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

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PRACTICAL SECTION

OBJECTIVES AND BACKGROUND

Basal rot seriously reduces narcissus yield and quality in some years, and is one of the main problems faced by UK bulb producers. The physical handling of bulbs during lifting, drying, storage and hot-water treatment (HWT) can have a major impact on the amounts of basal rot in a bulb stock. Post-lifting bulb spray treatment with Storite Clear Liquid (thiabendazole) fungicide, high temperature (35°C) first-stage-drying, controlled temperature bulb storage at 17°C, and including Storite Clear Liquid (thiabendazole) in the HWT tank have been previously shown to be important for controlling basal rot and producing bulbs of high quality. However, these techniques do not appear to have been critically tested, individually and collectively, on a ‘farm scale’. This was the objective of the present project.

SUMMARY OF RESULTS

Three commercial bulb stocks, from growers in eastern England, were used as ‘case studies’ in the project. Two stocks (B and C) were of the highly base rot-susceptible cultivar ‘Golden Harvest’, while the third (A) was a stock of ‘Carlton’ which had previously shown a high incidence of base rot. Six tonnes of each stock ‘as lifted’ were transported to HRI, Kirton, and each stock was allocated in ca. 1 tonne lots to receive one of six treatments, as described in the table below.

Treatment number	Post-lifting Storite spray (□) *or* no treatment post-lifting (□)	High-temp. drying (□) *or* ambient drying (□)	17C controlled storage (□) *or* ambient storage (□)	HWT with Storite (□) *or* HWT with formalin (□)
1	□	□	□	□
2	□	□	□	□
3	□	□	□	□
4	□	□	□	□
5	□	□	□	□
6	□	□	□	□

When bulbs of the three stocks were examined on the cleaning/grading line after the completion of drying, in the second half of July, it was clear that variable numbers and types of rotted and damaged bulbs were present. There were large differences between the three stocks in the number of rotted bulbs removed at this stage. Least rotted bulbs were found in stock B and most in stock C. Most rots were of the base or neck type in stocks A and C, with many mummified bulbs in stock C, perhaps indicating that many bulbs had begun to rot in the ground. There was evidence of narcissus fly infestations in all stocks, and bulbs with damaged base plates were present. Soft rot (due to *Rhizopus*) was suspected, and was confirmed by isolation and culturing on agar media, in small number of bulbs of all three stocks. These findings, including the relative diseases levels of the three stocks, were confirmed in samples of bulbs taken on receipt and subjected to a storage test (8 weeks at 25°C) before examination.

After HWT, following the completion of treatments, bulbs were again inspected on the cleaning/grading line. The number of rotted bulbs removed was again greatest in stock C and smallest in stock B, and in stock B bulb rots were generally not so far advanced as in stocks A and C. These results were confirmed in random samples of bulbs taken at the same time and subjected to a storage test.

The total amounts of rotted and damaged bulbs removed, based on a starting weight of about 750kg per treatment, never exceeded 10kg in any treatment for stock B, but varied between 22 and 113kg for stock A and between 112 and 357kg for stock C.

Treatments 1 and 4 consistently resulted in fewer rotted bulbs and a greater yield of sound bulbs. This effect became more evident in the poorer stocks. Both treatments 1 and 4 involved controlled temperature bulb storage at 17°C rather than at ambient temperatures. The mean daily maximum temperatures at Kirton in July and August in 1999 were considerably higher than the long-term average.

Plots of bulbs from all treatments are being grown-on both at Kirton and on the suppliers' farms. Bulb rots will be assessed at intervals over the two-year growing cycle, and bulb yields and final bulb quality (including rots in a storage test) will be assessed when the crops are lifted.

ACTION POINTS FOR GROWERS

Until the current project is completed, no recommendations can be made.

PRACTICAL AND FINANCIAL BENEFITS FROM STUDY

The assessments of potential benefits must also await the conclusion of the project.

EXPERIMENTAL SECTION

INTRODUCTION

Basal rot is the main cause of yield loss in UK-grown daffodil bulbs. In the long-term, the solution is the development of cultivars that are either resistant or considerably less susceptible to the disease. In the short-term, however, fungicide treatments alone are not reliably effective, and other means of managing the disease are needed. The control of base rot was reviewed in an earlier HDC-funded project (BOF 31).

MAFF-funded R&D at Kirton and Rosewarne in the 1980s showed that aspects of bulb handling are important in controlling basal rot, in particular:

- Immediate post-lifting fungicide treatment
- High-temperature (35ºC) bulb drying
- Continued drying and storage of bulbs at 17 to 18ºC
- Hot-water treatment (HWT) with thiabendazole fungicide and formalin

Although the benefits of a bulb handling regime including these components have been tested an experimental scale (Hanks, 1992, 1996), it does not appear that either the individual components, or the combined programme, have been evaluated at the level of a 'development project' with commercial-scale plot sizes. The techniques are rarely all used by growers, perhaps because of the level of investment needed to implement all the procedures, or because of doubts about the translation of results from relatively small-scale research to a commercial farm level. Also, it can be difficult to assess the impact of different procedures at a farm level, because it is usually impractical to split stocks, apply different treatments, and monitor closely the progress of basal rot in the various batches. Bulb farms with basal rot problems can, therefore, find it difficult to manage affected stocks, or to know how to do so cost-effectively.

