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# REPORT FOR HDC
# Producing soil-free narcissus bulbs for export (1991 trial)

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**Authentication**

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

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# PRODUCING SOIL-FREE NARCISSUS BULBS FOR EXPORT (1991 TRIAL)


## Summary

Freedom from soil is an important criterion with bulbs for export. This report describes a trial in which combinations of drying temperatures and washing regimes were examined for their effects on bulb quality.

Bulbs of narcissus cultivars Carlton, Golden Harvest, Barrett Browning and Magnet were lifted in mid-July 1991. The first three cultivars had been grown on silt soil, while the stock of Magnet was from clay soil to provide a contrast. Barrett Browning was included as typifying varieties with difficult-to-clean, long-necked bulbs. After lifting, bulbs were treated with thiabendazole fungicide either as an on-line spray, or by dipping. Bulbs were dried in bulk bins for a 21-day period, either entirely at ambient temperatures or initially at 35°C for three days and then at ambient. Dried bulbs were cleaned and graded, and either (1) returned to ambient temperature storage, (2) washed, dipped in aqueous formaldehyde, and re-dried at ambient temperatures, or (3) treated as (2) but with the initial two days' drying at 35°C. Seven days after cleaning and grading, bulbs were assessed for soil contamination and weight loss since harvest. After storage at ambient temperatures until December 1991, the number of bulbs with rots was assessed.

The mean weight loss over the 28 day drying period was 23 per cent for cv Magnet but only 19 to 21 per cent for the other varieties. Drying at 35°C entailed weight losses a few percent higher than using ambient temperatures. Double use of 35°C drying produced the greatest weight losses.

Highest quality of soil-free bulbs was characteristic of drying at 35°C. In the cases of the more difficult-to-clean stocks (long-necked bulbs or bulbs grown on clay), high-temperature drying needed to be combined with washing and (or) a further passage along the cleaning-grading line to achieve the best results. Non-washed bulbs dried at ambient-temperatures were not soil-free, and in the case of the clay-grown Magnet stock, non-washed bulbs were unacceptable even after high-temperature drying. No general rule about bulb washing can be proposed: any stock would have to be considered individually, especially on the basis of bulb shape, soil type and lifting conditions.

The percentage of bulbs rotting in different treatments also varied with cultivar. In Carlton, most rotting was associated with post-planting dipping and ambient drying. In Golden Harvest, drying at 35°C and not washing gave the lowest levels of rotting, otherwise rotting was unacceptable. In Barrett Browning, washing and re-drying at 35°C gave very high levels of rotting, and other treatments low levels. For Magnet, the amount of rotting was unacceptable, but the lowest percentages were in non-washed bulbs.

## Introduction

For export of narcissus bulbs to some destinations, absolute freedom from soil is demanded by the importing countries, primarily to guard against the transmission of potato cyst nematode (PCN) in adhering soil. For many countries, however, virtual or substantial soil-freedom is adequate. This is the situation at present, although, if stricter controls (as for potato tubers) were invoked, either PCN-free land might have to be used (probably impractical for the bulk of the UK bulb industry), or only washed bulbs exported. With these considerations in mind, the Horticultural Development Council has funded trials to investigate the most appropriate regimes for bulb drying and washing for producing soil-free bulbs. The interaction of bulb washing with bulb drying is an important one to consider, as much adhering soil is lost with the dry skins when bulbs are thoroughly dried, especially by using high-temperature (35°C) drying (Tompsett, 1977). Drying at 35°C is also more rapid (2 to 3 days) than using ambient temperatures, and does not lead to increased problems with basal rot which is associated with storage at 20 to 30°C. However, in practice bulbs are very often dried at ambient temperatures, so that other means of soil removal may be needed under unfavourable lifting conditions. In varieties with long-necked bulbs, soil may also adhere in the necks, and may not be removed with the dry skin.

