Project title:	**Virus-tested narcissus: evaluation and re-infestation studies**
Report:	**Final Report (December 1998)**
Previous reports:	**Annual Report (December 1997)** **Annual Report (December 1996)** **Annual Report (December 1995)** **Annual Report (December 1993)**
Project number:	**BOF 2a**
Project leader:	**Gordon R Hanks** **HRI** **Kirton** **Boston** **Lincs PE20 1NN**
Location:	**HRI Kirton**
Project Co-ordinators:	**Mr D Almond**
Date commenced:	**September 1991**
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Keywords:	**Narcissus, daffodil, bulbs, virus**

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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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In the report some materials (pesticides, etc) have been referred to by their proprietary names for the sake of accurate reporting; no endorsement of these products is intended, nor is criticism implied of products not mentioned.

PRACTICAL SECTION

Objective and background

The project was designed:

- To establish the rate of re-infestation with viruses in virus-tested (VT) narcissus bulbs (varieties Carlton and Fortune) grown in isolation or adjacent to ordinary bulb stocks
- To determine if re-infestation of VT narcissus (Carlton and Fortune) with aphid-borne viruses can be reduced by using regular insecticide or oil sprays
- To evaluate the performance of VT stocks of four other narcissus varieties (Dutch Master, Golden Harvest, St. Keverne and Tête-à-Tête) against ordinary stocks

Summary

Experiment 1: re-infestation study Virus-tested mother stocks (VTMS) of narcissus varieties Carlton and Fortune were grown (1) under the full protection of VTMS conditions, (2) in a sterilised, isolated field site (either under a mesh tunnel or in the open), or (3) in a field adjacent to ordinary (non-VT) narcissus stocks. Virus re-infection was measured by recording foliar symptoms and by laboratory testing using enzyme-linked immunosorbent assay (ELISA).

After the first two-year-down growing cycle all virus tests were negative for Fortune. After four years two out of 20 tests for Fortune were positive for the aphid-borne narcissus yellow stripe virus (NYSV) in the plots adjacent to ordinary stocks. After six years all tests were again negative. No foliar symptoms of virus were seen in Fortune throughout the six years of the trial.

In Carlton there was a single positive test (out of 20) for narcissus mosaic virus (NMV) in plants growing adjacent to ordinary stocks after two years. After four years there were two positive tests for NMV in plants in the protected, isolated site. After six years there was one positive test for narcissus latent virus (NLV) in plants adjacent to ordinary stocks, corresponding to the first appearance of a low rate of foliar symptoms in these plants. NLV is aphid-borne, and NMV has no known vector but may be transferred mechanically.

The results show a slow rate of re-infection by aphid-borne viruses in Carlton and Fortune. It is possible that the NMV may have originated from very low, previously undetected levels of the virus in the original stock.

Experiment 2: chemical control of re-infestation VTMS bulbs of Carlton and Fortune were also grown adjacent to ordinary stocks and treated with regular sprays of pyrethroid insecticides (Decis, Fastac and Ambush C) or oils (Actipron, Fyzol 11E and Codacide) throughout the growing season, to determine whether re-infestation by aphid-borne viruses can be reduced.

After the first two-year-down cycle, none of the Carlton plants tested positive for viruses, whereas there were eight positive tests (for NYSV and NLV) in Fortune (each out of a total of 140 tests).

After four years, all tests on Carlton remained negative, while 4 out of 140 tests in Fortune were positive for NYSV.

After six years there were totals of 25 positive tests in Fortune, and 20 in Carlton. In Fortune, all positives were for NYSV, all were detected at low levels, and no foliar symptoms were seen. In Carlton, the positive tests were mainly for NYSV, with some positives for NLV and one for the nematode-transmitted *Arabis* mosaic virus (ArMV). Virus scores in Carlton were generally low, but were high (and accompanied by the appearance of foliar symptoms) in the two treatments (Ambush C and Fyzol 11E) where most NLV positives occurred. Generally, the positive results were spread amongst the treatments and controls at a low rate such that no treatment effects could yet be seen.

The mineral oil treatments (Actipron, Fyzol 11E) had a number of adverse effects on the crop, including shorter plants, paler foliage, earlier senescence and lower bulb yields with more smaller bulbs. In some cases Codacide oil treatment also reduced bulb yield. There were no adverse effects of pyrethroid insecticide spray treatments on the crop.

Experiment 3: evaluation studies VTMS bulbs of varieties Dutch Master, Golden Harvest, St. Keverne and Tête-à-Tête were acclimatised for two years on an isolated site and then evaluated alongside five commercial (ordinary, non-VT) stocks of these varieties (which had also been acclimatised by growing for two years on the same site). Despite using bulbs of the same grade for each variety, the starting weights of VT bulbs were lighter than non-VT bulbs in the case of three varieties, and heavier than non-VT bulbs in the case of Tête-à-Tête.

In the first year of the trial, VT bulbs of Dutch Master, Golden Harvest and St. Keverne always had the greatest flower production (occasionally equalled by some non-VT stocks), and often had longer stems and larger flowers than non-VT stocks. Differences between stocks in foliage length were not consistent.

In the second year, the VT stocks of these three varieties no longer produced more flowers than ordinary stocks (although VT Golden Harvest had larger and longer-stemmed flowers). In bulb yields, VT Golden Harvest was superior to non-VT stocks, but this was not true for Dutch Master and St. Keverne. On grading, VT Golden Harvest and VT St. Keverne produced more bulbs of the larger grades. Compared with non-VT bulbs, VT Tête-à-Tête had fewer stems, more florets per stem, larger florets and longer stems and leaves in year one, an advantage just maintained in year two (when the VT stock was also earlier to flower). Bulb yields were greatest in the VT Tête-à-Tête stocks.

In the third year, VT bulbs of Golden Harvest continued to perform better than non-VT stocks (except one) in flower yield, but this was not so for Dutch Master and St. Keverne, and there were few significant differences between these stocks. VT Tête-à-Tête had longer stems than non-VT stocks, but one of the non-VT stocks had most stems and florets per plot.

In the fourth year, VT Dutch Master had significantly longer stems and foliage, VT Golden Harvest longer foliage, and VT Tête-à-Tête larger florets, than non-VT stocks, but there were no significant differences between stocks in other aspects of flowering performance and none in St. Keverne. In terms of bulb yield, VT Golden Harvest was better than non-VT stocks, and Dutch Master was much better, while there were no significant differences between stocks for St. Keverne. VT Tête-à-Tête produced more bulbs in the larger grades than non-VT stocks, but there were no overall differences in yield.

In the first year, non-VT stocks had 3 to 63% of plants with visible symptoms of virus, depending on variety and stock, whereas in VT stocks no symptoms were seen in St. Keverne or Tête-à-Tête and only occasional symptoms in Dutch Master and Golden Harvest.

In the second year, all stocks (including VT stocks) of all varieties had some foliar symptoms of virus, and all stocks had some positive results in ELISA testing. However, in both field scores and ELISA results the VT stocks had much lower levels of virus than the ordinary stocks. NYSV was found in both VT and ordinary stocks, and other viruses (especially NLV) were often found in the ordinary stocks but not in the VT stock.

In the third year, VT stocks of Golden Harvest, St. Keverne and Tête-à-Tête continued to have a much lower rate of foliar virus symptoms then non-VT stocks, but now two non-VT stocks of Dutch Master were superior to the VT stock in this respect.

In the fourth year, visible virus symptoms were fewer in VT and one other stock of Dutch Master, and in VT Golden Harvest, than in other stocks of these varieties. In St. Keverne and Tête-à-Tête, virus symptoms were frequent even in VT stocks, but were still much lower than in non-VT stocks where, in some cases, almost 100% of plants were affected. In ELISA testing, in the case of Dutch Master the VT stock and two other stocks had the lowest scores for NYSV, but considering all viruses the VT stock was far superior to all non-VT stocks. VT stocks of Golden Harvest, St. Keverne and Tête-à-Tête had much lower ELISA scores than other stocks. In nearly all cases where VT stocks had positive ELISA tests, these were for NYSV; in the case of non-VT stocks, a range of viruses was detected.

Action points for growers

Although VT narcissus do not out-perform all ordinary (non-VT) stocks in all respects in all years, their performance, taken overall, is superior. This may include producing more flowers, larger or taller blooms, more vigorous leaves, higher bulb yields and larger bulbs. Grown adjacent to ordinary narcissus stocks, in which most plants are expected to be infected with viruses, and in the absence of any special measures against virus transmission by insect or nematode vectors, virus re-infection occurs within a few years, but at different rates in different varieties. Re-infection was relatively slow in Carlton and Fortune (even after 6 years), but faster in Dutch Master and Golden Harvest and particularly in St. Keverne and Tête-à-Tête (with foliar symptoms of virus appearing within two years of planting in an ordinary field).

The superior qualities of VT narcissus suggest that VT stocks should be considered by growers supplying the more demanding markets, or in any case where their own stocks are degenerating and causing concern because of high virus levels. From the present investigation it is clear, however, that the expenses associated with acquiring and growing VT narcissus stocks demand that such stocks are grown in a way to minimise re-infection by viruses, the most common of which is NYSV, an aphid-borne virus. These precautions should include:

- Growing in isolation from ordinary stocks and other sources of infection
- Planning varietal plantings in relation to their susceptibility to pick up viruses
- Applying regular pyrethroid sprays when aphids are present in significant numbers
- Developing a scheme to maintain a 'core' stock of VT bulbs from which bulbs are fed out into the 'production' stock

- Maintaining vigilance and roguing plants with virus symptoms, at least in these core stocks

Practical and financial benefits from the study

The prevalence of virus symptoms in narcissus stocks appears to be increasing, probably as the crop is grown more intensively and as the costs of labour preclude the amount of roguing previously carried out. While practical methods of control for fungal diseases and pests of narcissus are available, no field-scale control of viruses or their vectors is currently practised, suggesting that the impact of virus diseases is likely to increase over the next 10 years or so, as was evident in 'Sols' grown on the Isles of Scilly in the 1960s. In addition, demanding customers want high health status plants and are developing strict protocols. At present this has little effect in the narcissus industry, but the situation is likely to change, so growers should consider the possible effects of falling crop quality, due to virus, on their future marketing opportunities. The information contained in the present report should help to inform these decisions.

EXPERIMENTAL SECTION

Introduction

The story of 'virus-free' narcissus bulbs (more properly called virus-tested (VT) bulbs or bulbs free of detectable virus) began when the poor vigour (loss of productivity and general leaf chlorosis) of stocks of the tazetta cultivar Grand Soleil d'Or ('Sols') on the Isles of Scilly was linked with its widespread virus infestation. VT bulbs were obtained by meristem-tip culture, and stocks were bulked using twin-scaling or chipping, leading to the successful introduction of superior stocks (Stone, 1973; Stone *et al.*, 1978). VT bulbs had larger florets and brighter colours than ordinary commercial bulbs. Their critical bulb weight for flowering was lower, and they gave higher yields of flowers and bulbs (Stone, 1973; Tompsett, 1983). A substantial proportion of the present Sols on the Islands has originated from these superior stocks.

Mainstream narcissus cultivars were also found to be widely infested with viruses, and 'virus-free' bulbs of these were also sought. Apparently virus-free individuals were found in some cultivars (e.g., Carlton, Corinthian, Fortune and Sempre Avanti) but could not be found in others (e.g., Dutch Master, Golden Harvest, King Alfred and Rembrandt) (Mowat and Chambers, 1975a, b). VT plants were obtained, mainly by indexing bulbs in Scotland (Mowat, 1980b; Mowat *et al.*, 1986), and by using meristem-tip culture in England (Brunt, 1980; Brunt *et al.*, 1984). Mother stocks were built up by twin-scaling or chipping, grown under vector-proof conditions or in isolation, and nuclear stock schemes were set up under the Nuclear Stock Association (Bulbs) and the Scottish Nuclear Stock Association (NSAs) (Brunt, 1985; Ebbles, 1986; Mowat *et al.*, 1986; Rankin, 1986). A VT narcissus programme has recently been started in Denmark (Thomsen, 1986). In The Netherlands, work on the production of VT narcissus was reported to be in only its early stages in 1989 (Asjes, 1990), and had apparently not progressed beyond the initial production of VT bulbs of a few varieties by 1996 (C.J. Asjes, personal communication).

The uptake of VT daffodils in England has been frustratingly slow, largely due to the naturally slow multiplication rate of narcissus, always a serious hindrance to the uptake of elite stocks or new cultivars in this crop. Chipping can speed multiplication to some extent, but is labour-intensive and hampered by lack of really effective fungicides (see review in Hanks, 1993). A further inhibiting factor is the lack of critical data on either the yield benefits of VT bulbs, or on how quickly they would be likely to be re-infested with virus in the field. This lack of data is understandable, for there was naturally a reluctance in the early stages of the VT programme to release expensive bulbs for destructive testing. In experiments, there are also the practical problems of eliminating differences between VT and ordinary stocks due to previous cultural regimes and propagation. The few critical comparisons of the performance of VT and ordinary narcissus bulbs are summarised below. The dogma that 'VT is better' can hardly be expected, without data, to convince growers that investment in expensive VT bulbs is worthwhile. Nevertheless, a number of bulb growers did commit themselves to the concept of VT bulbs, first through the NSAs, and then by growing-on the small initial stocks through the long period of bulking-up.