In this project, three typical disease-susceptible commercial narcissus stocks are being used as 'case studies' to test the procedures of post-lifting fungicide application, 35ºC bulb drying, controlled-temperature storage, and HWT with Storite Clear Liquid (thiabendazole), either as individual treatments or combined. The bulk of the stocks have remained on-farm, where they continue to be subject to the usual local crop husbandry, while 6-tonne samples have been taken to HRI, Kirton, to receive specific treatments under controlled conditions. Following treatment at Kirton, stocks were again sub-divided for growing-on, either at the original farm or at HRI. Bulbs were assessed for storage rots initially and after the treatments had been applied, and will be assessed again after one and two years in the field. In this way it is hoped to see how typical bulb stocks respond to these handling procedures. The findings should enable growers to decide on the relative importance of using different procedures, so that future investments can be planned more effectively. They should highlight the most appropriate action to be taken when growing disease-susceptible varieties such as Carlton or Golden Harvest.

MATERIALS AND METHODS

Plant material

In consultation with the HDC Bulbs and Outdoor Flowers Panel and the HDC Project Co-ordinators, three narcissus stocks were identified for use in the project. These were 'typical' disease-susceptible commercial stocks from farms in eastern England, two of cultivar 'Golden Harvest', and the third a stock of 'Carlton' with a history of basal rot. The bulb handling and husbandry practices used on these farms are being collated for use in a later report.

Immediately after lifting in late-June/early-July 1999, approximately 6 tonnes of bulbs of each stock, as lifted and untreated except that normal soil/clod removal took place in bringing the bulbs back to the yard, were transported to HRI, Kirton, Lincolnshire in the growers' one-tonne bins. The remainder of the stocks remained on the farm of origin, to be treated and grown-on according to the prevailing local practice.

Bulb treatments at Kirton

Four aspects of bulb handling practice were tested:

- Post-lifting bulb spray application of thiabendazole fungicide. The 'control' treatment was no post-lifting fungicide treatment.
- High-temperature (35°C) first-stage drying. The 'control' treatment was drying at ambient temperatures.
- Second-stage drying and continued bulb storage at 17ºC. The 'control' treatment was drying and storage at ambient temperatures.
- Hot-water treatment (HWT) with Storite Clear Liquid (thiabendazole) fungicide. The 'control' treatment was HWT without Storite Clear Liquid (thiabendazole).

These key treatments were tested on bulbs either (a) as all four treatments used together or (b) as the four individual treatments, while a control group received none of the treatments, as shown in the table below. It was considered impractical to include all combinations of the four treatments, but this scheme should show the relative merits of the whole programme and of its main components.

Treatment number	*Post-lifting spray*	*First stage drying*	*Second stage drying and storage*	*HWT*
1	Storite Clear Liquid	3 days 35C	17C	With Storite Clear Liquid
2	Storite Clear Liquid	Ambient temps	Ambient temps	No Storite Clear Liquid
3	None	3 days 35C	Ambient temps	No Storite Clear Liquid
4	None	Ambient temps	17C	No Storite Clear Liquid
5	None	Ambient temps	Ambient temps	With Storite Clear Liquid
6	None	Ambient temps	Ambient temps	No Storite Clear Liquid

On receipt at Kirton, 100 bulbs were sampled at random from each of the 18 one-tonne bins. These samples were placed in clean, lined trays and stored at 25°C for bulb rots to be assessed 8 weeks later. Each of the three bulb stocks was divided amongst 12 sterilised '½-tonne' bulk bins (each holding approximately 375kg bulbs). Two ½-tonne bins of each stock were allocated at random to each of the six treatments. No cleaning or selection took place at this stage.

Bulbs for the post-lifting spray (treatments 1 and 2) were treated on a roller table with Storite Clear Liquid (thiabendazole) fungicide at the recommended rate (1 litre Storite Clear Liquid in 5 litres water per tonne of bulbs) via standard hydraulic nozzles, using a table speed of *ca.* 10 t/h.

Bins for high temperature drying (treatments 1 and 3) were placed on a letter-box drying wall at 35ºC, and those for drying at ambient temperatures (treatments 2, 4, 5 and 6) had 'fan tops' fitted and were placed in an unheated shed. At this stage, one fan-top was used per stack of two bins, keeping distinct treatments separate. These treatments were carried out on the day after lifting.

After 3 days, bins for 17ºC storage (treatments 1 and 4) were moved to a controlled-temperature store for continued drying under fan-tops as before, and those for storage at ambient temperatures (treatments 2, 3, 5 and 6) were kept in or moved to the unheated shed, under fan-tops. Drying and storage temperatures in the bins were logged at least hourly.