In the first trial of this series, conducted in 1990 (Hanks, 1991), bulbs from five stocks were dried for 21 days, either at ambient temperatures throughout or with the initial 3 days at 35°C; thereafter, some batches were washed and re-dried at ambient temperatures or at 35°C. Ambient-dried, non-washed bulbs generally had unacceptably high soil contamination, while either 35°C initial drying or washing produced virtual or substantial soil freedom, and the combination of 35°C drying and washing led to complete soil freedom. Re-drying at 35°C (rather than ambient temperatures) after washing improved soil freedom in some stocks, but pre-soaking bulbs before washing did not. Bulb washing increased bulb rotting in susceptible cultivars, especially in combination with 35°C drying and pre-soaking with wetter, but a thiabendazole spray largely controlled post-washing bulb rotting.

In the second trial, described in the present report, 35°C and ambient drying and re-drying temperatures were again compared. Following washing, bulbs received a formalin dip, and the effects of treatments on bulb rotting were further examined by using bulbs either sprayed with or dipped in thiabendazole fungicide after lifting. Carlton and Golden Harvest were used as examples of basal rot-susceptible varieties, along with Barrett Browning (a long-necked variety) and a stock of cv Magnet lifted from clay, rather than silt, soil.

## Materials and methods

### Plant material

Bulbs of *Narcissus* cultivars Carlton and Golden Harvest were grown at HRI Kirton under good commercial practice. The soil was a clayey marine alluvium classified as a pelo-alluvial gley. Bulbs (*c.* 1.25 t each batch) were lifted, from ridges planted with a single grade of bulbs, between 0900 and 1000 hours on 11 July 1991, using a Summerfield lifter.

Bulbs (*c.* 1.25 t each) of cultivars Barrett Browning, grown on silt soil at Friskney, Lincs, and of Magnet, grown on clay soil at Royston, South Cambs, and lifted by the suppliers, were transported to Kirton on 16 July and 18 July, respectively.

Bulb washing and drying treatments

The treatments applied were as follows:-

| Post-lifting treatment | 21-day drying treatment | Post-drying wash | 7-day re-drying |
|---|---|---|---|
| Thiabendazole spray | (35°C (3 days) then (ambient | Wash + formaldehyde dip | 35°C (2 days) then ambient |
| | (35°C (3 days) then (ambient | Wash + formaldehyde dip | Ambient |
| | (35°C (3 days) then (ambient | None | (Ambient) |
| | (Ambient temps | Wash + formaldehyde dip | 35°C (2 days) then ambient |
| | (Ambient temps | Wash + formaldehyde dip | Ambient |
| | (Ambient temps | None | (Ambient) |
| Thiabendazole + formaldehyde dip | (35°C (3 days) then (ambient | Wash + formaldehyde dip | 35°C (2 days) then ambient |
| | (35°C (3 days) then (ambient | Wash + formaldehyde dip | Ambient |
| | (35°C (3 days) then (ambient | None | (Ambient) |
| | (Ambient temps | Wash + formaldehyde dip | 35°C (2 days) then ambient |
| | (Ambient temps | Wash + formaldehyde dip | Ambient |
| | (Ambient temps | None | (Ambient) |

Immediately after lifting (or receipt at Kirton) bulbs were either sprayed and then placed in net bags (*c.* 25 kg each) or placed in net bags and dipped. In each case, four nets were allocated to each of the 12 treatments. For the spray treatments, bulbs were tipped onto a roller table ('Rolaflo', E W Down & Son Ltd) where they were sprayed with aqueous thiabendazole (as one litre Storite Clear Liquid (266 g ai/litre) diluted to 5 litres per tonne of bulbs), using hydraulic nozzles. For the dip treatments, nets of bulbs were immersed for 15 minutes at ambient temperatures in aqueous thiabendazole, formaldehyde and non-ionic wetter (as 500 ml Storite Clear Liquid, 500 ml commercial formalin and 62 ml Power Non-Ionic Wetter/100 litre).