A survey in 1994-1995 of VT stockholders in England and Wales indicated that there were probably 5 to 10 ha of field-grown 'VT' narcissus stocks, comprising some 50 t of bulbs, involving 50 cultivars, with some individual holdings of 10 t (G.R. Hanks, unpublished data). In addition, some 70 cultivars (each ranging in quantity from a few bulbs to several thousand bulbs) are maintained in vector-proof conditions as VT mother stocks (VTMS). This build-up of VT stocks means that management procedures will soon be needed for handling VT stocks and minimising their re-infestation. In Scotland, where pressure from aphids is less, and where there was a committed programme of twin-scaling, VT stocks have already been introduced more widely (W.P. Mowat, personal communication).

Van Slogteren and Ouboter (1946) suggested that virus infections might reduce bulb yields by two-thirds, a high figure later questioned by Rees (1972). Asjes (1990) stated that yields could be reduced by 10 to 35% in stocks seriously affected by narcissus yellow stripe and white streak viruses. Comparisons of VT and ordinary stocks of narcissus have been carried out in Scotland, England and New Zealand. Sutton *et al.* (1986, 1988) described trials in Scotland comparing five-year-old VT stocks with adjacent visually healthy commercial stocks. VT stocks consistently out-yielded commercial stocks by 15 to 20%, producing heavier bulbs, and emerging and flowering earlier. The potential precocity of VT bulbs had been shown much earlier by Rees (1966). In a series of comparative trials with cultivars Carlton, Fortune and Ice Follies grown at Rosewarne (Cornwall) and Kirton (Lincolnshire), the yield advantage of VT bulbs was found to be more consistent at Rosewarne (ADAS, 1987; Hanks, 1992). VT Fortune performed better than ordinary stocks at both sites. Full details of these comparisons are available in the HDC report of project BOF2 (Hanks, 1992). Differences between these results in the two areas of England may have been due to VT stock being better able to take advantage of an earlier growing season in the south-west, being more resistant to the foliar disease present in the south-west, or simply to differences (perhaps arising from prior growing conditions) between the non-VT stocks used for comparison at either site. Evaluations of 'VT' and ordinary stocks of Carlton, Fortune, Ice Follies and Soleil d'Or have also been carried out in New Zealand (Allen and McIntosh, 1994). These showed that bulb weight yields from VT stocks were about double those of ordinary stocks in the first year, but similar in the second year, although the VT bulbs produced greater bulb numbers (more offsets) in the second year.

Limited data are also available on rates of spread of narcissus viruses. Some 21 viruses have been reported to occur naturally in narcissus (Brunt, 1995). Many of these are aphid-borne, including cucumber mosaic (CMV), narcissus degeneration (NDV), latent (NLV), yellow stripe (NYSV), white streak (NWSV) and late seasons yellows (NLSYV) viruses. NYSV is probably the most important and probably ubiquitous of the narcisus viruses. *Arabis* mosaic (ArMV) and various ringspot viruses are nematode-borne. Narcissus mosaic, tip necrosis and Q viruses (NMV, NTNV, NVQ) have no known vectors, although the first may be spread mechanically, e.g. by flailing (Mowat, 1987). Aphids do not generally colonize narcissus, but can spread viruses during exploratory probing, so the spread of aphid-borne viruses would be expected to be slow, local and proportional to the numbers of aphids and infected plants (Broadbent *et al.*, 1962; Haasis, 1939). In a three-year period, 16, 46 and 90% of healthy plants were infected in plots with initial infector levels of 10, 20 and 50%, respectively. In field trials with 7 or 10% of plants infested with NYSV, there was little increase in one year, but when foliage was allowed to senesce naturally a three-fold increase occurred (Mowat, 1980a), confirming an earlier result of van Slogteren and Ouboter (1946) that virus infestation increased by up to 72% when harvesting was delayed by 8 weeks, presumably because aphid numbers are by then increasing. In another study, bulbs of four cultivars, free of tobacco black ring and raspberry ringspot viruses, were grown on infected soil, and after two years 10 to 65 % (depending on cultivar) were infected with the former and 0 to 10% with the latter (Mowat, 1980a).

The above re-infestation studies were not carried out with VT bulbs. However, in VT bulbs of Grand Soleil d'Or planted in a commercial situation, seven out of ten bulbs had positive tests for NDV after 18 months (Stone, 1973), and when VT and commercial bulbs of this cultivar were grown in proximity for three years, 62% of VT plants were positive for NDV and up to 75% for ArMV (Tompsett, 1983). VT bulbs of Carlton, planted adjacent to ordinary stocks, had 0.8% of tests positive for NTNV by the third year (Sutton *et al.*, 1988).

Control of the spread of virus diseases is mainly by rogueing, growing in isolation, and the use of healthy planting stocks (Broadbent *et al.*, 1962; Moore *et al.*, 1979). The possibility of mechanical transmission of some viruses (Mowat, 1987) implies that careful handling is advisable. Soil sterilization may be used on a small-scale to control nematode-transmitted viruses, but the control of aphids transmitting narcissus viruses is difficult, because of the rapidity of inoculation during probing by the aphid. On a small scale, growing under mesh covers can be used (Claessen, 1990). In other bulb crops, variable success has been reported by using regular sprays of either pyrethroid insecticides (at least weekly), which have an antifeedant action on aphids, or of mineral oils, which draw virus particles from the stylet before probing begins (Asjes, 1985). However, there are reports that the use of systemic insecticides may increase virus spread by increased irritability and feeding before death (Broadbent *et al.*, 1957), while mineral oil sprays may reduce bulb yields (ADAS, 1982; Asjes, 1985) and were reported not to prevent spread of NYSV in one study (Mowat *et al.*, 1984).

UK daffodil growers have earned a reputation for quality, part of which is dependant on maintaining low levels of pests and diseases. The demand for higher plant quality seems inexorable, and VT bulbs could have a significant role to play in the quest for 'high health status stocks', helping to maintain the quality of UK bulbs. This is vital if the UK is to maintain exports into the next century and seek even more demanding customers abroad. Ordinary daffodil stocks sometimes have levels of virus symptoms which would not have reached the quality standards required in Growing Season Inspections, yet with the need to reduce labour inputs roguing bulb stocks to remove affected plants becomes increasingly impractical. The answer is to feed in new virus-tested stocks - once we know more about how they perform and how quickly they may become re-infected. These key questions have been addressed in the present project, which has three aims:

Experiment 1 To study rates of virus re-infestation in the field, both adjacent to ordinary (non-VT) stocks and in isolated and protected situations. Information would also be gathered on the effects of re-infestation on performance and its relation to visible virus symptoms. Cultivars Carlton and Fortune were to be used because reasonable quantities of VT bulbs were available. The plan was to grow the bulbs for a number of two-year-down cycles, until clear trends could be determined. The experiment was continued for 6 years.

Experiment 2 To investigate controlling re-infestation by aphid-borne viruses by using regular sprays of antifeedant, pyrethroid insecticides or oil sprays. As in Experiment 1, cultivars Carlton and Fortune were used, and the experiment was continued for six years.

Experiment 3 To evaluate the performance of VT and commercial stocks of cultivars not so far assessed. The cultivars chosen were Golden Harvest and Dutch Master, because of their commercial importance, St. Keverne, an example of a variety which is very rapidly infested with virus in the field, and Tête-à-Tête, an important dwarf cultivar of which commercial stocks are highly infested with virus. An experimental design was used which would allow comparison of the VT stocks with a selection of commercial stocks. The experiment was continued for four years.

This is the final report on the project, and incorporates all information from the previous reports, with the addition of data acquired in 1998. The findings should enable growers to make sound decisions about growing VT bulbs.

Materials and methods

Plant material

VT bulbs of *Narcissus* cultivars were produced by the Virology Department of the former Glasshouse Crops Research Institute, Littlehampton, West Sussex. Initial VT bulbs, usually produced by meristem-tip culture, and multiplied by chipping or twin-scaling as appropriate, were grown in sterilized compost in insect-proof glasshouses to prevent exposure to nematode or aphid vectors. Details of initial procedures are given in Stone *et al.* (1978).

VT stocks were subsequently transferred to Rosewarne Experimental Horticulture Station, Cornwall, and then, on its closure in 1989, to HRI Kirton, Lincolnshire. They were grown under cultural conditions similar to those used before, and in conformity with the requirements for virus-tested mother stocks (VTMS) of MAFF's Plant Health Propagation Scheme (PHPS) (see below). In the two springs following transfer to Kirton, the stocks were subjected to random leaf sampling for testing for viruses by the Plant Health and Seeds Inspectorate (PHSI): there were no positive tests. The stocks continue to be subject to annual inspection under the PHPS, with satisfactory results up to the time of writing.

VTMS-grade bulbs of cultivars Carlton and Fortune were taken from these stocks in summer 1991 and used for Experiments 1 and 2 on re-infestation rates.

VTMS bulbs of cultivars Dutch Master, Golden Harvest, St. Keverne and Tête-à-Tête were taken from the same stocks in summer 1992, planted on an isolated field site at HRI Kirton and grown, under conditions equivalent to those required for the Foundation Stock (FS) grade of the PHPS (see below under Cultural details - bulbs for isolated growing), for two years to allow field acclimatization prior to setting up Experiment 3 in 1994. 10 random leaves from each of these four stocks were taken in May 1994 and tested individually for virus (methods as described below), all tests being found to be negative. Commercial (non-VT) stocks of bulbs of these four cultivars were obtained from five different sources in 1992 and grown at Kirton under normal field conditions for acclimatization in preparation for use in Experiment 3.

Experiment 1: re-infestation study

1991-1993 VTMS-grade bulbs of cvs Carlton and Fortune were allocated to four replicate plots for each of four treatments:

1. Retained in VTMS conditions as 'controls'
2. Isolated field conditions under the protection of a low mesh tunnel
3. Isolated field conditions
4. Standard field conditions adjacent to non-VT stocks

Plot size was determined and limited by stock availability. Carlton plots consisted of 100 bulbs (2.05 and 0.96 kg of 10-12 and 12-14 cm grades, respectively), and Fortune plots of 80 bulbs (0.04, 1.87 and 0.50 kg of 8-10, 10-12 and 12-14 grades, respectively). Further bulbs from the same stocks were allocated as guard plants for planting around the recorded plots.

Bulbs for treatment 1 were planted in trays of compost in a VTMS tunnel on 30 October 1991, as described below (Cultural details - VTMS bulbs). Bulbs for treatments 2 to 4 were planted in ridges in the field on 16 September 1991, either on an isolated site under the protection of a mesh tunnel (treatment 2), on an isolated site with no cover (treatment 3), or in an ordinary daffodil field (see below). All plots (whether in trays or ridges) were 3.5 m-long (corresponding to a planting density of *ca.* 10 t/ha).

The numbers of flowers per plot were recorded each spring, along with flower diameter (measured across the widest point), stem (scape) length (from the surface of the substrate to the base of the bud) and maximum foliage height, based on measuring 20 central plants per plot. Flowering dates were recorded, percentage foliage senescence was recorded about weekly, and crops were examined for visible virus symptoms early and late in each growing season. In the case of treatment 2, detailed records were omitted for reasons of accessibility and to help maintain the isolation of the plants. In the second spring (1993) plants were sampled for virus testing (see below). The bulbs were lifted over the period 16-18 June 1993 and treated as described below, and bulb yields (numbers and weights in grades, plus numbers of any rotted bulbs which were removed and discarded) were recorded. The bulbs were kept in their original plots throughout so that the experiment could be continued on a plot-by-plot basis.

1993-1995 For treatment 1, all bulbs from a plot were kept and planted in a number of trays such that the approximate bulb spacings recommended under the PHPS were maintained (Carlton bulbs were divided between 9 trays and Fortune bulbs between 7 trays). This procedure was adopted so that no valuable VTMS-grade bulbs were lost. Guard plants were taken from the stocks previously used. For treatments 2, 3 and 4, plots of equalised weight and grades were made up according to availability, and surplus bulbs were used as guards. The plots of these treatments consisted of 4.6 kg bulbs (each made up of 0.5 kg <8 cm, 1.5 kg 8-10 cm, 2.0 kg 10-12 cm and 0.6 kg 12-14 cm), for planting in 3 m-long plots (*ca.* 20 t/ha). Surplus bulbs from each plot were equally divided between two, 1 m-long guard areas at either end of the recorded plot. This procedure was adopted to provide strictly comparable recorded plots, whilst retaining all bulbs from each initial plot so that any build-up of virus levels was not lost.

The trial was replanted on 14 October 1993. During 1993-95, similar records and samples for virus testing were taken as previously. The bulbs were lifted from the field and recovered from VTMS trays on 4 July 1995. They were graded and kept in plots to continue the experiment.

1995-1997 Similar procedures were used as for the preceding period. For treatment 1, Carlton plots consisted of 11 trays of <8 cm bulbs and 4 trays of 8-10 cm bulbs, and, for Fortune, 7 trays of <8 cm bulbs and 3 trays of 8-10 cm bulbs. Surrounding guards were made up from the bulbs previously used. Bulbs from treatments 2, 3 and 4 were made up into equalized plots, all surplus bulbs and associated guards being combined and re-used as guards on a plot-by-plot basis. The plots consisted of 3.45 kg bulbs for treatments 3 and 4 (made up of 1.00 kg <8 cm, 1.20 kg 8-10 cm and 1.25 kg 10-12 cm grade bulbs) but only 2.3 kg bulbs for treatment 2 (where yields were poorer) (made up of 0.7 kg <8 cm, 0.8 kg 8-10 cm and 0.8 kg 10-12 cm grade bulbs). Plot lengths were 3 m long (treatments 3 and 4) or 2 m long (treatment 2) (corresponding to a planting density of *ca.* 15 t/ha), and in each case there was a 2 m length of guards at either end of each plot.