Twenty days after the start of drying, when the bulbs were considered adequately dry, all bulbs were passed along a cleaning/grading line to remove any remaining soil. All obviously rotted bulbs were removed by hand and assessed for type of rot immediately. The sound bulbs were replaced in the same bins as before and returned to the required conditions (17˚C or ambient) with fan-tops. From this point one fan-top was used per stack of nine bins.

On 23-25 August, all bulbs were given standard HWT (3 hours at 44.4ºC with commercial formalin (5 litres per 1000 litres) and non-ionic wetter (300 ml Activator 90 per 1000 litres)). For treatments 1 and 5, Storite Clear Liquid (thiabendazole) was added to the dip (5 litres Storite Clear Liquid per 1000 litres). Following HWT, bins were ventilated on a letter-box drying wall at ambient temperatures overnight.

The following day, bulbs were passed along a cleaning/grading line. Random bulb samples (3 x 100 bulbs each) were taken at the start of the line from each treatment for the assessment of rots after storage at 25˚C, as described previously. On the line, all obviously rotted bulbs were removed by hand and assessed for type of rot immediately. The weights of sound bulbs remaining were recorded as they were accumulated in 25 kg nets at the end of the line.

The key dates are shown in the following table:

Stock	*Lift and transport to Kirton*	*Spray and 1st stage drying*	*2nd stage drying and storage*	*Inspect*	*HWT*	*Return to growers*	*Plant at Kirton*	*Plant at growers*[a]
A	05 July	06 July	09 July	26 July	25 Aug	26 Aug	7 Sep	
B	29 June	30 June	03 July	19 July	23 Aug	25 Aug	7 Sep	
C	05 July	06 July	09 July	26 July	24 Aug	26 Aug	7 Sep	

[a] dates to be added

<u>Planting</u>

Because of the considerable losses due to bulb rots, and the variation in amounts of sound bulbs between stocks and treatments, the size of field plots originally planned (comprising 3 x 150kg replicates for each treatment) was modified. Apart from stock B (where 300kg quantities of bulbs were available for all treatments), uneven sized plots were used (in preference to reducing plot size to that possible with the lowest yielding treatment).

For stock B, 300kg bulbs were returned for re-planting at the supplier’s farm, and 300kg were allocated in three replicate lots of 100kg each for re-planting in a replicated field trial at Kirton.

For stocks A and C, 250kg bulbs of each treatment were returned for re-planting at the suppliers’ farms. The remaining bulbs in each treatment were divided into three equal replicate lots for planting in a replicated field trial at Kirton. For stock A, the weight of each replicate was 110, 83, 75, 104, 67 and 76kg for treatments 1 to 6, respectively, and for stock C, 103, 55, 48, 97, 46 and 42kg, respectively.

<u>Bulbs grown on at suppliers’ farms</u>

Bulbs for re-planting at the suppliers’ farms were placed in the original bins in which they had been supplied by the growers, and were despatched from Kirton on 25 or 26 August 1999. The bins were first rinsed out with a pressure washer then sprayed with disinfectant (1 part ‘Jet 5’ to 125 parts water), using a coarse spray to ensure that all surfaces were thoroughly wetted. Each treatment was planted in labelled rows, alongside the bulb stocks from which they were taken, and using the usual local practices.

Bulbs grown on at Kirton

Bulbs for planting at Kirton were planted on 7 September 1999. The lengths of ridge used for each treatment was proportional to the weight of bulbs planted, planting at a density of 20 t/ha in ridges at 0.76m centres (1.52kg bulbs per 1m run of ridge). Following the usual procedures for planting field trials at Kirton, the trials area was ridged out, the position of plots was marked in the furrows, the bulbs were placed evenly in the plots by hand, and the bulbs were covered by splitting-back the ridges. Each plot was three ridges wide and up to 23m long. The trial was arranged in a randomised block design, with three replicate blocks. A separate area was used for each stock, and each area had spare bulbs of that stock planted on either side as guards. The husbandry of these bulbs followed the usual HRI Kirton protocols.

Further records

Samples of bulbs will be taken and assessed for rots after lifting at the end of the first and second growing seasons (June/July 2000 and 2001) from the commercial bulb farms and from Kirton. Bulb yields will be determined after harvest and grading in July/August 2001. Further samples will then be taken of the cleaned, dried bulbs for storage and rot assessment.

Bulb rot assessments

Bulbs were assessed for rots either immediately after sampling, or after a storage period of 8 weeks at 25˚C (see above). Where necessary, bulbs were bisected lengthwise to determine the type of rots. Bulbs and rots were classified into typical base rot, neck rot or whole-bulb rot (where the start of the rot could not be identified), soft rots, mummified (completely rotted and desiccated) bulbs, bulbs damaged by narcissus flies, and other mechanical damage. In the case of rotted bulbs removed from the line after bulb drying, typical rotted bulbs were also examined by John Carder (HRI, Wellesbourne), and cultures were made in order to identify the fungi present.

Statistical analysis

Because of the gross effects of stocks and treatments, no formal statistical analysis has been carried out at this stage. In the tables of results, standard deviations (SD) are given alongside means, where appropriate.