After these initial treatments and allocation of bulbs, 25 kg nets were placed in half tonne bulk bins and dried, either under fans at ambient temperatures, or on a drying wall at 35°C for 3 days and then under fans at ambient temperatures. The drying period extended to 21 days from lifting.

After the 21 day drying period, all nets were passed along a cleaning (including light brushing, dust extraction and hand cleaning) and grading line (although bulbs were not separated into grades). Bulbs for post-drying washing treatments were washed using plain water in a barrel washer (Cooch & Sons Ltd, Model RDT), allowing 2 minutes washing per 25 kg batch, and then dipped for 15 minutes at ambient temperatures in aqueous formaldehyde (500 ml commercial formalin/100 litres). The washed bulbs were dried as before, either at 35°C for 2 days and then at ambient temperatures for 5 days, or at ambient temperatures only for 7 days. Non-washed bulbs were retained at ambient temperatures.

28 days after lifting, bulbs from all treatments were assessed before and after passing along the cleaning-grading line as before.

Bulb assessments

Each net of bulbs was weighed initially (following spraying in the case of the first six treatments), and at the conclusion of the 28 day treatment period.

Bulb appearance was assessed 28 days after lifting. Soil retention was scored on a scale of 1 (low quality) to 5 (high quality). In practical terms, scores were interpreted as follows:

1, bulbs heavily smeared with soil and with adhering soil among the roots and in the bulb neck;

2, obvious, if occasional, smears of soil and soil in the bulb neck;

3, occasional small traces of soil in neck or slight soil smearing (substantial soil freedom);

4, very small traces in neck, very slight smearing or dusting with soil (virtual soil freedom);

5, no soil found (complete soil freedom).

In carrying out these assessments, scores were not downgraded because of soil in the necks of multi-nosed bulbs. Except for lots scoring 5 for soil retention, assessments were repeated after another passage along the cleaning-grading line. Skin retention and colour, bruising, dryness and root retention were also checked.

Following these assessments, samples (*c.* 200 bulbs) of each net were transferred to wooden trays and stored at ambient temperatures in a well ventilated building until wbm 9 December 1991, when they were bisected lengthwise for the determination of the number of bulbs showing basal, neck or whole-bulb rot.

Statistical analysis

Analysis of variance was used as appropriate for weight loss and bulb rot data, analysing each cultivar separately.

Meteorological data

Data were obtained from the weather station at HRI Kirton. Notable weather features in the first half of 1991 were a warm, dry March (monthly means 30 mm rain, maximum 11.4°C and minimum 4.6°C, compared with 20-year averages of 48 mm, 8.9°C and 1.9°C) and a dry, dull May (monthly mean of 15 mm rain and monthly total of 139 sun hours, compared with 20-year figures of 51 mm and 202 hours). In the month preceding lifting, an average rainfall occurred evenly through the month, while only traces of rain fell at Kirton in the 2-week period before lifting on 11 July.

**Results**

Weight loss during processing

Weight losses for the four stocks are shown in Table 1. Magnet showed a greater weight loss than other varieties during the 4-week processing period. The overall mean for Magnet was 23.1 percent, compared with 19.1 to 20.8 percent for othe other three varieties. The greater weight loss from bulbs of Magnet was probably correlated with loss of tunics in this variety.