Re-planting dates were 18 September 1995 (treatment 4), 12 October 1995 (treatments 2 and 3) and 18 October 1995 (treatment 1). The usual records and samples were taken in 1995-97. The experiment was lifted on 23 June (treatment 1) and 15 July 1997 (treatments 2 to 4) and bulb yields were recorded.

Experiment 2: chemical control of re-infestation

1991-1993 VTMS Carlton and Fortune were used, as for Experiment 1. Bulbs of 8-10 cm grade were allocated to 100-bulb plots (weighing 1.62 and 1.67 kg for Carlton and Fortune, respectively), with four replicate plots for each of seven treatments. Bulbs were planted in ridges in 3.5 m-long plots, adjacent to ordinary narcissus stocks, on 16 October 1991 (planting density, *ca.* 6 t/ha). Cultural treatments were standard (see below).

Spray treatments were applied weekly, or as soon as weather conditions allowed, beginning in early-March (the earliest time aphids had been observed in insect traps at Kirton), and continuing until leaf senescence. 13 sprays were applied between 5 March and 16 July in 1992, and 10 sprays between 4 March and 8 June in 1993. The treatments were:

1. control (not sprayed);
2. deltamethrin (as 1 litre Decis (25 g a.i./litre; Hoechst) /ha);
3. alpha-cypermethrin (as 0.2 litre Fastac (100 g a.i./litre; Shell) /ha);
4. cypermethrin (as 0.25 litre Ambush C (100 g a.i./litre; ICI) /ha);
5. adjuvant oil (as 5 litre Actipron (containing 97% highly refined mineral oil; Bayer) /ha);
6. adjuvant oil (as 5 litre Fyzol 11E (containing 99% highly refined mineral oil; Schering) /ha); and
7. adjuvant oil (as 5 litre Codacide Oil (containing 95% emulsifiable vegetable oil; Microcide) /ha).

All sprays were applied in 1000 litre water/ha, using an Oxford Precision Sprayer and a medium spray quality.

Records of flowering were made annually, and virus testing was carried each two years, as described for Experiment 1. In addition, plants were checked at intervals for any visual evidence of spray toxicity (such as foliage discolouration). As for Experiment 1, bulbs were lifted (on 17 June 1993), graded, and allocated for re-planting and continuing the trial, keeping all plots separate.

_1993-1995_ For each plot, 6.0 kg bulbs were allocated for replanting in 1993, consisting of a mixture of the available grades (0.5 kg <8cm, 1.5 kg 8-10 cm, 2.5 kg 10-12 cm and 1.5 kg 12-14 cm), approximately 180 bulbs per plot. Each plot was 4 m long, giving a planting density of *ca.* 20 t/ha. Bulbs were planted on 19 October 1993, other details of husbandry, recording etc, being as before. Spray treatments were applied as before: in 1994, 10 sprays were applied between 18 March and 7 July, and in 1995, 11 sprays between 8 March and 16 June. The trial was lifted on 5 July 1995 and recorded as before.

_1995-1997_ Procedures used were similar to those of the previous year. However, each 6 kg plot consisted of 1.0 kg 8-10 cm, 2.0 kg 10-12 cm and 3.0 kg 12-14 cm grade bulbs. The re-planting date was 19 September 1995. In 1996, 15 spray treatments were applied between 11 March and 22 July, and in 1997, 13 sprays between 3 March and 24 June. The usual records were taken and the experiment was lifted on 14 July 1997, recording bulb yields as usual.

Experiment 3: evaluation studies

_1994-1996_ Bulbs of cvs Dutch Master, Golden Harvest, St. Keverne and Tête-à-Tête, from VTMS stocks and five commercial stocks, acclimatised in the field at Kirton for two years, were used to set up this experiment in 1994. Bulb grades used were 8-10 cm for St. Keverne and Tête-à-Tête, and 10-12 cm for Dutch Master and Golden Harvest. For each cultivar and stock, four replicate lots of 100 bulbs each were allocated, and initial plot weight was recorded. Bulbs were planted on 9 September 1994 in 3.0 m-long plots, each of which was surrounded by guard bulbs. All guard bulbs were taken from one of the non-VT stocks which was considered to have a low incidence of visible virus symptoms. This procedure was adopted so that all plots were subjected to approximately equal disease pressure. The planting density corresponded to about 15.5 t/ha for Dutch Master and Golden Harvest, 10 t/ha for St. Keverne, and 6 t/ha for Tête-à-Tête. The experiment was sited adjacent to ordinary narcissus stocks, and standard cultural practices were used.

The usual records of flowering, etc, were taken in 1995 and 1996. The percentage of plants in each plot with visual symptoms of virus was recorded on 12 May 1995 and was scored again on 15 May 1996. Leaf samples were taken for virus testing in 1996, as described for Experiment 1. The plots were lifted on 25 June 1996, and yields were recorded as previously described. Bulbs were allocated for re-planting and continuing the trial, keeping all plots separate.

_1996-1998_ The weight and grade of bulbs allocated for re-planting varied between the cultivars according to availability. For Golden Harvest and St. Keverne, each new plot was composed of 20 bulbs each of grades <8, 8-10 and 10-12 cm, and for Dutch Master 10 bulbs each of grades <8, 8-10, 10-12 and 12-14 cm; each plot was weighed. For Tête-à-Tête, each new plot consisted of 1 kg of bulbs of grade <8 cm. Each batch was planted in a plot 1.5 m long, giving approximate planting densities of 14 t/ha for Golden Harvest, 11 t/ha for St. Keverne and Dutch Master, and 9 t/ha for Tête-à-Tête. In some replicates there were insufficient bulbs to make up these plots, and between one and three plots were missing in the different varieties.

The experiment was planted on 10 September 1996 and lifted on 30 June 1998. Records taken in 1997 and 1998 were similar to those described above.

Experimental design and statistical analysis

In Experiment 1 there were four plots for each cultivar at each of the four sites, each variety block being surrounded by equivalent guard plants. In Experiment 2, there was a randomised block design with four replicates for each treatment of each cultivar, and each plot was surrounded by an unplanted guard area. In Experiment 3, there was a randomised block design with four replicates for each cultivar, and each plot was surrounded by a guard area planted with bulbs all taken from a single stock. In all cases, cultivars were grown in separate areas and were analysed separately. Data were subjected to the analysis of variance where appropriate. In Experiment 3, analyses were also done with data adjusted for initial planting weight as a covariate: the covariate was not significant and therefore non-adjusted values are quoted in Results.

Virus testing

Five leaves were sampled randomly across each plot, taking 5 to 10 cm long leaf tips from fully expanded (but not yet senescing) leaves, and testing these individually. Testing was carried out at HRI Littlehampton or (from 1995) Wellesbourne, using ELISA (enzyme-linked immunosorbent assay), against narcissus yellow stripe virus (NYSV), narcissus latent virus (NLV), narcissus mosaic virus (NMV), arabis mosaic virus (ArMV), narcissus tip necrosis virus (NTNV) and narcissus Q viruses, some of the most common viruses affecting narcissus. From 1996 on, ELISA readings (at OD405 after 60 minutes) were quantified on a scale of 1 (readings <0.3) to 5 (readings >1.2).

Up to 1996, confirmation tests were made using ISEM (immunosorbent electron microscopy) and by inoculation to indicator species (such as *Chenopodium quinoa*, *Nicotiana benthamiana*, *N. clevelandii*, *N. glutinosa*, *N. megalosiphon*, *N. rustica*, *N. tabacum* or *Tetragonia expansa*) for cucumber mosaic and soil-borne ringspot viruses, checking plants for symptoms after 7 and 14 days. No other viruses were incidently detected.

Cultural details

Virus-tested mother stock (VTMS) bulbs (for stocks and for plots of treatment 1 in Experiment 1) were grown in trays of compost in insect-proof polythene tunnels. Tunnels were equipped with inward-blowing ventilation fans (set at 15°C for ventilation, and also turned on before entering the tunnel to deter entry of insects). Fan housings, etc, were covered with suitable aphid-proof mesh (Nicotex 336). Entrance was via a double-door foyer, in which appropriate hygienic precautions (overalls, boot-dip, etc) were observed by operatives. VTMS structures were approved by the PHSI and were maintained in good condition. Trays used for growing the bulbs were *ca.* 61 x 45 x 11 cm in size, with plant spacings generally corresponding to those required by the PHPS (approximately 60, 30 and 20 bulbs per tray for grades <8 cm, 8-10 cm and >10 cm, respectively). The compost used consisted of a 3:1 medium sphagnum peat-grit mixture, with nutrients, lime and trace elements added as for 'GCRI Compost B' (ADAS, 1984).

A regular pesticide programme was maintained. Up to and including 1993-94, nicotine (as Nicotine 40% Shreads (40% w/w a.i.; DowElanco)) was used as a smoke every 2 weeks, according to the manufacturer's instructions and, during the growing season, cypermethrin (as 5 g Ambush C (100 g a.i./litre; ICI) /10 litres) was applied as a spray each 2 weeks, alternating with the use of nicotine. From 1994-95 onwards, sprays of nicotine (XL-All Insecticide (70 g a.i./litre; Vitax)) and of malathion (MTM Malathion 60 (600 g a.i./litre; MTM Agrochem)) plus cypermethrin (Ambush C (100 g a.i./litre; Zeneca)) were alternated weekly throughout the growing season. Dichlorvos (as Vapona Fly Killer) was also used for additional insect control, according to manufacturer's instructions, and yellow and blue sticky traps were placed in the tunnels and tunnel entrances. During the growing season a fungicide spray programme was used. Originally, a spray was applied every two weeks, the materials being varied but typically consisting of alternating applications of vinclozolin, chlorothalonil and mancozeb with benomyl, all at appropriate rates. From 1994-95 onwards, monthly sprays of dichlofluanid (as 10 g Elvaron WG (50% w/w a.i.; Bayer)/10 litres) were used instead.

VTMS bulbs were lifted, hot-water treated and replanted annually. In the case of experimental treatments, bulbs from each tray were kept separate and were re-planted in one tray to maintain the experimental layout for both years of the two year period, and hot-water treatment in these years (from 1996 onwards) was the milder treatment of 2 hours at 43.5°C. Details of bulb handling between lifting and re-planting were as given for standard bulb growing (see below).

Foundation stock (FS) bulbs (VT stocks for use in Experiment 3) were grown in at least 50 m isolation from other bulbs in a field which had not grown bulbs or other nematode hosts for at least 10 years previously. Before planting, the area to be used was sterilized using a methyl bromide-based soil fumigant, and soil sampled for nematode vectors of narcissus viruses and found to be free of the relevant genera (*Trichodorus, Paratrichodorus, Longidorus* and *Xiphinema*). Within the field, cultivars were separated by gaps of at least 1 m. Bulbs were lifted, hot-water treated and re-planted every 2 years. Standard cultural and bulb handling methods were used (see below).

Bulbs for isolated growing (treatments 2 and 3 of Experiment 1) were grown under similar conditions to FS bulbs (including pre-planting soil sterilization with a methyl bromide-based soil fumigant or (from 1995 onwards) 1,3-dichloropropene (as Telone II)), except that the area used had not been free of bulb crops for a full 10 years beforehand. Pre-planting soil sampling of the sites used in 1991, 1993 and 1995 confirmed these to be free of nematode genera which transmit narcissus viruses (see above). For bulbs grown under protection, a low tunnel (*ca.* 1.2 m high) of insect-proof gauze (Tygan initially, Nicotex 153 from 1995-96 on) was placed over the plots from before shoot emergence until after foliage senescence; during the growing season, routine herbicide and fungicide sprays were applied over the top of the tunnel.

Standard bulb growing (for ordinary stocks, treatment 4 of Experiment 1, and all treatments of Experiments 2 and 3) involved two-year-down growing under good commercial conditions (e.g., see ADAS, 1985) alongside ordinary (non-VT) narcissus stocks. From previous virus testing on these ordinary stocks, it had been established that, typically, only 10 to 50% of plants were virus-free, 50 to 80% having positive tests for NMV and up to 40%for aphid-borne potyviruses (e.g., NYSV); these stocks typically showed a low level of virus symptoms, for which they were rogued regularly, and they had satisfactory annual PHSI Growing Season Inspections. Virus testing on stocks surrounding the trials in 1995 showed that 19 out of 20 samples had NYSV, two of these additionally having NMV, while a single sample was negative for viruses. In 1997 comparable tests showed that the stocks surrounding the trials had 11 out of 20 samples positive for NYSV, 6 out of 20 positive for NTNV, 3 out of 20 positive for NLV, and 6 out of 20 positive for NMV; 3 samples tested negative. Although the sites used were not sterilized pre-planting, pre-planting soil sampling in 1991, 1993 and 1995 (experiments 1 and 2) and 1994 and 1996 (experiment 3) showed that nematode genera transmitting narcissus viruses were absent.

For experimental plots, bulbs were planted in lengths of tubular nylon netting (Netlon Oriented 1) to ensure good recovery: at planting, the trials area was ridged out, the plots marked in the furrows, and the nets of bulbs were laid in the furrows before the ridges were split back. Ridges were at 0.76 m centres. 'Guard' plants were not netted. Fertilizers were applied according to analysis and MAFF recommendations, nitrogen as a top-dressing pre-emergence and other fertilisers in the base before planting. Routine crop husbandry included autumn weed control with paraquat + diquat, pre- and post-emergence residual herbicide application (usually chlorpropham + linuron and cyanazine) and late-season residual herbicide (bentazone). A routine fungicide programme was used from crop emergence, typically alternating materials such as iprodione, chlorothalonil and carbendazim, and with five sprays in the first year and three in the second. Between the first and second years, crops were re-ridged, and paraquat + diquat was used to control weeds. Roguing was not carried out on experimental plots, nor (except for the removal of off-types) on the commercial non-VT stocks during acclimatization prior to use in Experiment 3. For harvesting bulbs, the remaining foliage was flailed off and the bulbs were lifted the same day. Bulbs were dipped in aqueous thiabendazole, formalin and non-ionic wetter within two days of lifting, dried for 3 days at 35°C on a drying wall and then further dried and stored under fans at 17 to 18°C. Dried bulbs were cleaned by hand, separating offsets where these easily became detached, and graded. Bulbs received standard hot-water treatment in early- to mid-August (3 hours at 44.4°C with aqueous thiabendazole, formalin and non-ionic wetter), followed by drying and storage under fans at ambient temperatures. Where appropriate, plots of bulbs were allocated at this stage for further growing-on.