RESULTS

Storage assessment of bulbs as received

The percentage of bulbs with rots, sampled at receipt and stored for 8 weeks at 25ºC, is shown in Table 1. Stocks A and C had high numbers of rotted bulbs, 68 and 83%, respectively, while stock B had only 4% rots. Most of the bulb rots found were typical base or whole-bulb rot. Occasional mummified bulbs and bulbs with soft rot, neck rot and rots due to narcissus fly damage were also seen.

Table 1. Percentage bulb rots in stored, initial sample. Values are means of 6, 100-bulb samples, with SD in parenthesis

Stock	Percentage of sample with rot types						
	Base	Neck	Whole bulb	Mummified bulbs	Soft rot	Narcissus fly	All rots
A	55 (8.4)	1 (0.9)	10 (2.8)	0	1 (0.8)	1 (1.0)	68 (8.6)
B	2 (2.1)	0	1 (0.9)	0	1 (0.8)	1 (0.8)	4 (2.3)
C	47 (12.9)	1 (0.5)	33 (8.2)	1 (1.6)	1 (1.2)	0	83 (8.9)

Assessment of bulb rots after drying

Initial assessment of the rotted bulbs removed on the cleaning/grading line, after drying but before further storage and HWT, identified variable numbers and types of rotted and damaged bulbs present in the three stocks.

Stock B contained the lowest percentage of unhealthy bulbs (the mean for all treatments was 12 bulbs (0.19kg) per bin), and most of these were soft, grey and completely rotted with a musty smell suggesting the presence of *Rhizopus*. This batch also contained a few bulbs with obvious internal damage due to narcissus fly larvae (larvae of small narcissus flies were seen, but none of the large narcissus fly), and, in addition, many bulbs had physically damaged base plates (which could be due to a variety of causes). Except for treatment 4, where there were few rotted bulbs and no fully rotted ones, samples were examined and fungi isolated by John Carder. *Rhizopus* was identified in many of these cultures. *Penicillium* and bulb scale mites were also recorded.

In stock A, many more unhealthy bulbs were found (mean for all treatments, 52 bulbs (1.33kg) per bin), mostly with clear base or neck rot or bulbs that were mummified. Very few bulbs were completely rotted, but these were soft and similar to those suspected of having *Rhizopus* in stock B. Many bulbs had obvious internal narcissus fly damage, and many more had physically damaged base plates. Cultures made from typical soft-rotted bulbs again showed that *Rhizopus* was present on several samples.

Stock C had the largest number of unhealthy bulbs (mean for all treatments, 288 bulbs (10.91kg) per bin), and, like stock A, these consisted mainly of neck rot, base rot and mummified bulbs. Some bulbs had narcissus fly damage (larvae of large and small narcissus flies were seen), and there was some physical damage to the base plates. Although no bulbs were seen that were fully rotted by soft rot, samples of bulbs with base and neck rots were examined further, and *Rhizopus* was confirmed in cultures of three of 35 bulbs tested.
The number and weight of rotted bulbs is given in Table 2. Bulbs of treatment 4 consistently

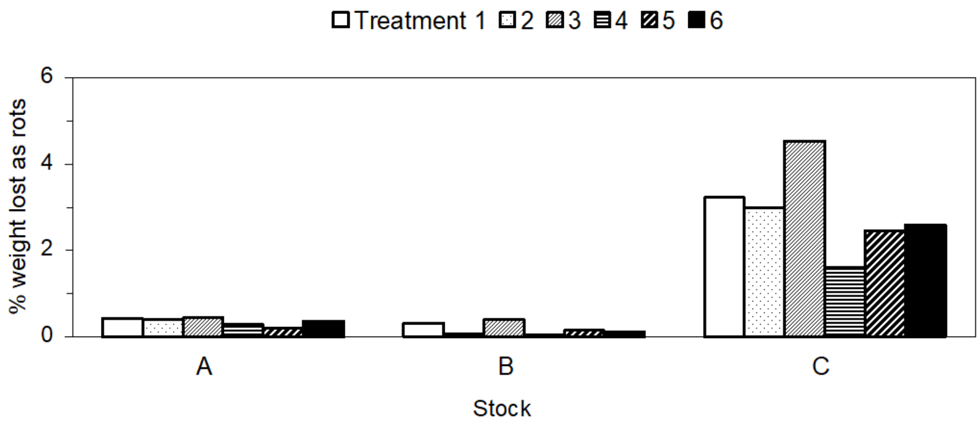
showed the least amount of bulb rot, while those in treatment 3 consistently had most. The high values found for the standard deviations (SD) in stock A, treatment 3, were due to particularly high levels of rotting in one bin.