Table 1 Effect of drying and washing treatment on percentage weight loss from lifting to four weeks later. (Results from the first six treatments are not strictly comparable with the last six, as the former were weighed after spraying on the roller table).

| Treatment | Carlton | Golden Harvest | Barrett Browning | Magnet |
|---|---|---|---|---|
| Spray - 35°C - wash - 35°C | 21.8 | 21.6 | 24.4 | 31.9 |
| Spray - 35°C - wash - ambient | 19.8 | 18.7 | 21.3 | 28.6 |
| Spray - 35°C - not washed | 20.1 | 20.4 | 19.5 | 24.0 |
| Spray - ambient - wash - 35°C | 19.2 | 19.8 | 21.8 | 21.8 |
| Spray - ambient - wash - ambient | 17.9 | 16.9 | 18.8 | 20.0 |
| Spray - ambient - not washed | 18.0 | 16.5 | 17.7 | 18.9 |
| Dip - 35°C - wash - 35°C | 24.0 | 22.3 | 25.6 | 24.9 |
| Dip - 35°C - wash - ambient | 25.1 | 19.7 | 22.2 | 26.2 |
| Dip - 35°C - not washed | 23.6 | 20.5 | 19.0 | 21.9 |
| Dip - ambient - wash - 35°C | 22.2 | 19.2 | 19.8 | 23.1 |
| Dip - ambient - wash - ambient | 18.5 | 16.7 | 16.4 | 20.0 |
| Dip - ambient - not washed | 18.6 | 16.5 | 15.6 | 17.0 |
| SED (df = 36) | 1.73 | 1.19 | 0.89 | 1.34 |

Routines involving 35°C drying entailed weight losses a few percent higher than ambient drying. In Carlton, for example, weight losses in sprayed bulbs were 19 to 22 per cent for 35°C treatments, and 18 per cent for ambient treatments; in dipped bulbs, corresponding figures were 22 to 25 percent (35°C) and about 18.5 per cent (ambient). As expected, the greatest weight losses followed double use of 35°C drying. The recorded weight losses for dipped bulbs exceeded those of sprayed bulbs as the latter were initially weighed after spraying, the former before dipping, following the most convenient practical routines.

Table 2 Effect of drying and washing treatment on soil retention score (5 = soil free). Scores in parenthesis are for bulbs passed a second time along the grading line

| Treatment | Carlton | Golden Harvest | Barrett Browning | Magnet |
|---|---|---|---|---|
| Spray - 35°C - wash - 35°C | 4 (5) | 4 (5) | 4 (5) | 5 |
| Spray - 35°C - wash - ambient | 4 (5) | 4 (4) | 4 (5) | 4 (5) |
| Spray - 35°C - not washed | 4 (5) | 4 (5) | 2 (3) | 2 (3) |
| Spray - ambient - wash - 35°C | 4 (5) | 3 (4) | 3 (4) | 5 |
| Spray - ambient - wash - ambient | 4 (5) | 2 (3) | 3 (4) | 4 (4) |
| Spray - ambient - not washed | 2 (3) | 1 (2) | 1 (2) | 1 (2) |
| Dip - 35°C - wash - 35°C | 5 | 4 (5) | 4 (4) | 5 |
| Dip - 35°C - wash - ambient | 5 | 4 (5) | 4 (5) | 4 (5) |
| Dip - 35°C - not washed | 2 (4) | 4 (4) | 2 (3) | 3 (3) |
| Dip - ambient - wash - 35°C | 4 (4) | 4 (5) | 4 (5) | 5 |
| Dip - ambient - wash - ambient | 3 (5) | 4 (5) | 4 (4) | 5 |
| Dip - ambient - not washed | 1 (2) | 2 (2) | 1 (1) | 2 (2) |

Bulb appearance

Soil retention on bulbs is given in Table 2.

Carlton Soil-free bulbs were obtained from treatments which had been dipped initially and then dried at 35°C. With a second passage along the cleaning line, all other treatments gave bulbs which were either virtually or completely soil-free - with the exception of non-washed, ambient-dried bulbs. In the latter treatments, although a second passage along the cleaning line removed further soil, bulbs remained unacceptably contaminated.

Bulb quality in Carlton was judged acceptable, and there were no obvious differences between treatments in other aspects of quality such as skin loss, drying or bruising.

