included visit to BOF 61b trial site, Moulton)
- *Life after formalin*, talk at HDC Narcissus Technical Seminar ‘Maintaining bulb quality’, Rosewarne, 5 May 2011
- *New dips show promise*, HDC News, 164 (June 2010), 30
- *Hot new treatments for daffodils*, HDC News, 172 (April 2011), 28-30

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, Mark Clark for reviewing the draft report, and Adrian Jansen for helpful discussion of the work.

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Appendix 1: Details of spray programme applied

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
25 October 2010	'Sencorex' + 'Alpha Linuron 50SC' + 'Clinic Ace'	0.5kg + 1.2L + 2.0L

Appendix 2: Tables of results

In these tables the 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' (for cultivars and HW treatments), and can be used to indicate whether the differences between individual pairs of means are significantly different from each other. Where AoV 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 (e.g. HWT in Appendix Table 1).

The analysis of variance (AoV) 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.

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

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					

AoV

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				

Appendix Table 2
Means and LSD values (above) and AoV (below) for leaf height (cm) at flowering 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	35.0	36.7	35.7	37.6	37.3	36.8	36.5	
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	*LSD (5%) = 3.05*
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					

AoV

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				

Appendix Table 3
Means and LSD values (above) and AoV (below) for flower yield (number of stems with undamaged flowers/plot) 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	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					

AoV

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				

Appendix Table 4
Means and LSD values (above) and AoV (below) for stem/flower height (cm) at flowering 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	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	
Great Leap	43.7	41.6	41.5	43.8	43.7	47.6	43.6	*LSD (5%) = 3.24*
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					

AoV

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				

Appendix Table 5
Means and LSD values (above) and AoV (below) for total marketable bulb yield (kg/plot) after 1 year's growth

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					

AoV

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				

Appendix Table 6
Means and LSD values (above) and AoV (below) for total number of marketable bulbs lifted per plot after 1 year's growth

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*'FAM 30' Half-rate*	*'FAM 30' Full-rate*	*'Bravo 500' Half-rate*	*'Bravo 500' 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					

AoV

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				

Appendix Table 7
Means and LSD values (above) and AoV (below) for the percentage of marketable bulb weight in grades 10-14cm (10-16cm for 'Hugh Town') after 1 year's growth

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*'FAM 30' Half-rate*	*'FAM 30' Full-rate*	*'Bravo 500' Half-rate*	*'Bravo 500' 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					

AoV

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				

Appendix Table 8
Means and LSD values (above) and AoV (below) for the percentage of bulbs rotted or damaged at grading 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	2.37	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							

AoV

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				

Appendix Table 9
Means and LSD values (above) and AoV (below) for number of marketable stems per plot in year 2; data for all eight cultivars

Cultivar	HWT chemicals						Cultivar means	
	Control (water)	'FAM 30'		'Bravo 500'		Both at half-rate		
		Half-rate	Full-rate	Half-rate	Full-rate			
Actaea	156.3	131.3	159.0	150.0	119.0	155.3	145.2	
Carlton	169.3	213.0	199.3	201.0	220.0	200.0	200.4	
Dutch Master	106.7	117.3	86.3	116.3	104.7	135.0	111.1	
Great Leap	169.5	153.3	140.7	161.0	152.0	179.3	159.3	*LSD (5%) = 15.02*
Hugh Town	50.3	53.0	54.7	47.0	49.3	53.7	51.3	
Kerensa	148.3	163.3	142.0	171.3	163.3	149.3	156.3	
Red Devon	162.3	152.0	151.3	170.0	174.3	163.3	162.2	
Yellow Cheerfulness	228.0	215.0	204.3	224.3	234.3	227.0	222.2	
	LSD (5%) = 7.08							
HWT means	148.9	149.8	142.2	155.1	152.1	157.9		
	LSD (5%) = 17.34							

AoV

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	347314.57	7	49616.37	219.928	<0.000	***
HWT	3573.72	5	714.74	3.168	0.011	*
Interaction	16767.13	35	479.06	2.123	0.002	**
Residual	21657.83	96	225.60			
Total	389313.25	143				