Table 2. Numbers and total weight of rotted bulbs removed per bin (containing *ca.* 375 kg) after drying. Values are mean of two bins with SD in parenthesis

Stock	Treatment	Number of bulbs per bin with rot types					Total of all rots	
		Base rot	Neck rot	Whole rot	Mummified bulbs	Narcissus fly	Number per bin	Weight (kg) per bin
A	1	16 (2.8)	7 (4.2)	2 (0.7)	27 (0)	10 (3.5)	61 (1.4)	1.62 (0.051)
A	2	19 (0.7)	8 (7.1)	1 (0.7)	30 (2.8)	6 (2.1)	63 (7.8)	1.52 (0.465)
A	3	20 (7.8)	4 (2.1)	1 (0)	29 (17.0)	12 (7.8)	65 (34.6)	1.64 (0.946)
A	4	11 (1.4)	1 (0)	1 (0.7)	11 (8.5)	6 (1.4)	30 (4.9)	1.09 (0.201)
A	5	6 (0)	4 (0)	0	22 (5.7)	5 (2.1)	37 (3.5)	0.76 (0.014)
A	6	13 (1.4)	6 (0)	1 (0.7)	34 (1.4)	4 (1.4)	58 (2.1)	1.37 (0.082)
B	1	1 (0.7)	1 (0)	16 (7.1)	0	2 (0.7)	19 (7.1)	1.23 (0.298)
B	2	0	0	4 (0)	0	1 (0.7)	5 (0.7)	0.25 (0.035)
B	3	0	1 (0.7)	21 (4.2)	0	1 (0.7)	22 (5.7)	1.49 (0.354)
B	4	2 (1.4)	1 (0.7)	0	0	1 (0.7)	3 (1.4)	0.14 (0.018)
B	5	3 (2.8)	3 (3.5)	5 (2.1)	0	2 (0.7)	12 (0.7)	0.55 (0.283)
B	6	3 (0.7)	0	6 (4.9)	3 (3.5)	3 (2.1)	13 (4.2)	0.46 (0.212)
C	1	166 (23.3)	16 (6.4)	0	75 (20.5)	11 (0.7)	266 (36.8)	12.13 (1.667)
C	2	196 (7.1)	15 (7.8)	0	89 (18.4)	23 (1.4)	323 (34.6)	11.18 (1.106)
C	3	237 (7.8)	21 (9.2)	0	107 (16.3)	20 (4.9)	383 (4.2)	17.04 (4.241)
C	4	103 (21.2)	23 (3.5)	0	90 (40.3)	21 (3.5)	236 (54.4)	6.04 (0.792)
C	5	128 (20.5)	16 (4.2)	0	93 (14.8)	15 (10.6)	251 (50.2)	9.28 (1.182)
C	6	126 (0.7)	28 (12.7)	0	101 (34.6)	17 (0.7)	271 (47.4)	9.76 (0.631)

The overall percentage loss in weight due to bulb rots is summarised in Figure 1. This shows that the losses were relatively small at this stage, except in stock C.

Figure 1. Weight of rotted bulbs removed after drying



Assessment of bulbs after completion of treatments

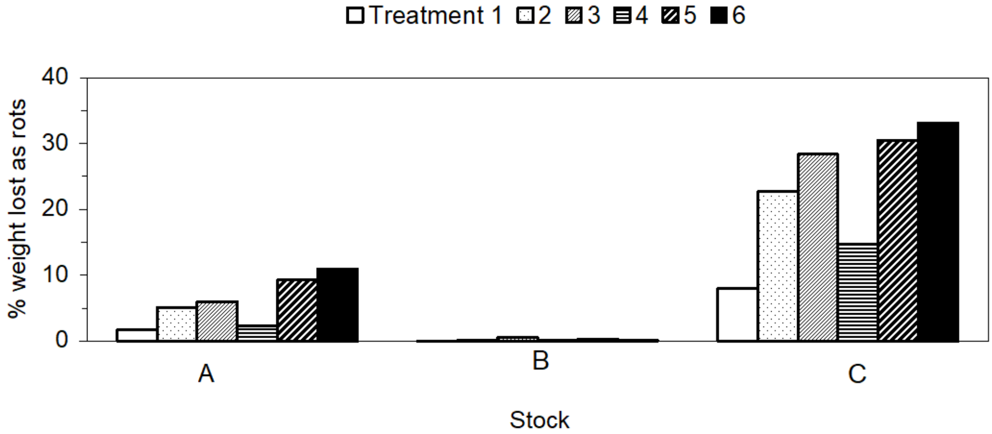
After HWT, when all experimental treatments had been completed, all bulbs were again passed along a cleaning/grading line and re-inspected. The numbers and weights of rotted bulbs removed are shown in Table 3. As for the previous inspection, most rotted bulbs were found in stock C and least in stock B. In stock C, the numbers of rotted bulbs (per original lot of 750kg bulbs) for the various treatments varied from 1085 to 4042, for stock A, from 318 to 1708, and for stock B, 9 to 83. For stocks A and C, the vast majority of affected bulbs had progressed to whole-bulb rots, whereas in stock B there were about equal numbers of bulbs with whole-bulb rot or with rots that could be assigned to basal or neck rots. In stocks A and C, the numbers of rots in the different treatments was 6 > 5 > 3 > 2 > 4 > 1. In the 'worst case', over 248kg of rotted bulbs (33% of the original weight) were rejected at this stage per treatment; in the best, only 0.4kg (0.005%).