Golden Harvest Although none of the treatments produced bulbs which were judged completely soil-free at the first assessment, a second passage along the cleaning line gave completely or virtually soil-free bulbs when 35°C drying had been used (either initially or for re-drying after washing), and in this case washing was not essential for achieving soil-freedom. Soil-free bulbs were also obtained from ambient-dried bulbs when an initial dip plus washing was used. Ambient-drying without washing gave bulbs of unacceptable appearance.

Other aspects of bulb quality were judged similar and satisfactory in all treatments.

Barret Browning The longer-necked bulbs of this variety proved more difficult to clean. No treatment achieved complete soil freedom without a second passage of the cleaning line. 35°C drying and washing produced the cleanest bulbs, although washing ambient-dried bulbs also gave an acceptable product. Non-washed bulbs reached substantial soil-freedom following 35°C drying, but remained contaminated with soil when ambient drying was used. A high level of rotted bulbs was evident in this stock.

Magnet Washing combined with re-drying at 35°C produced bulbs which were judged soil-free at the first assessment. Washed bulbs re-dried at ambient temperatures also reached a satisfactory appearance, although a second passage along the cleaning line was usually required to achieve this. Non-washed bulbs achieved only substantial soil freedom, even following initial 35°C drying and passing along the cleaning line a second time, and ambient-dried, non-washed bulbs remained contaminated with soil.

Magnet bulbs lost a large amount of skins during processing, perhaps associated with a high proportion of multi-nosed bulbs in the stock as supplied. Otherwise, bulb quality was satisfactory.

Bulb rotting in storage

Most rotting found was the characteristic form associated with *Fusarium oxysporum* f.sp. *narcissi*. The percentages of bulbs rotting in storage are given in Table 3. The statistical significance of the different experimental factors and interactions of factors (see discussion) is given in Table 4.

Carlton The highest percentages of rotting bulbs (5 to 9% over all rot categories) occurred in bulbs dipped post-planting and dried at ambient temperatures, whether or not the bulbs were subsequently washed. Medium percentages (3 to 4%) were found in dipped, washed bulbs and in sprayed and washed bulbs re-dried at 35°C. In other treatments, percentage rotting was one per cent or less. In this variety, most rotting was evident as characteristic basal rot. The preferred treatment would be a post-lifting spray with bulbs either not washed or washed then re-dried at ambient temperatures.

Golden Harvest Most treatments resulted in unacceptably high levels of rotting (4 to 12% over all categories), but drying at 35°C and not washing reduced the percentage to one or two per cent. Most rotting was typical basal rot, although significant levels of neck rot, of the form associated with *F. oxysporum*, was also present.

Barrett Browning High levels of rotting (14 to 23% over all rot categories) were found in bulbs washed and re-dried at 35°C, irrespective of whether post-lifting sprays or dips, or initial 35°C or ambient drying, was used. In all other treatments, overall levels of rotting were 2 to 5 per cent, indicating that, following post-lifting spraying or dipping, or initial 35°C or ambient drying, either washing and re-drying at ambient temperatures, or not washing, was suitable. In bulbs re-dried at 35°C, the characteristic effect was an increase in the number of bulbs which had progressed to the 'whole-bulb rot' category.

A low level (<1%) of bulbs of this cultivar were infested with large narcissus fly larvae.

Magnet Bulbs of this stock exhibited the greatest level of bulb rotting, damaged bulbs being distributed about equally between basal rot, characteristic invasive neck rot, and whole-bulb rot at the time of examination. Although the percentage of bulbs affected varied from 7 to 32 in different treatments, all treatments were unacceptable with this stock. The lowest percentages of rotted bulbs occurred in non-washed bulbs (except where these had initially been sprayed and dried at 35°C).