Appendix Table 10
Means and LSD values (above) and AoV (below) for number of marketable stems per plot in year 2; data for 'Hugh Town' excluded

Cultivar	Control (water)	'FAM 30' Half-rate	'FAM 30' Full-rate	'Bravo 500' Half-rate	'Bravo 500' Full-rate	Both at half-rate	Cultivar means	
	HWT chemicals							
Actaea	156.3	131.3	159.0	150.0	119.0	155.3	145.2	*LSD (5%) = 17.07*
Carlton	169.3	213.0	199.3	201.0	220.0	200.0	200.4	
Dutch Master	106.7	117.3	86.3	116.3	104.7	135.0	111.1	
Great Leap	169.5	153.3	140.7	161.0	152.0	179.3	159.3	
Kerensa	148.3	163.3	142.0	171.3	163.3	149.3	156.3	
Red Devon	162.3	152.0	151.3	170.0	174.3	163.3	162.2	
Yellow Cheerfulness	228.0	215.0	204.3	224.3	234.3	227.0	222.2	
			LSD (5%) = 8.25					
HWT means	162.9	163.6	154.7	170.6	166.8	172.8		
			LSD (5%) = 18.44					

AoV

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*	
Cultivar	142983.66	6	23830.61	93.474	<0.000	***	17.07
HWT	4330.77	5	866.15	3.397	0.008	**	18.44
Interaction	15880.74	30	529.36	2.076	0.005	**	8.25
Residual	21415.17	84	254.94				
Total	184610.34	125					

Appendix Table 11
Means and LSD values (above) and AoV (below) for number of florets per stem for 'Hugh Town' and 'Yellow Cheerfulness' in year 2

Cultivar	Control (water)	'FAM 30' Half-rate	'FAM 30' Full-rate	'Bravo 500' Half-rate	'Bravo 500' Full-rate	Both at half-rate	Cultivar means	
	HWT chemicals							
Hugh Town	5.8	6.2	5.9	6.0	5.6	5.9	5.9	*LSD (5%) = 0.66*
Yellow Cheerfulness	2.9	2.8	3.0	2.9	2.9	2.7	2.9	
			LSD (5%) = 0.38					
HWT means	4.4	4.5	4.4	4.5	4.3	4.3		
			LSD (5%) = 0.38					

AoV

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	80.867	1	80.867	785.684	0.000	***
HWT	0.278	5	0.056	0.540	0.744	NS
Interaction	0.450	5	0.090	0.874	0.513	NS
Residual	2.470	24	0.103			
Total	84.065	35				

Appendix Table 12
Means and LSD values (above) and AoV (below) for flower height (cm) in year 2

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*'FAM 30'*		*'Bravo 500'*		*Both at half-rate*		
		Half-rate	*Full-rate*	*Half-rate*	*Full-rate*			
Actaea	62.7	62.6	62.0	62.9	60.0	61.5	61.9	
Carlton	42.7	44.1	47.6	44.3	46.5	43.5	44.8	
Dutch Master	31.9	32.5	31.5	32.0	32.4	33.1	32.2	
Great Leap	52.1	44.3	60.1	50.5	53.2	46.7	51.2	*LSD (5%) = 5.84*
Hugh Town	40.1	40.9	39.2	40.4	41.9	42.7	40.9	
Kerensa	48.1	47.4	48.4	47.0	48.1	46.9	47.6	
Red Devon	47.7	46.4	45.8	46.6	44.9	44.5	46.0	
Yellow Cheerfulness	41.9	34.9	41.6	50.0	43.6	43.7	42.6	
	LSD (5%) = 2.38							
HWT means	45.9	44.1	47.0	46.7	46.3	45.3		
	LSD (5%) = 6.74							

AoV

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	9221.60	7	1317.37	38.67	<0.000	***
HWT	131.84	5	26.37	0.77	0.571	NS
Interaction	798.25	35	22.81	0.67	0.910	NS
Residual	3270.68	96	34.07			
Total	13422.38	143				