Table 3. Numbers and total weight of rotted bulbs removed per 2 bins (containing *ca.* 750 kg bulbs originally) after completion of treatments

Stock	Treatment	Number of bulbs with rot types					Total of all rots	
		Base rot	Neck rot	Whole rot	Mummified bulbs	Narcissus fly	Number	Weight (kg)
A	1	0	13	280	19	6	318	13.3
A	2	0	0	783	0	16	799	38.4
A	3	0	56	878	0	0	934	45.3
A	4	0	16	375	8	8	408	17.5
A	5	0	30	1468	0	0	1498	69.6
A	6	0	68	1640	0	0	1708	82.1
B	1	3	0	5	0	1	9	0.4
B	2	7	0	2	0	1	10	0.6
B	3	21	39	12	10	1	83	4.3
B	4	8	4	4	0	2	18	0.8
B	5	11	7	27	2	2	49	2.5
B	6	9	2	16	1	2	30	1.5
C	1	0	0	1063	0	22	1085	59.9
C	2	0	0	2735	0	56	2791	170.3
C	3	0	69	3326	0	69	3465	212.5
C	4	0	91	2129	0	45	2265	109.9
C	5	0	0	3752	0	0	3752	228.6
C	6	0	0	3961	0	81	4042	248.3

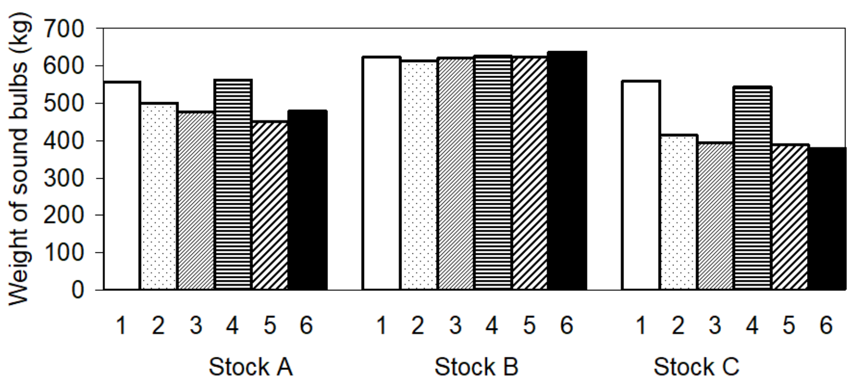
The overall percentage loss in weight due to bulb rots is summarised in Figure 2. This shows that losses have increased dramatically since the previous inspection in stocks A and C. Treatment effects are at their most obvious: Figure 2 clearly shows the benefits of treatments 1 and 4.

Figure 2. Weight of rotted bulbs removed after completion of treatments



Each treatment started with a weight of 'as lifted' bulbs of approximately 750kg. The weight of sound bulbs remaining after the completion of treatments and re-inspection is shown in Figure 3. Weight losses include not only those due to the removal of rotted and damaged bulbs and those due to drying, but also those due to bulb cleaning and the removal of samples for storage assessments. Although a rough guide, these figures may be useful in estimating yields from different treatments and from stocks with different amounts of bulb rots. The weight of sound bulbs of stock B varied between 614 and 637 kg for the six treatments (82-85% of the starting weight). In stock A, between 451 and 562 kg remained (60-75%), and in stock C, between 378 and 560 kg (50-75%). In stocks A and C, the yield of bulbs for treatments 1 and 4 (72-75% of initial weight) were higher than yields for the other four treatments (50-67%), an effect particularly evident in stock C where, otherwise, yields were very low.

Figure 3. Approximate weight of sound, dried bulbs remaining (from 750kg as lifted) after the completion of treatments 1-6



Storage assessment of bulbs after completion of treatments

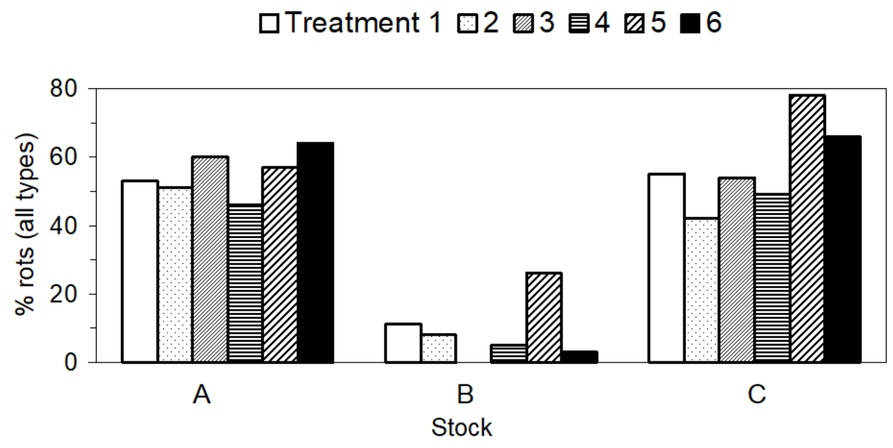
The percentage of bulbs with rots, sampled after HWT and stored for 8 weeks at 25ºC, is shown in Table 4 (also summarised in Figure 4). Storage increased the losses due to rotting in almost all treatments of all stocks, treatment effects were reduced, and rots in stock A increased to levels similar to those in stock C. The high percentage of bulb rots previously seen in untreated, stored samples of stocks A and C (Table 1) was still evident in all treatments, with total rots of 42-78%. In bulbs of stock B, the percentage rots were 11% or lower, except for treatment 5, where it was 26%, and treatment 5 also gave very high rots (78%) in stock C; at present there is no obvious explanation for the high level of rots in treatment 5. Most of the bulb rots observed by this time had progressed to a whole-bulb rot. No bulb damage due to narcissus fly was observed, but this may have been due to the overwhelming effect of fungal rots.