Table 3 Effect of drying and washing teatment on percentage of bulbs rotting in storage. Figures in parenthesis are logistic transformed data used for statisical analysis where valid.

| Treatment | Basal rot | Neck rot | Whole-bulb rot | All rots |
|---|---|---|---|---|
| cv Carlton | | | | |
| Spray - 35°C - wash - 35°C | 0 | 1 | 1 | 4 (-3.2) |
| Spray - 35°C - wash - ambient | 0 | 0 | 0 | 1 (-4.5) |
| Spray - 35°C - not washed | 0 | 0 | 0 | 0 (-5.0) |
| Spray - ambient - wash - 35°C | 1 | 0 | 1 | 4 (-3.2) |
| Spray - ambient - wash - ambient | 0 | 0 | 0 | 1 (-4.1) |
| Spray - ambient - not washed | 0 | 1 | 0 | 1 (-4.1) |
| Dip - 35°C - wash - 35°C | 0 | 0 | 2 | 3 (-3.2) |
| Dip - 35°C - wash - ambient | 1 | 0 | 1 | 3 (-3.3) |
| Dip - 35°C - not washed | 1 | 0 | 0 | 1 (-4.5) |
| Dip - ambient - wash - 35°C | 4 | 0 | 1 | 5 (-2.8) |
| Dip - ambient - wash - ambient | 8 | 0 | 1 | 8 (-2.4) |
| Dip - ambient - not washed | 9 | 0 | 0 | 9 (-2.2) |
| SED (df = 36) | - | - | - | - (0.47) |

Table 3 Continued

| Treatment | Basal rot | Neck rot | Whole-bulb rot | All rots |
|---|---|---|---|---|
| cv Golden Harvest | | | | |
| Spray - 35°C - wash - 35°C | 3 (-3.2) | 1 (-4.2) | 1 | 6 (-2.8) |
| Spray - 35°C - wash - ambient | 1 (-4.0) | 1 (-4.3) | 1 | 4 (-3.1) |
| Spray - 35°C - not washed | 0 (-5.3) | 0 (-4.6) | 0 | 1 (-4.3) |
| Spray - ambient - wash - 35°C | 4 (-3.1) | 2 (-3.7) | 2 | 8 (-2.3) |
| Spray - ambient - wash - ambient | 2 (-3.5) | 2 (-3.6) | 2 | 7 (-2.5) |
| Spray - ambient - not washed | 3 (-3.4) | 2 (-3.7) | 0 | 6 (-2.7) |
| Dip - 35°C - wash - 35°C | 5 (-2.8) | 1 (-4.2) | 5 | 12 (-2.0) |
| Dip - 35°C - wash - ambient | 2 (-3.7) | 3 (-3.5) | 1 | 6 (-2.7) |
| Dip - 35°C - not washed | 1 (-4.3) | 0 (-4.8) | 1 | 2 (-3.6) |
| Dip - ambient - wash - 35°C | 4 (-3.0) | 3 (-3.2) | 0 | 9 (-2.2) |
| Dip - ambient - wash - ambient | 4 (-3.1) | 2 (-3.8) | 0 | 6 (-2.6) |
| Dip - ambient - not washed | 8 (-2.5) | 1 (-4.1) | 0 | 10 (-2.2) |