Appendix Table 13
Means and LSD values (above) and AoV (below) for foliage height (cm) in year 2 (no data collected for 'Hugh Town')

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*'FAM 30'*		*'Bravo 500'*		*Both at half-rate*		
		Half-rate	*Full-rate*	*Half-rate*	*Full-rate*			
Actaea	59.0	61.1	59.8	60.6	59.6	60.6	60.1	
Carlton	63.7	62.9	66.2	65.8	64.5	66.1	64.9	
Dutch Master	62.7	64.9	63.8	63.8	63.4	64.6	63.9	*LSD (5%) = 6.29*
Great Leap	50.4	43.3	55.9	48.5	52.5	46.4	49.5	
Kerensa	56.9	57.7	56.2	53.6	58.3	57.3	56.6	
Red Devon	65.5	66.1	64.3	60.3	63.9	62.8	63.8	
Yellow Cheerfulness	48.6	41.3	49.7	52.3	51.1	49.5	48.8	
	LSD (5%) = 2.57							
HWT means	58.1	56.8	59.4	57.8	59.1	58.2		
	LSD (5%) = 6.80							

AoV

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	5025.53	6	837.59	24.18	<0.000	***
HWT	92.90	5	18.58	0.54	0.748	NS
Interaction	590.72	30	19.69	0.57	0.959	NS
Residual	2910.26	84	34.65			
Total	8619.40	125				

Appendix Table 14
Means and LSD values (above) and AoV (below)
for total marketable bulb yield (kg/plot) after 2 years

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*'FAM 30' Half-rate*	*'FAM 30' Full-rate*	*'Bravo 500' Half-rate*	*'Bravo 500' Full-rate*	*Both at half-rate*		
Actaea	8.21	8.15	8.26	7.20	8.77	7.83	8.07	
Carlton	11.89	12.11	13.20	13.09	14.47	13.69	13.07	
Dutch Master	10.10	11.15	10.36	10.98	10.99	11.03	10.77	
Great Leap	9.43	9.56	8.18	9.44	9.93	8.62	9.19	*LSD (5%) =1.141*
Hugh Town	9.62	10.76	11.43	11.41	11.41	11.08	10.95	
Kerensa	10.83	11.49	10.05	11.43	11.38	11.37	11.09	
Red Devon	10.86	13.17	12.23	12.90	12.59	12.77	12.42	
Yellow Cheerfulness	11.99	13.20	9.90	11.95	12.91	11.41	11.89	
			LSD (5%) = 0.538					
HWT means	10.37	11.20	10.45	11.05	11.56	10.97		
			LSD (5%) = 1.317					

AoV

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	341.89	7	48.84	18.23	<0.001	***
HWT	24.71	5	4.94	1.84	0.111	NS
Interaction	46.02	35	1.31	0.49	0.991	NS
Residual	257.25	96	2.68			
Total	669.87	143				

Appendix Table 15
Means and LSD values (above) and AoV (below)
for total number of marketable bulbs lifted per plot after 2 years

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*'FAM 30' Half-rate*	*'FAM 30' Full-rate*	*'Bravo 500' Half-rate*	*'Bravo 500' Full-rate*	*Both at half-rate*		
Actaea	401.0	403.7	419.0	396.0	390.0	406.7	402.7	
Carlton	229.3	273.7	262.0	237.0	261.3	280.7	257.3	
Dutch Master	230.7	251.0	245.7	221.3	241.3	243.7	238.9	
Great Leap	253.0	255.0	280.0	264.3	257.7	261.7	261.9	*LSD (5%)* = 33.17
Hugh Town	151.7	176.7	178.7	176.5	181.3	190.3	175.9	
Kerensa	262.7	284.7	251.7	268.7	266.0	269.7	267.2	
Red Devon	315.0	338.3	344.7	374.0	335.7	370.3	346.3	
Yellow Cheerfulness	386.7	423.3	341.0	389.0	397.3	353.0	381.7	
			LSD (5%) = 15.64					
HWT means	278.8	300.8	290.3	290.9	291.3	297.0		
			LSD (5%) = 38.30					