RESULTS

Experiment 1: re-infestation study

Virus levels Crop inspections in 1992 and 1993 revealed no visible symptoms of virus infection. Laboratory tests in 1993 (of five leaves per plot, i.e. 20 samples per site per variety) revealed a single positive (for NMV) in Carlton plots in the ordinary field situation, and no other positives.

No visible signs of virus infection were seen in 1994 and 1995. For Carlton, in 1995 laboratory tests had two positives (out of 20 samples per site) for NMV in the protected, isolated situation. Fortune had two positives (out of 20) for NYSV in the ordinary site.

No visible virus symptoms were seen in 1996. In 1997 Fortune had no visible virus symptoms and no positive laboratory tests. However, one of the four replicate plots of Carlton in the ordinary field site had about 10% of plants showing mild virus symptoms, and from the same plot one laboratory sample (out of 20) was positive for NLV. No visible virus symptoms were seen, and no other positive laboratory tests were obtained, for Carlton in the other sites. NYSV and NLV are aphid-borne, while NMV has no known vector but may be transferred mechanically (e.g. by flailing).

Crop performance Flowering data for the six years of the study are given in Table 1.1. Because of the totally different growing conditions pertaining for VTMS plots, compared with field-grown bulbs, great care should be exercised in comparing crop performance between the four 'treatments'. Further, different planting weights and bulb sizes were, of necessity, used in different years and in different treatments (see Materials and methods).

In general, VTMS crops produced fewer and smaller flowers, and shorter stems and foliage, than field-grown bulbs, a consequence of the poorer environment when bulbs are growing in trays of compost in a tunnel. In winter 1996/97 the VTMS bulbs suffered severe frost damage and growth was very poor with some bulb rots.

The generally better growth of bulbs of both cultivars under 'ordinary' field conditions, compared with growing in the isolated field, is less easy to explain, but may simply have been a consequence of differing field factors. No appreciable differences in flowering or senescence dates between the field-grown treatments were seen.

Bulb yields after each two-year-down cycle are shown in Table 1.2. In the VTMS bulbs, weight increases were poor, again a reflection of the inadequate VTMS growing conditions, but yields increased over the first four year period as bulb size increased. VTMS produced many small bulbs. Following frost damage in 1996/97, yields of VTMS bulbs were very poor. Yields of field-grown bulbs, whether in protected, isolated or standard conditions, were acceptable and relatively comparable in the first two-year period. However, yields were poor in both cultivars grown in the isolated field (whether in the tunnel or in the open) in the second two-year period. In the case of these bulbs in the open, some bulb rotting was evident and yields were still poor in the final two years of the trial.

Experiment 2: chemical control of re-infestation

Virus levels No visible symptoms of virus were observed on inspections in the first five years of the experiment (1991-1996). In the sixth year, slight virus symptoms were seen in two plots of Carlton (one replicate of the Ambush C treatment and one of the Fyzol 11E treatment), but none was seen in Fortune.

There were no positive laboratory tests for viruses in Carlton in 1993 or 1995, out of the total of 140 leaves sampled each year. In the Fortune plots, in contrast, there was a total of 8 positive tests in 1993 and 4 in 1995, but as there was a maximum of 2 positive tests per treatment (out of 20 samples per treatment) the results were too sparse to allow any conclusions about the effect of treatments to be drawn (Table 2.1). Of these 12 positive tests in Fortune samples, one was for NLV and the rest were for NYSV, both aphid-borne.

In the sixth year of the experiment, 1997, there was a number of positive tests for virus in both cultivars. In Fortune there was a total of 25 positive results (out of 140), all for NYSV, and all scores were low (Table 2.1). In Carlton, there were 20 positive tests (out of 140), mainly for NYSV but also including 10 positives for NLV and one for ArMV (nematode-borne); scores were generally low, except for two treatments where most of the NLV occurred. In Fortune, positive virus tests occurred sporadically in all treatments, including the control. The Actipron treatment had the lowest virus levels. In Carlton, the control and Decis treatments had no positive virus tests, but several positives (including NLV) occurred in plots treated with Ambush C and Fyzol 11E, scores being low in the other treatments (Fastac, Actipron and Codacide). The lack of consistency of treatment effects between the two cultivars suggests no firm evidence for control of virus re-infestation by the insecticides and oils used. Re-infection was still too slow to allow effective control treatments to be demonstrated at this stage.

Crop performance Flowering data for the six years of the experiment are shown in Tables 2.2 to 2.7, respectively. In the first two years, flower number and size, stem length and foliage length were unaffected by treatments except that the two mineral oils (Actipron and Fyzol 11E) reduced plant height (particularly foliage length) in Fortune in the second year of treatment. In the second two years of the experiment, several treatments (Fastac and the three oils) appeared to enhance the number of flowers in Carlton in the first year, while Codacide appeared to shorten plants of Carlton in the second year; there were no other significant effects on flowering measurements in Carlton, and none in Fortune. In the fifth and sixth years of the experiment there were no significant effects of treatments on these variables, apart from some small differences in flower size of Carlton. However, although overall the effects of the chemical treatments just failed to achieve statistical significance, mineral oils (especially Actipron) apeared to reduce flower size in Fortune in year 6. No flower damage was noted in any treatment in any year; the number of shrivelled buds did not reach one per plot in any treatment, occurring very sporadically across all treatments. No appreciable differences between treatments in flowering dates were seen.

In 1995, plots of both cultivars which had received oil sprays appeared to senesce earlier than controls or insecticide-treated plots; 50% senescence was reached 1 to 2 weeks earlier. In 1996, this effect was observed again where mineral oils had been used, but only in Fortune. Yellowing due to senescence may be confused by changes in leaf colour induced by the oils. No crop toxicity was observed, except that Actipron- and Fyzol 11E-treated plants (and Codacide-treated plants to a lesser extent) of both cultivars had noticeably and consistently paler foliage than the untreated controls when examined after flowering and before senescence.

Bulb yields after the first two-year-down cycle are given in Table 2.8. The mineral oils (Fyzol 11E and, especially, Actipron) caused significant reductions in the weight of bulbs harvested in both Carlton and Fortune, with a slight shift to smaller grades. There were no significant effects on the numbers of bulbs harvested. After the second two-year-cycle, the yield-reducing effect of Fyzol 11E and Actipron were again marked in Fortune, but were not significant in Carlton; however, Codacide also appeared to reduce yield (Table 2.9). Actipron and Fyzol 11E also increased the numbers of bulbs harvested (Decis also produced more bulbs but this was due to an overall yield increase). Actipron and Fyzol 11E resulted in a shift to smaller grades of bulbs (Table 2.10). Similar effects on yield, especially with Actipron, were seen in the third cycle of the trial (Table 2.11). Few rotted bulbs were lifted in this trial, with no obvious effects of treatments.

Experiment 3: evaluation studies

Despite using graded bulbs for this experiment, there were significant differences between stocks in the 100-bulb planted weights for all four cultivars (Tables 3.1, 3.6, 3.11 and 3.16). In

Dutch Master, Golden Harvest and St. Keverne, the VT stocks were lighter than the non-VT stocks, whereas in Tête-à-Tête the VT bulbs were heavier.

Dutch Master - Year 1 (Table 3.1a) The VT stock and one non-VT stock (stock B) had much greater flower numbers than the other four stocks. The similarity in flower production of the VT and B stocks were not due to similar initial bulb size, as these two stocks represented the extremes of planting weights. The VT stock had greater stem length (but not foliage length) than the non-VT stocks, despite the small initial bulb weight. Flower diameters were not available for this cultivar, owing to weather damage before the records could be made. In 1995 the VT stock started to flower 1 to 2 weeks earlier than the other stocks. There were no appreciable differences in senescence dates between the stocks. A low percentage of VT bulbs (5%) showed foliar symptoms of virus. The percentage of plants with virus symptoms in the other five stocks varied from 8 to 18.

Year 2 (Table 3.1b) Although, statistically, there was no significant effect of stock on flower numbers in the second year, the VT stock and stock B, which had had most flowers in the preceding year, had fewer flowers than the other stocks in the second. There were also no significant differences between stocks in stem or leaf length, although the VT stock had somewhat smaller flower diameters.

There were no differences between stocks in the dates of shoot emergence, flowering or foliar senescence.

Foliar symptoms of NYSV, suspected in the first year, were confirmed in all stocks including the VT stock (Table 3.1b). Scoring in the field on visible symptoms, the VT stock had the lowest score, with only a few plants per plot showing symptoms. On the basis of ELISA, this result was confirmed - all leaf samples of all stocks had positive virus tests although the ratings for the VT stock were much lower than for the other five stocks. All samples were positive for NYSV; most also had lower levels of NLV, although this was rare in the VT stocks; and a few samples were also positive for NMV.

Bulb yields after the first two years are shown in Table 3.2. The number of bulbs per plot varied from 118 to 183 for the five non-VT stocks, the VT stock producing 173 bulbs per plot (all from 100 planted bulbs): the most significant finding was that two stocks (A and D) performed poorly in this respect. In terms of yield by weight, stock C had a high weight gain (143%), while stock B was poor (23%); increases for other non-VT stocks varied from 61 to 88%, compared with 84% for the VT stock. Despite the relatively low statistical significance of these overall yields, there were significant differences between numbers and weights of bulbs in different grades. Table 3.3 shows the percentage distribution (by weight) to grades: although some stocks produced more bulbs in the smaller or larger grades, the performance of the VT stock was about average. These figures refer to marketable bulbs: a few bulbs (<6%, overall) were rotted at harvest, but there were no statistically significant differences attributable to stocks.

Year 3 (Table 3.1c) The VT stock produced significantly fewer flowers than the other stocks, and there was also a suggestion (not statistically significant) of smaller flowers. There were no significant differences in stem or foliage length between the six stocks.

There were no significant differences between stocks in the date of shoot emergence or flowering. There were some significant differences in the amount of foliar senescence recorded in early-May, with the VT stock and stock E being later to senesce (Table 3.1c). These differences were not apparent in later observations (late-June).

All stocks showed visible symptoms of virus, between 10 and 63% of plants being affected in the different stocks. Stocks A and E had the least plants affected (10 or 13%) and stock D the most (63%); the VT stock was intermediate (24%).

Year 4 (Table 3.1d) There were no significant differences in flower numbers or diameter between the six stocks, but stem and foliage lengths were greater in VT stocks than in other stocks.

There were no differences between stocks in the dates of shoot emergence or flowering. VT stocks were slower than other stocks to senesce: by week 24 (early-June) the VT foliage was 20% senescent, whereas in other stocks the assessment was 40%.

All stocks showed visible symptoms of virus, with the percentage of affected plants being low (about 20%) in the VT stock and stocks A and E, and higher (40 to 80%) in the other three stocks. Tested using ELISA, all stocks gave some positive tests. For NYSV, the VT stock and stocks A and C had the lowest scores, while, tested for all viruses, the score was much lower for the VT stock than for any of the other stocks. Most VT samples had NYSV only, and 11 of the 20 VT leaves sampled were negative for viruses. NLV and NMV, as well as NYSV, were commonly detected in non-VT stocks.

Bulb yields are shown in Table 3.4. Starting from 40 bulbs per plot in all cases, the VT stock and stocks A and D multiplied well, with 70 to 80 marketable bulbs lifted, while 63 to 71 bulbs were lifted in the other three stocks. By weight, much greater bulb yields were obtained from the VT stock (237% weight increase) than for other stocks, where increases ranged from 140 to 174%. These differences in yields were not related to differences in planting weights, the means of which were not significantly different between stocks (in fact, the VT stock had slightly lower initial weight than the other stocks). Nor were differences related to differences in the numbers of rotted bulbs harvested, which was low overall (<3 bulbs per plot). The distribution of bulbs to grades (Table 3.5) showed there was little difference between stocks.

Golden Harvest - Year 1 (Table 3.6a) Flower numbers in the VT stock (85 per plot) greatly exceeded those in the ordinary stocks (37-70 per plot), despite the smaller planting weight of VT bulbs. The VT stock also had relatively large flowers; its stems were of average length and leaves were short, compared with the non-VT stocks. There were no appreciable differences in 1995 between stocks in flowering or senescence dates. A low percentage of plants of the VT stock (5%) showed virus symptoms, compared with 15 to 35% in the non-VT stocks.

Year 2 (Table 3.6b) There were no statistically significant differences between stocks in flower yield, although the VT stock, which had the greatest number of flowers in the first year, now had the fewest. In contrast, however, in its second year the VT stock had the largest flowers (significantly) and the longest stems and foliage (but not always significantly so).

There were no differences in stocks between the dates of shoot emergence, flowering or foliar senescence.

As in the case of the preceding cultivar, virus was confirmed in all stocks in the second year (Table 3.4b). For all scores (field scores or ELISA), the VT stock had the lowest figures, about half that of the non-VT stocks. All 120 leaf samples (except one) were positive for NYSV, but other viruses were only rarely detected: ArMV in five leaf samples (three from stock B, two from stock C), NTNV (Sempre Avanti strain) in four samples (all from stock D), NTNV (Quirinus strain) in five samples (all from one plot of stock A), and NLV in one sample only (from stock B). NTNV, like NMV, has no known vector.