| SED (df = 36) | - ( 0.43) | - ( 0.55) | - | - ( 0.35) |
| cv Barrett Browning | | | | |
| Spray - 35°C - wash - 35°C | 3 (-3.4) | 0 | 20 | 23 (-1.2) |
| Spray - 35°C - wash - ambient | 2 (-3.8) | 0 | 0 | 3 (-3.3) |
| Spray - 35°C - not washed | 1 (-4.0) | 1 | 0 | 3 (-3.4) |
| Spray - ambient - wash - 35°C | 2 (-3.5) | 0 | 11 | 14 (-1.8) |
| Spray - ambient - wash - ambient | 2 (-3.6) | 0 | 1 | 4 (-3.1) |
| Spray - ambient - not washed | 2 (-3.6) | 0 | 0 | 4 (-3.1) |
| Dip - 35°C - wash - 35°C | 1 (-4.2) | 0 | 21 | 22 (-1.3) |
| Dip - 35°C - wash - ambient | 3 (-3.3) | 1 | 0 | 5 (-2.9) |
| Dip - 35°C - not washed | 1 (-4.1) | 0 | 0 | 2 (-3.5) |
| Dip - ambient - wash - 35°C | 4 (-3.2) | 0 | 13 | 18 (-1.5) |
| Dip - ambient - wash - ambient | 3 (-3.2) | 0 | 0 | 4 (-3.0) |
| Dip - ambient - not washed | 3 (-3.2) | 0 | 0 | 4 (-3.0) |
| SED (df = 36) | - ( 0.44) | - | - | - ( 0.33) |
| cv Magnet | | | | |
| Spray - 35°C - wash - 35°C | 9 (-2.3) | 11 (-2.1) | 11 (-2.1) | 32 (-0.8) |
| Spray - 35°C - wash - ambient | 2 (-3.8) | 9 (-2.3) | 6 (-2.7) | 18 (-1.5) |
| Spray - 35°C - not washed | 1 (-4.3) | 4 (-3.2) | 14 (-1.8) | 19 (-1.5) |
| Spray - ambient - wash - 35°C | 3 (-3.3) | 3 (-3.2) | 6 (-2.7) | 17 (-1.6) |
| Spray - ambient - wash - ambient | 1 (-4.3) | 8 (-2.4) | 4 (-3.2) | 12 (-1.9) |
| Spray - ambient - not washed | 1 (-4.4) | 4 (-3.1) | 3 (-3.3) | 8 (-2.3) |
| Dip - 35°C - wash - 35°C | 5 (-2.9) | 7 (-2.5) | 5 (-2.9) | 18 (-1.5) |
| Dip - 35°C - wash - ambient | 1 (-4.0) | 9 (-2.3) | 6 (-2.7) | 18 (-1.5) |
| Dip - 35°C - not washed | 1 (-4.1) | 2 (-3.6) | 3 (-3.3) | 7 (-2.5) |
| Dip - ambient - wash - 35°C | 2 (-3.7) | 6 (-2.7) | 1 (-4.0) | 11 (-2.1) |
| Dip - ambient - wash - ambient | 1 (-4.0) | 9 (-2.3) | 1 (-4.0) | 13 (-1.9) |
| Dip - ambient - not washed | 2 (-3.7) | 3 (-3.4) | 1 (-4.1) | 8 (-2.4) |
| SED (df = 36) | - ( 0.63) | - ( 0.51) | - ( 0.51) | - ( 0.28) |