AoV

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	761073.6	7	108724.8	97.852	<0.001	***
HWT	6742.9	5	1348.6	1.214	0.309	NS
Interaction	29447.1	35	841.3	0.757	0.823	NS
Residual	106667.2	96	1111.1			
Total	903930.7	143				

Appendix Table 16
Means and LSD values (above) and AoV (below)
for the percentage of marketable bulb weight in grades
10-14cm (10-16cm for 'Hugh Town') after 2 years

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*'FAM 30'*		*'Bravo 500'*		*Both at half-rate*		
		Half-rate	*Full-rate*	*Half-rate*	*Full-rate*			
Actaea	70.2	70.0	66.4	70.0	70.6	67.1	69.1	
Carlton	70.5	75.5	58.4	62.7	59.1	64.1	65.1	
Dutch Master	55.7	58.8	57.3	60.9	63.1	64.8	60.1	
Great Leap	75.7	73.5	70.7	75.2	77.9	71.2	74.0	*LSD (5%) = 9.74*
Hugh Town	76.3	81.6	78.5	84.0	79.7	79.7	79.9	
Kerensa	51.8	59.5	57.8	59.5	53.1	54.3	56.0	
Red Devon	73.2	70.7	64.6	67.9	69.4	71.4	69.5	
Yellow Cheerfulness	66.0	60.8	70.9	65.3	70.7	72.1	67.6	
			LSD (5%) = 4.59					
HWT means	67.4	68.8	65.6	68.2	67.9	68.1		
			LSD (5%) = 11.24					

AoV

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	7157.03	7	1022.43	10.675	<0.001	***
HWT	149.94	5	29.99	0.313	0.904	NS
Interaction	1572.58	35	44.93	0.469	0.994	NS
Residual	9194.85	96	95.78			
Total	18074.40	143				

Appendix Table 17
Means and LSD values (above) and AoV (below)
for the percentage of bulbs rotted or damaged at grading in year 2

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*'FAM 30'*		*'Bravo 500'*		*Both at half-rate*		
		Half-rate	*Full-rate*	*Half-rate*	*Full-rate*			
Actaea	3.1	2.0	1.7	3.5	3.6	1.9	2.6	
Carlton	6.7	2.8	1.6	3.2	2.3	1.5	3.0	
Dutch Master	2.4	3.0	1.6	2.3	3.3	1.0	2.2	
Great Leap	1.8	3.2	2.0	5.1	1.3	5.3	3.1	*LSD (5%) = 2.05*
Hugh Town	7.9	6.1	3.1	3.8	3.4	5.4	4.9	
Kerensa	1.6	1.0	1.6	1.2	2.3	1.1	1.5	
Red Devon	1.7	2.7	1.3	1.4	2.0	1.5	1.8	
Yellow Cheerfulness	1.5	1.2	3.9	2.1	1.2	2.6	2.1	
			LSD (5%) = 0.97					
HWT means	3.3	2.7	2.1	2.8	2.4	2.5		
			LSD (5%) = 2.36					

AoV

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	147.172	7	21.025	4.966	<0.001	***
HWT	21.520	5	4.304	1.017	0.412	NS
Interaction	177.507	35	5.072	1.198	0.243	NS
Residual	406.434	96	4.234			
Total	1136.74	143				

Appendix Table 18
Means and LSD values (above) and AoV (below) for the incidence of BPD (bulbs per 100 bulbs) after grading in year 2

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*'FAM 30'*		*'Bravo 500'*		*Both at half-rate*		
		Half-rate	*Full-rate*	*Half-rate*	*Full-rate*			
Carlton	3.3	0.0	4.0	0.0	1.3	1.9	3.3	
Dutch Master	4.7	1.3	0.0	0.7	0.0	1.2	4.7	*LSD (5%) = 3.33*
Kerensa	0.0	2.0	2.0	1.3	1.3	1.3	0.0	
Yellow Cheerfulness	6.7	12.0	1.3	4.7	1.3	5.0	6.7	
			LSD (5%) = 1.67					
HWT means	3.7	3.8	1.8	1.7	1.0	3.7		
			LSD (5%) = 2.72					