Bulb yields are given in Table 3.7. The total number of bulbs lifted (from 100 planted) was lower in the VT stock (153 per plot) than in the non-VT stocks (178 to 214 per plot). Bulb yield by weight, in contrast, was highest in the VT stock and stock B than the others, and, when expressed as percentage weight increase (to take account of differences in planted weights) was far greater for the VT stock (127%) than for all non-VT stocks (72-92%). There were very significant differences between stocks in bulb yield in different bulb grades: Table 3.8 shows that the VT stock produced a much greater proportion of its yield in the larger (>12 cm) grades. Very few bulbs (<2 per plot) were affected by rots at harvest.

Year 3 (Table 3.6c) The VT stock and stock D had most flowers at 55 to 56 per plot, compared with 48 to 53 for the other stocks. There were no significant differences between stocks in flower diameter or stem or foliage length.

There were no significant differences between stocks in the date of shoot emergence or flowering. There were significant differences in the degree of foliar senescence in early-May (Table 3.4c): the VT stock senesced later than the other stocks. These differences disappeared later in the season.

All stocks had visible virus symptoms (Table 3.4c). Only 9% of plants of the VT stocks were affected, whereas in the five non-VT stocks 27 to 40% were affected.

Year 4 (Table 3.6d) There were no significant differences in flower numbers, flower diameter or foliage length between stocks, although the VT stock and stock E had longer leaves than the other stocks.

There were no differences between stocks in the dates of shoot emergence or flowering. VT stocks were slower than other stocks to senesce: the senescence scores at week 24 were 30% for the VT stock against 40% for the other stocks.

All stocks showed visible symptoms of virus, with the lowest incidence of symptoms in the VT stock; three stocks (A, B and C) had very high percentages, while the other two stocks were intermediate. Tested using ELISA, all stocks had some positive tests, although only three of the VT leaves tested positive (out of 20). The VT stock had much lower scores than the five non-VT stocks, both for NYSV and all viruses. Most of the positive tests in the VT stocks were the result of a single leaf sample which tested positive for NTNV (Quirinus strain), NTNV (Sempre Avanti strain) and NMV. Other positive VT samples had NYSV only. In the other stocks there were occassional positives for NLV and NMV, besides NYSV.

Marketable bulb yields are shown in Table 3.9. All plots started with 60 bulbs, and the highest number of bulbs harvested, 100, occurred with the VT stock; in the other stocks the number harvested was 82 to 93 per plot. There were no significant differences in the weight of bulbs harvested, although the VT stock presented the greatest percentage weight increase (174%, against 130 to 152 in the non-VT stocks). Although the initial (planting) weights were slightly greater in the VT stock and stock D than other stocks, adjusting yields using initial weights as a covariate had no significant effect on yields. A small number of rotted bulbs was recorded after harvest (overall, <4 per plot), and the number of rotted bulbs did not account for differences in marketable yields. The distribution of yield to grade is given in Table 3.10. There were no obvious differences in distribution to grades between stocks.

St. Keverne - Year 1 (Table 3.11a) The VT stock produced flower yields similar to two of the non-VT stocks (A and E), whereas the other non-VT stocks had lower flower numbers. There were no significant differences in flower diameter between stocks, but stem and foliage lengths were relatively short in the VT stock compared with the others. There were no appreciable differences in 1995 between stocks in flowering or senescence dates. Strikingly, no virus symptoms were seen in the VT stock, whereas the ordinary stocks had 33 to 63% of plants clearly affected with virus.

Year 2 (Table 3.11b) In the second year there were no significant differences between stocks in flower numbers, flower size, stem length or foliage length. There were also no differences between stocks in the timing of shoot emergence, flowering or foliar senescence.

In contrast to the previous year, all stocks, including the VT stock, showed virus symptoms in the field (Table 3.11b). All leaf samples tested positive for NYSV, the VT stock having the lowest score in ELISA testing. No other viruses were detected in the VT stock, whereas NLV was found in all 20 samples of stock E, 15 samples of stock B, 10 samples of stock C and 5 samples each of stocks A and D. NTNV (Quirinus strain) and NMV were each found in three leaf samples only.

Bulb yields (Table 3.12) revealed no significant differences between stocks; nevertheless, it is interesting to note that the VT stock had the lowest rate of increase in bulb numbers, and despite having more rotted bulbs, the highest percentage weight increase of marketable bulbs. There were significant differences in yields of bulbs in individual grades. Table 3.13 shows the percentage distribution of bulb yield to grades; the VT stock yielded relatively little yield in the smaller (<10 cm) grades and more in the larger sizes.

Year 3 (Table 3.11c) There were no significant differences between stocks in flower numbers, flower size, stem length or foliage length.

There were no significant differences between stocks in the dates of shoot emergence or flowering. The VT stock senesced later than the non-VT stocks, with only 2% foliage senescence in early-May compared with 9 to 14% senescence in the other stocks (Table 3.11c). These differences disappeared later in the season.

The VT stock had 21% of plants with visible symptoms. However, in the non-VT stocks the percentage of affected plants was 90 to 100% (Table 3.11c).

Year 4 (Table 3.11d) There were no significant differences between stocks in flower numbers, flower diameter, stem length and foliage length.

There were no differences between stocks in the dates of shoot emergence or flowering. VT stocks were slower to senesce than other stocks: at week 24 VT foliage was 5% senescent whereas the figure for the other stocks was 10%.

All stocks showed visible symptoms of virus. Although the percentage of the VT plants affected was high (39% seen in April), in the other stocks the percentage was much higher (58 to 97%). The VT stocks had much lower scores by ELISA testing than the non-VT stocks. Most VT samples had NYSV, and other stocks had frequent NYSV and NLV and occassional NMV and NTNV.

Bulb yields are given in Table 3.14. There were no significant differences between stocks in the number or weight of marketable bulbs harvested. Although the planting weight of the VT stock and of stock B were higher than for the other stocks, using planting weight as a covariate to adjust yields had no significant effect. The number of rotted bulbs recovered was low (<3 per plot overall) and did not vary significantly between treatments. The distribution of bulbs to grades is shown in Table 3.15. There were no obvious differences between stocks.

Tête-à-Tête - Year 1 (Table 3.16a) The VT stock of this variety produced fewer stems per plot than non-VT stocks. However, stems of the VT stock had an average of 1.6 florets each, compared with only 1.0 to 1.2 in the non-VT stocks. VT stocks had slightly larger first floret sizes than most non-VT stocks, and much longer stems and foliage. There were no appreciable differences in 1995 between stocks in flowering or senescence dates. VT stocks were free of virus symptoms, whereas the percentage of affected plants in the ordinary stocks varied from 3 to 9%.

Year 2 (Table 3.16b) The numbers of stems per plot and of florets per stem were higher in the VT stock than in the non-VT stocks, although these effects were not statistically significant (in the case of stem numbers the data were highly variable). There were no differences between stocks in first floret diameter, but both stem and leaf lengths were longer in the VT stock than in non-VT stocks.

Shoots first emerged in the VT stocks in week 4, significantly earlier than in non-VT stocks where shoots began to emerge in weeks 6 to 8. VT plots flowered about a week earlier than non-VT plots. There were no differences in foliar senescence dates between the stocks.

Foliar symptoms of virus were present in all stocks, although at a much lower level in the VT stock than in other stocks (Table 3.16b). In ELISA testing, all leaf samples were positive for NYSV, although the score was lower for the VT stock than for the non-VT stocks. The only other virus detected was NLV, which occurred in only one leaf sample (out of 20) from the VT stock, but in between 14 and 19 of the leaf samples of the non-VT stocks.

Bulb yields (Table 3.17) in both weights and numbers were higher in the VT stocks than for the non-VT stocks. In the case of yields by weight, the percentage weight increase of stock A was higher than for that of the VT stock. Overall, <11 rotted bulbs were harvested per plot, but there was no significant effect of stock. The distribution of yields to grades (Table 3.18) showed that the VT stock yielded a greater percentage of bulbs in the larger grades (>8 cm) than non-VT stocks.

Year 3 (Table 3.16c) Stock A had more stems per plot and significantly more florets per plot than the other stocks (including the VT stock). There were no significant differences between stocks in floret diameter. The VT stock had longer stems and foliage than the non-VT stocks, although these effects were not statistically significant.

There were no significant differences between stocks in the date of shoot emergence or flowering. At the early stages of senescence (early-May), the VT stock was significantly later to senesce than any of the non-VT stocks (Table 3.16c); in later stages of senescence differences were not significant.

All stocks appeared to show symptoms of virus: in the VT stock 25% of plants were affected, whereas in the non-VT stocks 50 to 68% of plants were affected (Table 3.16c). Since this cultivar is sensitive to hot-water treatment damage, causing leaf mottling and possibly confusing virus symptoms, confirmation of this result should await data from next year.

Year 4 (Table 3.16d) The VT stock had significantly larger florets than the other stocks. The number of stems and florets per plot, and stem and leaf length, did not differ significantly between stocks.

There were no appreciable differences between stocks in the dates of shoot emergence, flowering or foliar senescence.

The incidence of virus symptoms was high in all stocks; however, in the VT stock the percentage of plants affected (in March) was 58%, compared with 93 to 100% in non-VT stocks. This result was confirmed by ELISA testing, with much lower scores for the VT stock. Eight of the VT leaves sampled (out of 20) remained free of positive tests, while the others had NYSV and NLV. In non-VT stocks NYSV and NLV were common, with occasional positives for NMV.

Bulb yields are shown in Table 3.19. The statistical analysis showed that there were no significant differences in the number of marketable bulbs harvested, nor in the number of rotted bulbs, which was high in this variety. However, lack of statistical significance was probably due to a high variability between replicates of the same treatment. The apparent significant difference between the weights of bulbs harvested appeared to be related to variations in the number of rotted bulbs; this suggested there were no or only small differences due to virus status. The distribution of bulb yield to grades is shown in Table 3.20. The VT stock appeared to produce a greater yield in the largest grade (10-12 cm).

DISCUSSION

Experiment 1: re-infestation study

Even in bulbs planted adjacent to ordinary, almost totally infested narcissus stocks, VT Carlton bulbs remained free of any positive test results for aphid-borne viruses for four years, although

NLV (aphid-borne) was detected (in one sample out of 20) after six years of the trial (a result confirmed, in a larger number of tests, in experiment 2). At this stage some visible symptoms of virus were seen, but only in about 10% of plants of one of the four plots. In isolation, no visible symptoms or positive laboratory tests for aphid-borne viruses were seen, even after six years. The VT Carlton stock did, however, have a low level of positive tests for NMV, which is neither aphid- nor nematode-borne, with one and two tests (out of 80) positive after 2 and 4 years, but none in year 6. This occasional finding of NMV in the VT Carlton suggests that the VTMS stock itself may have carried a very low, previously undetected level of this virus. It has been shown elsewhere that some viruses, including NMV, are difficult to eliminate by meristem-tip culture, while improved means of indexing now makes low levels of virus easier to detect (Mowat *et al.*, 1988a, b; Boonekamp *et al.*, 1990).

The VT Fortune had no positive virus tests after six years of the trial, although the plots adjacent to ordinary stocks had two positives (out of 20), both for the aphid-borne NYSV, in the fourth year. This suggests a slow re-infection rate, with the number of positive tests falling within the limits of experimental error.

The conclusion of the experiment is that Fortune is likely to remain largely free of aphid-borne viruses for a number of years (in excess of six), even when planted next to infested stocks, and probably for longer in isolated sites. Carlton, on the other hand, appeared to be picking up significant levels of virus, including NLV, by year six.

While it is difficult to make valid comparisons of crop performance and bulb yield between the different treatments of this experiment, because of the very varied conditions used, the yield data showed the poor growth obtained under VTMS conditions. This may be due to the technique of growing bulbs in trays (a successful and convenient technique in Cornwall, but by which the small bulbs are vulnerable to frost damage in colder climates), or perhaps to the requirement (under the terms of the PHPS) for the hot-water treatment (HWT) of bulbs each year.

Experiment 2: chemical control of re-infestation

The six years' results confirmed the findings of Experiment 1, that, in VT stocks growing adjacent to ordinary daffodil stocks, virus-freedom was substantially unaffected for the first four years, and by year six Carlton was becoming re-infected more seriously than Fortune. In Fortune, 8, 4 and 25 tests (out of 120 in each case) were positive for virus after 2, 4 and 6 years respectively. However, virus scores were still low by the sixth year, only NYSV was detected, and there were no visible symptoms. In Carlton, although no positive laboratory tests were found in the second and fourth years, by year six 20 positives were found (out of 120 tests), including NLV and ArMV as well as NYSV, and in some cases virus scores were substantial; some visible symptoms of virus were also seen in this variety.

Because the rates of virus re-infestation were slow, even after 6 years, it was not possible to determine the beneficial effects of the aphicide and oil treatments.

It was clear that the oil sprays (particularly the mineral oils) have phytotoxic effects when used as regular sprays. If effective against re-infestation, however, their benefits may outweigh their harmful effects. Reduced rate oil sprays, used in combination with insecticide sprays (Asjes, 1984, 1991), are a further possibility which could be investigated.

Experiment 3: evaluation studies

Despite using bulbs of the same grade for the different stocks, average bulb weights differed between VT and non-VT stocks, generally being smaller in VT bulbs except in Tête-à-Tête, where VT bulbs were larger. In the first year, however, VT stocks nearly always out-performed the selection of non-VT stocks against which they were compared.