During these assessments it was noted that the flower buds were dead in many bulbs of treatments 1 and 4 of stocks B and C (both 'Golden Harvest'); buds in all other bulbs were normal. Treatments 1 and 4 both incorporated 17°C storage.

Table 4. Percentage bulb rots in stored samples after the completion of treatment. Values determined from 100-bulb samples

Stock	Treatment	Percentage of bulbs with rot types				All
		Base rot	Neck rot	Whole rot	Mummified bulbs	rots (%)
A	1	9	0	44	0	53
A	2	4	0	47	0	51
A	3	4	0	56	0	60
A	4	8	0	38	0	46
A	5	2	0	55	0	57
A	6	4	0	60	0	64
B	1	2	0	9	0	11
B	2	0	0	8	0	8
B	3	0	0	0	0	0
B	4	0	0	5	0	5
B	5	6	0	20	0	26
B	6	1	0	2	0	3
C	1	3	0	52	0	55
C	2	1	0	41	0	42
C	3	0	0	54	0	54
C	4	2	2	45	0	49
C	5	1	0	73	4	78
C	6	0	0	66	0	66

Figure 4. Bulb rots after HWT and storage assessment



Temperature records

The temperatures recorded by probes placed with the bulbs in bulk bins on the drying wall are shown in Figure 5. This showed that the mean temperatures achieved were close to the target (35°C). Temperature records during 17°C storage also showed that the required temperature was achieved within acceptable limits (Figure 6).

Figure 5. Temperatures in bins on drying wall

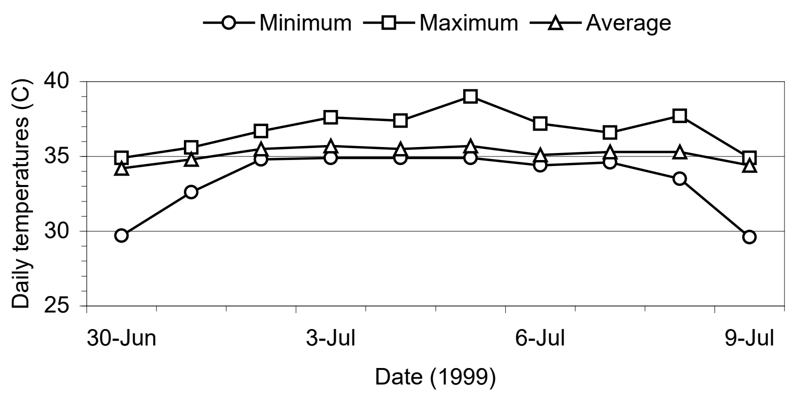
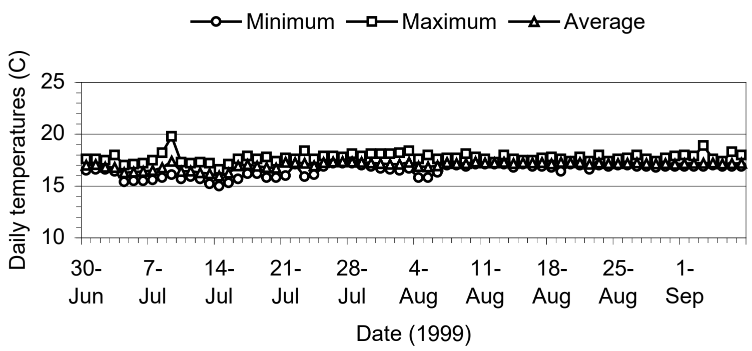
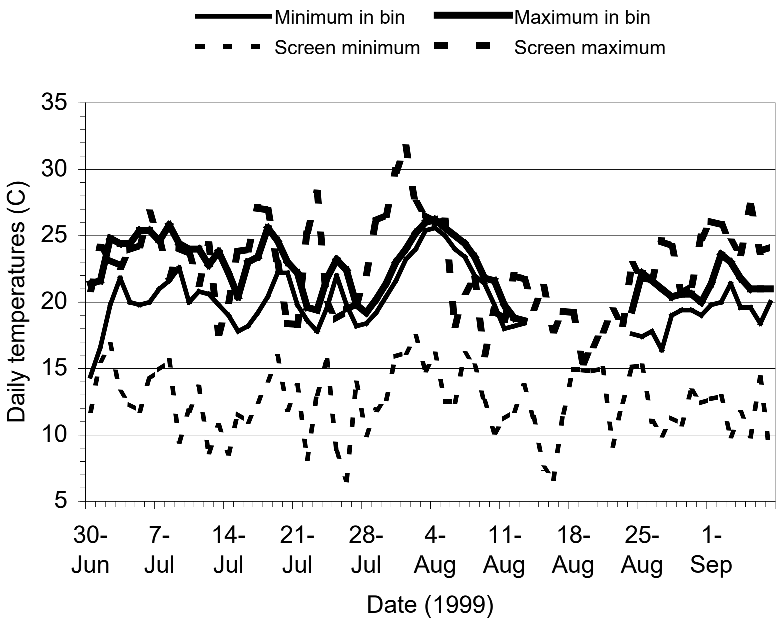