AoV

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	173.819	3	57.940	10.669	<0.001	***
HWT	78.736	5	15.747	2.900	0.023	*
Interaction	259.097	15	17.273	3.181	0.001	**
Residual	260.667	48	5.431			
Total	772.319	71				

Appendix Table 19
Means and LSD values (above) and AoV (below) for the incidence of old large narcissus fly larva damage (bulbs per 100 bulbs) after grading in year 2

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*'FAM 30'*		*'Bravo 500'*		*Both at half-rate*		
		Half-rate	*Full-rate*	*Half-rate*	*Full-rate*			
Carlton	1.3	1.3	0.0	0.0	0.7	0.3	0.6	
Dutch Master	1.3	0.0	0.3	0.7	0.7	1.3	0.7	*LSD (5%) = 1.69*
Kerensa	0.5	0.0	0.3	0.0	0.0	0.3	0.2	
Yellow Cheerfulness	0.7	1.7	1.3	2.0	5.3	0.3	1.9	
			LSD (5%) = 0.69					
HWT means	1.0	0.8	0.5	0.7	1.7	0.6		
			LSD (5%) = 1.38					

AoV

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	28.483	3	9.494	6.785	<0.001	***
HWT	10.990	5	2.198	1.571	0.186	NS
Interaction	48.080	15	3.205	2.291	0.015	*
Residual	67.167	48	1.399			
Total	154.719	71				

Appendix Table 20
Means and LSD values (above) and AoV (below) for the incidence of new large narcissus fly larva damage (bulbs per 100 bulbs) after grading in year 2

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*'FAM 30'*		*'Bravo 500'*		*Both at half-rate*		
		Half-rate	*Full-rate*	*Half-rate*	*Full-rate*			
Carlton	0.7	2.0	2.0	2.0	0.0	2.7	1.6	
Dutch Master	2.0	5.3	2.7	2.0	4.0	2.0	3.0	*LSD (5%) = 2.89*
Kerensa	5.0	1.3	1.3	4.0	4.0	2.7	3.1	
Yellow Cheerfulness	1.3	0.7	4.0	0.0	0.7	2.0	1.4	
			LSD (5%) = 1.18					
HWT means	2.3	2.3	2.5	2.0	2.2	2.3		
			LSD (5%) = 2.36					

AoV

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	42.153	3	14.051	3.429	0.024	*
HWT	1.736	5	0.347	0.085	0.994	NS
Interaction	107.431	15	7.162	1.748	0.073	NS
Residual	196.667	48	4.097			
Total	347.986	71				

Appendix Table 21
Means and LSD values (above) and AoV (below) for the incidence of base rot damage (bulbs per 100 bulbs) after grading in year 2

Cultivar	*HWT chemicals*						*Cultivar means*	
	Control (water)	*'FAM 30'*		*'Bravo 500'*		*Both at half-rate*		
		Half-rate	*Full-rate*	*Half-rate*	*Full-rate*			
Carlton	4.7	3.3	1.3	1.0	2.0	1.3	2.3	
Dutch Master	0.7	2.0	0.0	0.7	0.7	0.0	0.7	*LSD (5%) = 2.25*
Kerensa	2.0	0.7	0.0	2.0	0.7	1.3	1.1	
Yellow Cheerfulness	0.7	0.0	0.7	0.7	0.7	0.0	0.4	
			LSD (5%) = 0.92					
HWT means	2.0	1.5	0.5	1.1	1.0	0.7		
			LSD (5%) = 1.84					

AoV

Source of variation	*SS*	*df*	*MS*	*F*	*P*	*Significance*
Cultivar	36.042	3	12.014	4.832	0.005	**
HWT	18.292	5	3.658	1.472	0.217	NS
Interaction	32.208	15	2.147	0.864	0.606	NS
Residual	119.333	48	2.486			
Total	205.875	71				