VT bulbs of Dutch Master, Golden Harvest and St. Keverne produced more flowers than most non-VT stocks, despite VT bulbs being smaller, indicating that VT bulbs may have a lower critical weight for flowering. VT bulbs often had larger flowers and longer stems, but leaf length was generally shorter, indicating that leaf size was proportional to bulb size.

In the second year the VT stocks of these three varieties no longer produced more flowers than ordinary stocks, and, in the case of Dutch Master and Golden Harvest, in fact produced significantly fewer flowers (although the flowers of the VT Golden Harvest were still superior in size and stem length). In terms of bulb weights harvested, the performance of VT Dutch Master bulbs was only average, of VT St. Keverne bulbs was slightly greater than for non-VT stocks, and for VT Golden Harvest was greater than non-VT stocks. In the case of VT Golden Harvest and St. Keverne, there was more bulb yield in the larger grades than in the case of non-VT bulbs. The disappointing second-year flower yields of VT bulbs, and the indifferent bulb yields (except in the case of Golden Harvest), suggest a measure of compensation for the better flower yields in the first year. It may be that VT stocks may require lower planting densities for their potential yields to be realised.

In the third year of the trial, VT bulbs of Golden Harvest continued to perform well, with a high flower yield (equalled by one non-VT stock). This was not true for Dutch Master and St. Keverne. There were few significant differences in flower size or plant height. It was notable that VT stocks began to senesce later (an effect also noted in year 4).

The responses of Tête-à-Tête contrasted with the other varieties. In the first year the larger VT bulbs produced more and larger florets, but not more stems, than the non-VT stocks. In the second year, the VT stock produced slightly more stems and florets per stem than ordinary stocks. The VT stocks were also earlier to emerge and flower. Bulb yields were greatest in the VT stock, with more large bulbs being produced. In the third year the VT stock appeared to have longer stems, but floret and stem numbers were greater in one of the non-VT stocks.

Visible virus symptoms were clear in most non-VT stocks (particularly St. Keverne and some Golden Harvest stocks) in the first year, but were also seen (at lower levels) in VT stocks of Dutch Master and Golden Harvest. By the second year, all stocks of all varieties had foliar symptoms of virus, although these were relatively mild in the VT stocks. ELISA tests confirmed this finding. All stocks were positive for NYSV, although at a lower level in the VT stocks. Other viruses (especially NLV) were found in non-VT stocks, but were rare in the VT stocks. In the third year, VT stocks of Golden Harvest, St. Keverne and Tête-à-Tête continued to show much lower levels of virus symptoms than the non-VT stocks (in the case of St. Keverne, these were almost totally infected). However, in the case of Dutch Master, two non-VT stocks had lower levels of symptoms than the VT stock.

The relatively quick re-infestation of VT bulbs of these four cultivars was in contrast to the findings with Carlton and Fortune in Experiments 1 and 2. However, the superiority of VT stocks, in general terms, was confirmed. Experiment 3 is continuing for a further year, to 1998.

General discussion

The prevalence of virus symptoms in narcissus stocks appears to be increasing, probably as the crop is grown more intensively and as the costs of labour preclude the amount of roguing previously carried out. While practical methods of control for fungal diseases and pests of narcissus are available, no field-scale control of viruses or their vectors is currently practised, suggesting that the impact of virus diseases is likely to increase over the next 10 years or so, as was evident in 'Sols' grown on the Isles of Scilly in the 1960s. In addition, demanding customers want high health status plants and are developing strict protocols. At present this has little effect in the narcissus industry, but the situation is likely to change, so growers should consider the possible effects of falling crop quality, due to virus, on their future marketing opportunities. The information contained in the present report should help to inform these decisions.

Although VT narcissus did not out-perform all ordinary (non-VT) stocks in all respects in all years, their performance, taken overall, is superior. This may include producing more flowers, larger or taller blooms, more vigorous leaves, higher bulb yields and larger bulbs. This apparent lack of consistency may simply reflect that the more vigorous VT bulbs interact differently with climatic factors or inter-plant competition than ordinary bulbs. Grown adjacent to ordinary narcissus stocks, in which most plants are infected with viruses, and in the absence of any special measures against virus transmission by insect or nematode vectors, virus re-infection occurred within a few years, but at different rates in different varieties. Re-infection was relatively slow in Carlton and Fortune, with few positive ELISA tests and few symptoms on the foliage, even after 6 years. But it was faster in Dutch Master and Golden Harvest and particularly in St. Keverne and Tête-à-Tête, with foliar symptoms of virus appearing within two years of planting in an ordinary field.

Despite this problem of re-infection, the superior qualities of VT narcissus suggest that VT stocks should be considered by growers supplying the more demanding markets, or in any case where their own stocks are degenerating and causing concern because of high virus levels. From the present investigation it is clear that the expense associated with acquiring and growing VT narcissus stocks merits that such stocks are grown in a way to minimise re-infection by viruses, the most common of which is the aphid-borne NYSV. These precautions should include:

- Growing in isolation from ordinary stocks and other sources of infection
- Planning varietal plantings in relation to their susceptibility to pick up viruses
- Applying regular pyrethroid sprays when aphids are present in significant numbers (and investigating a combined spray programme with pyrethroids and mineral oil)
- Developing a scheme to maintain a 'core' stock of VT bulbs from which bulbs are fed out into the main 'production' stock
- Maintaining vigilance and roguing plants with virus symptoms, at least in these core stocks

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Table 1.1 Flowering performance of VT Carlton and Fortune bulbs in each year of Experiment 1. Values are means with standard errors in parenthesis.

Situation and year		No. flowers per plot [a]	Flower diam. (mm)	Stem length (mm)	Foliage length (mm)
Carlton					
VTMS	1992	- [b]	98 (1.0)	226 (8.4)	279 (5.5)
	1993	64 (4.1)	87 (0.5)	328 (14.8)	354 (9.2)
	1994	87 (4.1)	89 (0.5)	268 (31.0)	295 (3.9)
	1995	64 (10.8)	82 (0.6)	229 (8.7)	275 (3.2)
	1996	81 (6.6)	90 (1.0)	181 (3.5)	264 (9.5)
	1997	12 (1.9)	86 (1.3)	233 (27.2)	285 (8.1)
Isolated	1992	86 (3.7)	104 (0.6)	296 (3.2)	313 (7.1)
	1993	122 (5.9)	103 (1.2)	466 (4.0)	512 (13.5)
	1994	125(7.2)	100 (0.8)	328 (9.4)	317 (3.7)
	1995	87 (23.4)	92 (1.5)	361 (25.1)	382 (22.1)
	1996	59 (5.2)	102 (1.1)	289 (9.5)	332 (10.9)
	1997	103 (3.0)	106 (0.9)	491 (13.7)	491 (8.1)
Standard	1992	98 (2.3)	105 (1.0)	319 (3.0)	337 (6.3)
	1993	168(1.4)	111 (1.1)	473 (6.2)	513 (14.4)
	1994	130(3.8)	104 (0.8)	320 (4.7)	299 (1.5)
	1995	181(5.1)	-	575 (8.4)	613 (12.0)
	1996	111(3.4)	108 (0.6)	354 (3.5)	382 (8.7)
	1997	151(3.8)	110 (0.7)	510 (11.5)	537 (12.9)

(continued)

Table 1.1 (continued)

Fortune					
VTMS	1992	-	-	408 (9.7)	342 (2.1)
	1993	47 (16.7)	77 (1.0)	430 (1.1)	371 (3.4)
	1994	151(6.0)	79 (0.7)	355 (12.8)	285 (9.6)
	1995	84 (20.0)	73 (1.1)	309 (4.7)	296 (10.2)
	1996	80 (13.4)	77 (0.6)	292 (12.0)	287 (12.2)
	1997	25 (9.1)	74 (1.9)	338 (26.8)	335 (9.9)
Isolated	1992	95 (1.4)	88 (0.4)	397 (7.6)	342 (7.4)
	1993	189(4.5)	85 (1.2)	503 (8.4)	471 (11.3)
	1994	123(9.8)	91 (0.9)	397 (12.3)	367 (7.7)
	1995	65 (16.1)	83 (2.3)	444 (16.0)	443 (12.8)
	1996	48 (2.5)	88 (0.7)	350 (11.4)	352 (10.0)
	1997	96 (1.9)	99 (0.5)	576 (7.9)	529 (11.7)
Standard	1992	89 (3.0)	87 (0.7)	397 (4.4)	372 (3.2)
	1993	175(7.4)	96 (0.9)	575 (3.2)	533 (8.7)
	1994	126(5.3)	95 (0.7)	397 (5.0)	348 (2.1)
	1995	195(3.5)	-	670 (9.1)	623 (2.9)
	1996	99 (2.9)	95 (0.7)	437 (9.4)	411 (11.6)
	1997	154(3.7)	98 (0.8)	580 (5.0)	567 (5.4)

[a] note that planting weights and grades used varied between plantings and treatments (see text for details)

[b] -, not determined

Table 1.2 Bulb yields for VT Carlton and Fortune after each two-year growing cycle of Experiment 1. Values are means with standard errors in parenthesis.

Situation and year		Marketable bulbs per plot [a]			Additional rotted bulbs (no./plot)
		Weight (kg)	% weight increase	Number	
cv Carlton					
VTMS	1993	2.93 (0.046)	-3 (1.5)	350 (7.3)	1 (0.5)
	1995	5.66 (0.292)	93 (9.1)	685 (19.3)	2 (1.0)
	1997	4.20 (0.347)	-25 (6.8)	727 (46.3)	38 (7.7)
Protected+isolated	1993	8.33 (0.413)	177 (13.7)	264 (8.2)	17 (4.3)
	1995	7.44 (0.752)	62 (16.4)	242 (21.1)	0 (0)
	1997	9.16 (0.410)	298 (17.8)	221 (5.5)	0 (0)
Isolated	1993	8.83 (0.554)	194 (18.4)	294 (12.9)	13 (2.3)
	1995	5.28 (0.699)	15 (15.2)	237 (6.1)	6 (2.1)
	1997	5.84 (0.220)	69 (6.4)	179 (8.8)	2 (0.9)
Standard	1993	10.39 (0.196)	245 (6.5)	305 (8.3)	3 (1.3)
	1995	10.59 (0.188)	130 (4.1)	272 (13.4)	1 (0.3)
	1997	9.71 (0.195)	181 (5.6)	192 (3.7)	1 (0.3)

(continued)

Table 1.2 (continued)

Fortune								
VTMS	1993	3.15 (0.132)	5	(4.4)	229	(2.7)	0	(0)
	1995	4.42 (0.371)	40	(7.0)	456	(7.4)	0	(0)
	1997	3.74 (0.547)	-16	(6.3)	548	(77.4)	52	(3.7)
Protected+isolated	1993	7.42 (0.320)	146	(10.6)	218	(3.9)	2	(0.6)
	1995	8.90 (0.712)	93	(15.5)	216	(16.5)	0	(0)
	1997	9.07 (0.342)	294	(14.9)	190	(6.6)	0	(0)
Isolated	1993	8.54 (0.487)	184	(16.2)	226	(10.1)	3	(0.9)
	1995	4.35 (0.671)	-5	(14.6)	218	(12.4)	7	(1.5)
	1997	6.12 (0.141)	77	(4.1)	185	(10.0)	10	(6.6)
Standard	1993	8.46 (0.284)	181	(9.5)	230	(7.4)	3	(1.2)
	1995	10.59 (0.312)	130	(6.8)	256	(7.6)	1	(0.5)
	1997	8.96 (0.259)	160	(7.5)	177	(4.5)	1	(0.5)

[a] note that planting weights and grades used varied between plantings and treatments (see text for details)

Table 2.1 Results of laboratory virus tests on VT Fortune and Carlton after two, four and six years in the field (Experiment 2). All positives were for NYSV unless otherwise stated

Spray treatment	No. of positive tests (out of 20)			1997 virus ELISA scores	
	1993	1995	1997	NYSV	All viruses
Fortune					
None	0	0	6	2.5	2.5
Decis	2	2	5	1.3	1.3
Fastac	0	0	4	1.0	1.0
Ambush C	2	1	2	0.8	0.8
Actipron	2 [a]	0	1	0.5	0.5
Fyzol 11E	1	1	4	1.0	1.0
Codacide	1	0	3	0.8	0.8
Carlton					
None	0	0	0	0	0
Decis	0	0	0	0	0
Fastac	0	0	1	0.5	0.5
Ambush C	0	0	7 [b]	2.0	6.8
Actipron	0	0	1	0.5	0.5
Fyzol 11E	0	0	10 [c]	3.5	7.3
Codacide	0	0	1 [d]	1.5	2.3

[a] includes one positive test for NLV
[b] includes one positive test for ArMV, four for NLV
[c] includes five positive tests for NLV
[d] includes one positive test for NLV

Table 2.2 Flowering performance of VT Carlton and Fortune bulbs in the first year of Experiment 2 (1992)

Spray treatment	No. flowers per plot	Flower diam (mm)	Stem length (mm)	Foliage length (mm)
Carlton				
None	62.0	94	258	276
Decis	61.8	93	236	276
Fastac	62.0	92	245	276
Ambush C	57.8	91	237	279
Actipron	62.3	92	247	285
Fyzol 11E	58.8	93	255	292
Codacide	64.3	94	251	290
SED (18 df)	2.62	1.6	7.9	7.5
Significance [a]	NS	NS	NS	NS
Fortune				
None	- [b]	81	- [b]	312
Decis		82		325
Fastac		81		325
Ambush C		81		331
Actipron		81		332
Fyzol 11E		81		328
Codacide		81		329
SED (18 df)		0.9		11.6
Significance		NS		NS