Figure 6. Temperatures in 17C store



Temperatures recorded in bins of bulbs during drying and storage at 'ambient temperatures' (in a well ventilated, unheated shed) are shown in Figure 8 (there was a break in recorded temperatures in late-August due to a logger malfunction). For most of the time, bin temperatures fluctuated between 20 and 25°C. Screen temperatures from the nearby Kirton Meteorological Station are also shown in Figure 8. Temperature fluctuations recorded in the bins lagged behind changes in outdoor temperatures by a few days.

Figure 8. Temperatures in bins held at ambient temperatures and screen temperatures



The 1999 and long-term (30 year) mean screen temperatures for the June to September period, for the Kirton meteorological site, are given in Table 5. Temperatures in June were similar to the long-term average, but those in July and August were 1-2°C higher than expected. September temperatures were considerably higher (2-3°C) than the long-term values.

Table 5. Mean daily temperatures for June to September at Kirton

	Daily minima (°C)			Daily mean (°C)			Daily maxima (°C)		
	Long-term	1999	*Excess of 1999 over long-term*	Long-term	1999	*Excess of 1999 over long-term*	Long-term	1999	*Excess of 1999 over long-term*
June	9.5	9.3	*-0.2*	13.9	13.9	*0*	18.5	18.5	*0*
July	11.4	12.3	*0.9*	16.2	17.6	*1.4*	21.2	22.9	*1.7*
Aug.	11.1	12.9	*1.8*	16.1	17.3	*1.2*	20.9	21.6	*0.7*
Sep.	9.4	11.5	*2.1*	13.6	16.3	*2.7*	18.0	21.2	*3.2*

DISCUSSION

This project is still at an early stage, and only a few general points can be drawn from the results so far. When bulbs of the three stocks were examined on the cleaning/grading line after the completion of drying, in the second half of July, it was clear that variable numbers and types of rotted and damaged bulbs were present, and these were identified and removed. There were large differences between the three stocks in the number of rotted bulbs removed at this stage: the least numbers of unhealthy bulbs were found in stock B and most in stock C. Most rots were of the base or neck type in stocks A and C, with many mummified bulbs in stock C, perhaps indicating that many bulbs had begun to rot in the ground. There was evidence of narcissus fly infestations in all stocks, and bulbs with damaged base plates were present. Soft rot (due to *Rhizopus*) was suspected, and was confirmed by culture, in small number of bulbs of all three stocks. These findings, including the relative diseases levels of the three stocks, were confirmed in samples of bulbs taken on receipt and subjected to a storage test (2 months at 25°C) before examination.

After HWT, following the completion of treatments, bulbs were again inspected on the cleaning/grading line. The number of rotted bulbs removed was again greatest in stock C and smallest in stock B, and in stock B bulb rots were generally not so far advanced as in stocks A and C. These results, too, were confirmed in random samples of bulbs taken at the same time and subjected to a storage test. The huge losses due to rots in stocks A and C, even after the application of 'best practices', suggests that fungal infections were already beyond the control of the fungicide treatments applied, and that even rapid drying and controlled temperature storage served only to delay the onset of rotting.

Treatments 1 and 4, however, consistently resulted in fewer rotted bulbs and a greater yield of sound bulbs. This effect became more evident in the poorer stocks. The experimental factor linking these two treatments was bulb storage at 17°C rather than at ambient temperatures. This suggests that an appropriate storage temperature is more effective than giving a post-lifting spray with Storite Clear Liquid (thiabendazole) fungicide or using 35°C for first stage drying. Mean air temperatures in July-August in eastern England are not very dissimilar to 17°C, but the progress of basal rot may be affected by actual temperatures, and the mean daily maximum temperatures at Kirton in July and August in 1999 were considerably higher than the long-term average. Mean temperatures in September 1999 were exceptionally high, and although this would not have affected the results obtained so far, it suggests that conditions on re-planting would strongly favour the development of basal rot.

In the 'Golden Harvest' stocks (B and C) treatments 1 and 4 also led to the death of many flower buds. No explanation can be offered for this at present, and the observation needs confirmation.

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