## Discussion

Earlier trials (ADAS, 1986) on post-lifting bulb washing and drying temperatures indicated that both washing and high-temperature (35°C) drying could produce glossier bulbs than when bulbs were not washed or were dried at ambient temperatures. Subsequent work (ADAS, 1989) showed that a post-harvest wash could produce substantially or virtually soil-free bulbs, while washing after a 21 day drying period produced completely soil-free bulbs. Post-drying washing is to be preferred, as only those bulbs destined for export sales would need to be washed, and then only if lifting and other conditions were such that this were necessary; washing post-harvest would require whole stocks to be treated. An earlier, HDC-funded trial (Hanks, 1991), in which a variety of bulb stocks was used, showed that either high-temperature drying or bulb washing could produce bulbs which were virtually or substantially soil-free, but that the combination of high temperature drying and washing could lead to complete soil freedom, even in difficult-to-clean bulbs.

In the present trial, soil-free bulbs of cv Carlton were obtained in treatments which had been dipped then dried at 35°C; however, a second passage along the cleaning-grading line produced virtually or completely soil-free bulbs in all treatments except ambient-dried, non-washed bulbs. In cv Golden Harvest, none of the treatments gave completely soil-free bulbs at the first assesssment, but a second passage gave completely or virtually soil-free bulbs when 35°C drying or re-drying had been used, or if ambient drying had been used with initial fungicide dipping and washing; ambient-dried, non-washed bulbs were unacceptable. For cv Barrett Browning, 35°C drying, washing and a second passage along the line were needed to produce completely soil-free bulbs, although the equivalent ambient-dried bulbs reached a lower, but acceptable, standard. Non-washed bulbs were substantially soil-free with 35°C drying but not with ambient drying. For Magnet, washing and re-drying at 35°C gave soil-free bulbs, while re-drying at ambient temperatures produced satisfactory bulbs with a second passage. Non-washed bulbs achieved only substantial soil-freedom, even with 35°C drying and a second passage of the line; the equivalent ambient-dried bulbs remained contaminated.

In summary, the trial showed that the highest quality soil-free bulbs was characteristic of bulbs dried at 35°C. In the cases of the more difficult-to-clean stocks (long-necked bulbs or bulbs grown on clay), high-temperature drying needed to be combined with washing and (or) a further passage along the cleaning-grading line to achieve the best results. Non-washed bulbs dried at ambient-temperatures were not soil-free, and in the case of the clay-grown Magnet stock, non-washed bulbs were unacceptable even after high-temperature drying. No general rule about bulb washing can be proposed, but it is clear that any stock would have to be considered individually, especially on the basis of bulb shape, soil type and lifting conditions (the recent trials referred to here have all been conducted in relatively dry seasons). The benefits of high-temperature drying were clearly evident, from the viewpoint of achieving soil-freedom, but might need to be augmented by washing bulbs in some cases.

Bulb washing is likely to spread pests and diseases. In four seasons' trials of post-harvest washing, using cv Golden Harvest (ADAS, 1986), washing greatly increased the incidence of rotting (especially in combination with high-temperature drying) in one season, despite the addition of formalin to the barrel washer. In a trial with cv Carlton, post-harvest washing led to

increased rotting in some treatments, despite on-line spray application of thiabendazole after washing (ADAS, 1989). Post-drying bulb washing increased bulb rotting in five stocks in the earlier HDC-funded trial; this was exacerbated by using 35°C initial drying and, especially, a pre-soak before washing, but was largely controlled by applying a thiabendazole spray after washing (Hanks, 1991). In the present trial, in which all washing treatments were followed by a formalin dip, the four stocks of bulbs responded differently, in terms of the percentage of bulbs rotting, to the various treatment factors (see Table 4). These differences are likely to reflect differing disease levels in the four stocks, rather than genuine cultivar differences. In particular, the stock of cv Magnet had a high incidence of rotting. In Carlton, initial dipping and ambient-temperature drying enhanced rotting, while washing had little effect: the overall best treatment (for soil-freedom and low rotting) would involve fungicide spraying, 35°C drying and washing. In Golden Harvest, Barrett Browning and Magnet, washing increased rotting: for Golden Harvest, bulbs ought perhaps to be dried at 35°C and not washed, but for Barrett Browning and Magnet, high temperature and washing gave clean bulbs but caused much rotting, such that a best compromise treatment is difficult to suggest.

Table 4 Significance of experimental factors the overall percentage of bulbs with rotting

| Cultivar | Significant treatment effects |
|---|---|
| Carlton | Fungicide x washing (*)<br>Drying x washing (*) |
| Golden Harvest | Fungicide (***)<br>Drying x washing (***) |
| Barrett Browning | Drying x washing (*) |
| Magnet | Fungicide (**)<br>Drying (***)<br>Washing (***) |

*, **, and ***, significant at the 5, 1 and 0.1% levels of probability.

To achieve complete soil-freedom, bulb washing may often be necessary. Healthy bulb stocks, and optimum fungicide treatment, would be essential pre-requisistes for bulb washing. The mechanisation and disposal problems associated with bulb washing are yet to be considered, but would need to be addressed if bulb washing were to become a more widespread practice.

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