[a] The statistical significance of experimental treatments is indicated, in this and the following tables, by NS, not significant, and *, ** and ***, significant at the 5, 1 and 0.1% levels of probability, respectively.
[b] Not determined owing to wind damage to crop prior to recording

Table 2.3 Flowering performance of VT Carlton and Fortune bulbs in the second year of Experiment 2 (1993)

Spray treatment	No. flowers per plot	Flower diam (mm)	Stem length (mm)	Foliage length (mm)
Carlton				
None	104.8	109	442	476
Decis	102.0	110	428	460
Fastac	103.8	110	423	459
Ambush C	102.3	110	428	470
Actipron	99.5	108	421	467
Fyzol 11E	101.0	110	421	478
Codacide	104.0	110	424	453
SED (18 df)	4.12	1.0	8.5	12.4
Significance	NS	NS	NS	NS
Fortune				
None	137.0	95	545	507
Decis	142.8	96	540	493
Fastac	151.0	98	534	491
Ambush C	143.0	97	537	504
Actipron	125.5	94	526	475
Fyzol 11E	135.0	95	536	478
Codacide	138.5	95	543	486
SED (18 df)	8.35	1.2	8.5	10.3
Significance	NS	NS	NS	*

Table 2.4 Flowering performance of VT Carlton and Fortune bulbs in the third year of Experiment 2 (1994)

Spray treatment	No. flowers Per plot	Flower diam (mm)	Stem length (mm)	Foliage length (mm)
Carlton				
None	107.5	108	357	344
Decis	108.5	109	361	350
Fastac	131.5	110	361	348
Ambush C	116.5	107	362	346
Actipron	125.8	109	369	348
Fyzol 11E	124.3	108	375	361
Codacide	128.8	107	364	353
SED (18 df)	7.46	1.1	11.2	9.6
Significance	*	NS	NS	NS
Fortune				
None	161.5	99	509	392
Decis	168.0	99	497	377
Fastac	165.8	99	491	378
Ambush C	161.8	99	506	397
Actipron	164.0	99	496	383
Fyzol 11E	167.5	98	500	384
Codacide	169.5	98	504	388
SED (18 df)	6.96	1.3	11.5	11.9
Significance	NS	NS	NS	NS

Table 2.5 Flowering performance of VT Carlton and Fortune bulbs in the fourth year of Experiment 2 (1995) [a]

Spray treatment	No. flowers per plot	Stem length (mm)	Foliage length (mm)
Carlton			
None	194.8	492	534
Decis	197.0	515	549
Fastac	190.4	500	538
Ambush C	196.5	507	546
Actipron	204.5	528	555
Fyzol 11E	205.0	492	522
Codacide	190.5	469	508
SED (18 df)	8.36	15.2	17.9
Significance	NS	*	NS
Fortune			
None	235.0	599	569
Decis	230.3	611	560
Fastac	226.8	619	551
Ambush C	231.5	594	565
Actipron	233.5	604	545
Fyzol 11E	227.3	617	563
Codacide	230.5	612	557
SED (18 df)	12.66	17.1	19.7
Significance	NS	NS	NS

[a] Flower diameters not determined owing to wind damage to crop prior to recording.

Table 2.6 Flowering performance of VT Carlton and Fortune bulbs in the fifth year of Experiment 2 (1996)

Spray treatment	No. flowers per plot	Flower diam. (mm)	Stem length (mm)	Foliage length (mm)
Carlton				
None	151.8	97	334	351
Decis	144.5	95	330	344
Fastac	148.5	95	330	351
Ambush C	148.5	97	339	362
Actipron	152.5	99	343	366
Fyzol 11E	153.3	97	334	352
Codacide	149.8	95	321	347
SED (18 df)	7.83	1.3	10.3	10.7
Significance	NS	*	NS	NS
Fortune				
None	147.8	89	421	389
Decis	151.8	88	429	388
Fastac	148.8	89	421	382
Ambush C	150.8	89	408	394
Actipron	152.8	88	420	398
Fyzol 11E	153.3	88	413	391
Codacide	147.5	88	426	388
SED (18 df)	7.72	1.1	10.0	11.4
Significance	NS	NS	NS	NS

Table 2.7 Flowering performance of VT Carlton and Fortune bulbs in the sixth year of Experiment 2 (1997)

Spray treatment	No. flowers per plot	Flower diam. (mm)	Stem length (mm)	Foliage length (mm)
Carlton				
None	222.8	114	494	540
Decis	215.8	110	493	517
Fastac	213.5	111	517	527
Ambush C	211.0	113	513	538
Actipron	214.8	113	519	533
Fyzol 11E	219.0	112	512	519
Codacide	218.8	110	511	527
SED (18 df)	14.38	2.3	14.3	12.4
Significance	NS	NS	NS	NS
Fortune				
None	230.3	101	577	545
Decis	235.8	101	578	546
Fastac	234.3	100	576	558
Ambush C	233.0	100	582	560
Actipron	228.0	95	552	539
Fyzol 11E	234.8	98	574	555
Codacide	237.3	97	571	556
SED (18 df)	10.53	1.9	13.6	11.2
Significance	NS	NS	NS	NS

Table 2.8 Bulb yields for VT Carlton and Fortune after the first two-year growing cycle of Experiment 2 (1991-93)

Spray treatment	Marketable bulbs per plot [a]	
	Weight (kg)	Number
Carlton		
None	9.54	261
Decis	9.33	263
Fastac	9.54	259
Ambush C	9.12	262
Actipron	8.56	250
Fyzol 11E	8.75	260
Codacide	9.26	260
SED (18 df)	0.260	6.4
Significance	**	NS
Fortune		
None	8.78	246
Decis	8.64	255
Fastac	9.07	257
Ambush C	9.35	255
Actipron	7.77	248
Fyzol 11E	7.88	246
Codacide	8.75	253
SED (18 df)	0.415	8.5
Significance	*	NS

[a] based on planting 100 bulbs per plot (weighing 1.62 kg for Carlton and 1.67 kg for Fortune).

Table 2.9 Bulb yields for VT Carlton and Fortune after the second two-year growing cycle of Experiment 2 (1993-95)

Spray treatment	Marketable bulbs per plot [a] Weight (kg)	Number
Carlton		
None	14.85	301
Decis	15.70	319
Fastac	15.24	299
Ambush C	15.99	317
Actipron	14.35	328
Fyzol 11E	14.25	316
Codacide	13.68	308
SED (18 df)	0.539	8.7
Significance	**	*
Fortune		
None	15.04	302
Decis	15.12	316
Fastac	14.78	313
Ambush C	15.03	292
Actipron	12.95	320
Fyzol 11E	12.98	331
Codacide	14.02	304
SED (18 df)	0.632	13.2
Significance	**	NS

[a] based on planting approx. 180 bulbs per plot weighing 6.0 kg

Table 2.10 Percentage of bulb yield (by weight) in different grades for VT Carlton and Fortune after the second two-year growing cycle of Experiment 2 (1993-95)

	Percentage weight in grades						
Spray treatment	<8	8-10	10-12	12-14	14-16	16-18	>18
Carlton							
None	6	14	18	28	24	9	1
Decis	5	14	18	29	27	7	1
Fastac	6	12	18	28	30	6	1
Ambush C	5	13	18	28	27	8	0
Actipron	8	15	20	33	21	4	0
Fyzol 11E	7	14	21	33	22	3	0
Codacide	8	13	21	33	22	3	0
Fortune							
None	3	11	20	31	27	7	1
Decis	4	11	21	31	26	7	0
Fastac	4	13	20	31	25	8	0
Ambush C	2	11	18	32	29	8	0
Actipron	6	14	25	32	21	2	0
Fyzol 11E	6	14	27	34	16	2	0
Codacide	3	12	20	32	27	5	0

Table 2.11 Bulb yields for VT Carlton and Fortune after the third two-year growing cycle of Experiment 2 (1995-97)

Spray treatment	Marketable bulbs per plot [a]	
	Weight (kg)	Number
Carlton		
None	14.97	269
Decis	13.90	269
Fastac	13.89	276
Ambush C	15.14	262
Actipron	13.20	283
Fyzol 11E	13.51	288
Codacide	13.82	281
SED (18 df)	0.781	10.4
Significance	NS	NS
Fortune		
None	13.32	265
Decis	13.82	286
Fastac	12.55	266
Ambush C	13.98	278
Actipron	11.40	314
Fyzol 11E	12.28	306
Codacide	13.11	292
SED (18 df)	0.749	15.6
Significance	*	*

[a] based on planting approx. 150 bulbs per plot weighing 6.0 kg

Table 3.1 Flowering performance and virus scores of six stocks of cv Dutch Master in the four years of Experiment 3 (1995 to 1998)

(a) Year 1

Stock reference	Planted weight (kg)	Flowers per plot	Stem length (mm)	Foliage length (mm)	% with virus symptoms [a]
A	3.40	12	455	563	10
B	4.05	58	452	463	13
C	3.31	38	448	487	11
D	3.45	23	472	486	18
E	3.85	26	481	507	8
VT stock	3.00	59	492	477	5
SED (15 df)	0.122	7.6	14.6	6.8	4.1
Significance	***	***	*	***	NS

(b) Year 2

Stock reference	Flowers per plot	Flower diam. (mm)	Stem length (mm)	Foliage length (mm)	Virus symptom score [b]	ELISA [c] (NYSV)	ELISA (all viruses)
A	85	110	422	429	3	3.1	5.3
B	75	108	372	394	4	3.6	5.9
C	86	108	400	406	3	3.2	5.3
D	87	106	407	422	4	3.5	6.3
E	85	107	425	415	3	4.0	6.0
VT stock	76	104	408	425	2	2.2	2.5
SED (15 df)	7.8	1.6	16.9	11.8	0.7	0.34	0.35
Significance	NS	*	NS	NS	*	**	***

(continued)

(c) Year 3

Stock reference	Flowers per plot	Flower diam. (mm)	Stem length (mm)	Foliage length (mm)	% with virus symptoms [d]	% senescence (week 19)
A	31	98	372	383	13	22
B	34	96	364	353	31	19
C	28	97	379	389	38	28
D	30	95	387	382	63	18
E	34	96	357	356	10	11
VT stock	24	93	375	388	24	13
SED (15 df)	1.8	2.1	17.9	13.1	13.9	5.1
Significance	***	NS	NS	NS	*	NS

(d) Year 4

Stock reference	Flowers per plot	Flower diam. (mm)	Stem length (mm)	Foliage length (mm)	% with virus symptoms [e] March	April	ELISA [c] (NYSV)	ELISA (all viruses)
A	34	109	467	427	8	17	0.5	3.0
B	31	111	427	426	51	81	1.8	5.6
C	40	110	437	422	39	58	0.9	4.1
D	35	110	460	444	60	70	2.0	5.8
E	34	112	440	433	19	23	1.5	3.9
VT stock	38	113	482	484	16	21	0.9	1.4
SED (15 df)	4.0	1.3	10.1	15.5	10.4	9.8	0.44	0.77
Significance	NS	NS	**	*	**	***	*	***

[a] Percentage plants with virus recorded 12 May 1995

[b] Visual assessment of virus symptoms in the field on 15 May 1996. Plots scored from 0, no visible virus, through to 1, occasional plant with slight symptoms, 2, few plants with symptoms, rarely severe, to 5, most plants with symptoms, some severe.

[c] Each leaf sample was scored from 0 to 5 (see Materials and Methods) on the basis of ELISA testing. For NYSV, the scores of the five leaf samples per plot were summed and then averaged across the five leaves. For the assessment of 'all viruses', scores for all viruses detected were summed and averaged.

[d] Assessed 23 April 1997

[e] Assessed 31 March and 21 April 1998

Table 3.2 Bulb yields for six stocks of cv Dutch Master in the first two years of Experiment 3 (1994-96)

Stock reference	Yield (no. per plot)	Yield (kg per plot)	
		Weight	% increase
A	118	6.41	88
B	155	4.96	23
C	167	7.97	143
D	139	5.55	61
E	183	6.22	63
VT stock	173	5.53	84
SED (15 df)	18.1	0.949	31.3
Significance	*	NS	*

Table 3.3 Percentage distribution of marketable bulb yield to grades for cv Dutch Master in the first two years of Experiment 3 (1994-96)

Stock reference	Percentage of bulb yield (kg) in grade					
	<8	8-10	10-12	12-14	14-16	16-18
A	3	5	12	34	40	5
B	12	23	19	30	13	3
C	5	13	25	26	31	1
D	7	15	25	33	19	1
E	12	19	29	31	9	1
VT stock	12	13	25	36	13	1

Table 3.4 Bulb yields for six stocks of cv Dutch Master in the second two years of Experiment 3 (1996-98)

Stock reference	Yield (no. per plot)	Yield (kg per plot)	
		Weight	% increase
A	78	3.40	159
B	71	2.98	140
C	63	3.03	140
D	79	3.24	143
E	71	3.68	174
VT stock	76	4.17	237
SED (15 df)	3.7	0.147	12.8
Significance	**	***	***

Table 3.5 Percentage distribution of marketable bulb yield to grades for cv Dutch Master in the second two years of Experiment 3 (1996-98)

Stock reference	Percentage of bulb yield (kg) in grade						
	<8	8-10	10-12	12-14	14-16	16-18	>18
A	3	8	28	29	29	3	1
B	4	9	26	35	21	4	2
C	3	8	16	34	33	5	1
D	4	12	28	34	17	4	0
E	2	8	18	29	31	10	2
VT stock	3	7	17	32	28	14	0

Table 3.6 Flowering performance and virus scores of six stocks of cv Golden Harvest in the first four years of Experiment 3 (1995 to 1998)*

(a) Year 1

Stock reference	Planted weight (kg)	Flowers per plot	Flower diam. (mm)	Stem length (mm)	Foliage length (mm)	% with virus symptoms
A	3.72	70	102	317	351	35
B	3.83	66	102	330	327	15
C	3.57	58	102	310	337	24
D	3.74	68	101	318	336	24
E	3.54	37	97	334	346	16
VT stock	3.06	85	104	324	328	5
SED (15 df)	0.083	5.3	1.5	10.9	14.2	6.3
Significance	***	***	**	NS	NS	**

(b) Year 2

Stock reference	Flowers per plot	Flower diam. (mm)	Stem length (mm)	Foliage length (mm)	Virus levels		
					Symptoms score	ELISA (NYSV)	ELISA (all viruses)
A	122	110	438	446	4	1.6	2.0
B	131	111	445	459	4	1.8	2.3
C	119	110	442	466	4	1.7	1.8
D	125	108	438	446	4	2.0	2.2
E	121	109	429	445	4	2.2	2.2
VT stock	114	116	450	469	2	1.1	1.1
SED (15 df)	5.1	1.9	9.9	9.6	0.6	0.38	0.37
Significance	NS	*	NS	NS	*	NS	NS

(continued)

(c) Year 3

Stock reference	Flowers per plot	Flower diam. (mm)	Stem length (mm)	Foliage length (mm)	% with visual virus	% senescence (week 19)
A	48	106	394	422	35	40
B	53	107	397	428	48	28
C	52	105	395	421	50	33
D	55	104	412	430	25	39
E	53	104	409	428	49	27
VT stock	56	106	398	437	8	9
SED (15 df)	2.3	1.6	15.8	14.7	7.3	3.6
Significance	*	NS	NS	NS	***	***

(d) Year 4

Stock reference	Flowers per plot	Flower diam. (mm)	Stem length (mm)	Foliage length (mm)	% with virus symptoms		ELISA (NYSV)	ELISA (all viruses)
					March	April		
A	52	109	482	484	30	58	2.0	2.8
B	59	107	451	467	26	58	2.8	2.9
C	54	107	465	482	29	55	2.9	3.6
D	56	106	466	506	19	36	1.8	2.7
E	50	106	505	512	15	23	3.2	4.7
VT stock	59	108	503	497	4	10	0.3	0.9
SED (15 df)	3.6	1.4	15.6	22.6	8.4	12.9	0.41	0.71
Significance	NS	NS	*	NS	NS	**	***	**

* For footnotes, see Table 3.1

Table 3.7 Bulb yields for six stocks of cv Golden Harvest in the first two years of Experiment 3 (1994-96)

Stock reference	Yield (no. per plot)	Yield (kg per plot)	
		Weight	% increase
A	201	6.41	73
B	204	7.33	92
C	184	6.26	76
D	214	6.49	74
E	178	6.10	72
VT stock	153	6.96	127
SED (15 df)	9.6	0.274	9.2
Significance	***	**	***

Table 3.8 Percentage distribution of marketable bulb yield to grades for cv Golden Harvest in the first two years of Experiment 3 (1994-96)

Stock reference	Percentage of bulb yield (kg) in grade					
	<8	8-10	10-12	12-14	14-16	16-18
A	9	34	32	21	4	0
B	8	27	35	23	6	0
C	10	22	37	22	7	1
D	14	33	36	14	3	0
E	9	34	35	18	4	0
VT stock	7	12	16	42	21	2

Table 3.9 Bulb yields for six stocks of cv Golden Harvest in the second two years of Experiment 3 (1996-98)

Stock reference	Yield (no. per plot)	Yield (kg per plot)	
		Weight	% increase
A	86	3.74	139
B	91	4.23	152
C	82	3.85	130
D	93	4.25	150
E	82	3.97	148
VT stock	100	4.66	174
SED (15 df)	4.3	0.381	25.5
Significance	**	NS	NS

Table 3.10 Percentage distribution of marketable bulb yield to grades for cv Golden Harvest in the second two years of Experiment 3 (1996-98)

	Percentage of bulb yield (kg) in grade						
Stock reference	<8	8-10	10-12	12-14	14-16	16-18	>18
A	3	10	24	38	21	3	1
B	2	12	26	29	22	8	0
C	3	6	26	31	30	3	0
D	3	9	24	31	24	9	0
E	2	9	23	35	28	4	0
VT stock	2	11	24	29	29	4	0

Table 3.11 Flowering performance and virus scores of six stocks of cv St. Keverne in the four years of Experiment 3 (1995 to 1998)*

(a) Year 1

Stock reference	Planted weight (kg)	Flowers per plot	Flower diam. (mm)	Stem length (mm)	Foliage length (mm)	% with virus symptoms
A	2.38	48	79	371	310	33
B	1.89	34	77	332	253	45
C	2.33	31	77	352	316	43
D	2.33	39	78	353	298	61
E	2.34	46	79	365	293	63
VT stock	1.85	48	76	332	279	0
SED (15 df)	0.089	3.6	1.5	9.0	12.4	6.0
Significance	***	***	NS	**	**	***

(b) Year 2

Stock reference	Flowers per plot	Flower diam. (mm)	Stem length (mm)	Foliage length (mm)	Virus levels		
					Symptoms score	ELISA (NYSV)	ELISA (all viruses)
A	84	88	409	367	5	3.2	4.6
B	72	88	417	351	5	3.0	5.3
C	81	90	406	362	2	3.1	4.5
D	82	87	410	356	4	3.2	3.9
E	87	88	404	345	3	2.7	6.3
VT stock	79	91	413	364	3	2.3	2.3
SED (15 df)	4.3	1.1	10.4	9.3	0.5	0.32	0.94
Significance	NS	NS	NS	NS	**	NS	*

(continued)

(c) Year 3

Stock reference	Flowers per plot	Flower diam. (mm)	Stem length (mm)	Foliage length (mm)	% with visual virus	% senescence (week 19)
A	49	89	397	328	100	10
B	55	88	388	327	99	9
C	43	82	388	345	93	14
D	45	90	401	341	90	13
E	45	88	393	336	100	13
VT stock	47	90	397	340	21	2
SED (15 df)	3.9	4.3	7.6	8.0	4.9	1.6
Significance	NS	NS	NS	NS	***	***

(d) Year 4

Stock reference	Flowers per plot	Flower diam. (mm)	Stem length (mm)	Foliage length (mm)	% with virus symptoms		ELISA (NYSV)	ELISA (all viruses)
					March	April		
A	58	93	464	404	90	95	3.0	6.6
B	55	92	475	423	89	97	3.0	6.1
C	61	89	473	417	40	58	2.6	5.8
D	57	92	465	425	50	75	2.7	5.3
E	57	90	458	407	68	78	2.7	5.8
VT stock	61	92	477	424	29	39	1.2	2.0
SED (15 df)	4.8	1.2	10.6	10.6	10.6	5.6	0.22	0.69
Significance	NS	NS	NS	NS	***	***	***	***

* For footnotes, see Table 3.1

Table 3.12 Bulb yields (marketable bulbs and additional rotted bulbs) in six stocks of cv St. Keverne in the first two years of Experiment 3 (1994-96)

Stock reference	Yield (no. per plot)	Yield (kg per plot)		Rotted bulbs (kg per plot)
		Weight	% Increase	
A	136	3.24	37	0.06
B	101	2.50	31	0.15
C	130	2.92	26	0.18
D	118	2.61	12	0.12
E	121	2.75	19	0.12
VT stock	96	2.63	42	0.21
SED (15 df)	15.0	0.400	18.6	0.094
Significance	NS	NS	NS	NS

Table 3.13 Percentage distribution of marketable bulb yield to grades for cv St. Keverne in the first two years of Experiment 3 (1994-96)

Stock reference	Percentage of bulb yield (kg) in grade				
	<8	8-10	10-12	12-14	14-16
A	18	26	45	11	0
B	17	27	39	16	1
C	20	29	44	6	0
D	18	28	46	7	1
E	16	31	50	3	0
VT stock	12	20	52	13	3

Table 3.14 Bulb yields for six stocks of cv St. Keverne in the second two years of Experiment 3 (1996-98)

Stock reference	Yield (kg per plot)		
	Yield (no. per plot)	Weight	% increase
A	113	3.61	187
B	105	3.92	194
C	110	3.76	190
D	119	3.65	186
E	117	3.73	185
VT stock	121	3.71	172
SED (15 df)	9.7	0.291	23.7
Significance	NS	NS	NS

Table 3.15 Percentage distribution of marketable bulb yield to grades for cv St. Keverne in the second two years of Experiment 3 (1996-98)

Stock reference	Percentage of bulb yield (kg) in grade						
	<8	8-10	10-12	12-14	14-16	16-18	>18
A	11	20	31	28	10	0	0
B	10	12	35	28	8	7	0
C	9	17	37	25	11	0	1
D	12	17	36	24	10	1	0
E	12	15	36	27	11	1	0
VT stock	11	12	35	33	6	3	0

Table 3.16 Flowering performance and virus scores of six stocks of cv Tête-à-Tête in the four years of Experiment 3 (1995 to 1998)*

(a) Year 1

Stock reference	Planted weight (kg)	Stems per plot	Florets per stem	1st floret diam. (mm)	Stem length (mm)	Leaf length (mm)	% with virus symptoms
A	1.10	144	1.0	42	137	110	4
B	1.39	148	1.1	44	146	121	3
C	1.33	131	1.2	45	150	123	3
D	1.13	111	1.1	43	136	113	6
E	1.47	144	1.1	44	131	94	9
VT stock	1.60	126	1.6	45	167	141	0
SED (15 df)	0.092	10.8	0.10	0.8	4.0	6.2	1.9
Significance	***	*	**	*	***	***	**

(b) Year 2

Stock reference	Stems per plot	Florets per stem	1st floret diam. (mm)	Stem length (mm)	Foliage length (mm)	Virus levels: Symptom score	Virus levels: ELISA (NYSV)	Virus levels: ELISA (all virus)
A	238	1.1	50	197	223	4	3.1	4.3
B	220	1.2	49	201	232	4	3.1	4.8
C	200	1.2	50	206	238	5	3.0	4.0
D	215	1.1	50	186	212	5	3.1	4.5
E	242	1.2	50	204	219	5	3.1	4.3
VT stock	260	1.4	49	233	258	2	2.5	2.6
SED (15 df)	40.9	0.17	0.9	6.6	8.1	0.4	0.20	0.55
Significance	NS	NS	NS	***	***	***	*	*

(continued)

(c) Year 3

Stock reference	Stems per plot	Florets per plot	Floret diam. (mm)	Stem length (mm)	Foliage length (mm)	% with virus symptoms	% senescence (week 19)
A	145	163	43	214	234	60	11
B	126	138	43	205	243	50	13
C	119	134	43	214	235	53	15
D	130	138	45	213	239	66	18
E	113	124	44	210	234	68	18
VT stock	113	126	43	219	244	25	5
SED (15 df)	10.4	11.4	1.1	7.9	12.4	9.7	1.1
Significance	NS	*	NS	NS	NS	**	***

(d) Year 4

Stock reference	Flowers per plot	Flower diam. (mm)	Stem length (mm)	Foliage length (mm)	% with virus symptoms		ELISA (NYSV)	ELISA (all viruses)
					March	April		
A	198	49	227	245	88	100	3.5	5.9
B	167	51	221	242	83	93	1.9	3.6
C	162	50	213	237	88	100	3.5	5.5
D	149	48	195	221	90	99	4.4	7.2
E	149	50	199	211	95	100	3.0	4.6
VT stock	155	53	227	245	26	58	1.5	2.0
SED (15 df)	20.6	1.1	14.3	13.0	6.2	3.3	0.44	0.64
Significance	NS	*	NS	NS	***	***	***	***

* For footnotes, see Table 3.1

Table 3.17 Bulb yields in six stocks of cv Tête-à-Tête in the first two years of Experiment 3 (1994-96)

Stock reference	Yield (no. per plot)	Yield (kg per plot)	
		Weight	% increase
A	266	1.98	87
B	214	1.37	1
C	211	1.82	37
D	213	1.65	46
E	255	1.71	18
VT stock	284	2.50	56
SED (15 df)	36.4	0.310	26.1
Significance	NS	*	NS

Table 3.18 Percentage distribution of marketable bulb yield to grades for cv Tête-à-Tête in the first two years of Experiment 3 (1994-96)

Stock reference	Percentage of bulb yield (kg) in grades			
	<8	8-10	10-12	12-14
A	81	17	2	0
B	77	23	1	0
C	75	24	1	0
D	79	21	0	0
E	83	17	0	0
VT stock	63	26	10	1

Table 3.19 Bulb yields for six stocks of cv Tête-à-Tête in the second two years of Experiment 3 (1996-98)

Stock reference	Yield (no. per plot)	Yield (kg per plot)		No. of rotted bulbs
		Weight	% increase	
A	210	1.92	92	26
B	202	1.82	84	16
C	213	1.77	77	12
D	179	1.17	32	37
E	185	1.47	47	28
VT stock	198	1.76	76	19
SED (15 df)	18.8	0.190	18.6	12.2
Significance	NS	*	*	NS

Table 3.20 Percentage distribution of marketable bulb yield to grades for cv Tête-à-Tête in the second two years of Experiment 3 (1996-98)

Stock reference	Percentage of bulb yield (kg) in grade		
	<8	8-10	10-12
A	52	41	8
B	50	44	6
C	57	34	9
D	68	28	4
E	59	35	6
VT stock	47	33	20

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9 February 1999