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NARCISSUS: EXAMINATION OF THE LINKS BETWEEN SOIL NITROGEN AND BASAL ROT

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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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PRACTICAL SECTION

Objective and background

There have been occasional reports that growing narcissus in soil with high nitrogen levels may increase the amount of basal rot in stocks. This project was set up to see if this finding could be confirmed.

Summary

Narcissus bulbs, varieties Golden Harvest (highly susceptible to basal rot) and St. Keverne (much less susceptible) were planted in pots of soil in autumn 1996 and grown in a cold glasshouse. The soil had been amended before use by the addition of different amounts of ammonium nitrate, giving levels equivalent to 0 to 300 kg N/ha. A further batch of soil had ammonium nitrate added at the 100 kg N/ha rate, along with residue from a brassica crop. One other batch of soil had nitrogen added as a 'split dose' treatment, with ammonium nitrogen added at a rate of 150 kg N/ha before planting, and a further application at the same rate added as a top-dressing in the following April. Pots from each nitrogen treatment had an inoculum of chlamydospores of *Fusarium oxysporum f.sp. narcissi* (the basal rot fungus) added, at either a low or a high rate; further pots had no inoculum added and served as controls. In the glasshouse, pots were placed on saucers and were bottom watered, to prevent leaching.

Soil samples taken after the start of the experiment (November) showed that a wide range of nitrate-nitrogen levels had been achieved. This was reflected in the organic nitrogen levels in plants from different treatments in April. By April, nitrate-nitrogen in soil had fallen to very low levels in all treatments. By the end of the growing season (July), soil nitrate-nitrogen levels were higher in treatments where further nitrogen had been added in April as part of the split-dose treatment. *Fusarium oxysporum* was recovered at high rates from the soils at the start of the experiment, but levels had fallen considerably by April.

In Golden Harvest, 9 per cent of harvested bulbs, overall, showed *Fusarium*-type bulb rots when examined after storage. The incidence of rotting was low where no inoculum had been added (1%), and increased to 8% and 19% where inoculum had been added at the low and high rates, respectively. The split-dose nitrogen treatment increased the incidence of rotting in the low-inoculum treatments, but apart from this nitrogen levels (from 0 to 300 kg N/ha equivalent at the start of the experiment) had no effect on the amount of bulb rots. In St. Keverne, the amount of bulb rots was low overall, but was higher where the high rate of inoculum had been used in combination with the split-dose nitrogen treatment (4% rots compared with 0 to 2% in other treatments). Bulb yields reflected the different amounts of rotting in different treatments in both varieties. In St. Keverne, higher rates of nitrogen led to the production of more but smaller bulbs.

The conclusion from the project is that even very high rates of nitrogen at the start of the growing season did not lead to more basal rot; however, higher rates of nitrogen later in the season did increase the incidence of basal rot.

Action points for growers

Normal nitrogen fertilisation (pre-planting or pre-emergence) is unlikely to increase the incidence of basal rot in narcissus bulbs when grown following low N residue crops such as cereals.

However, where bulbs are to be planted following high residue brassica crops, the amounts of basal fertiliser applied should take into account the measured levels of soil mineral N at planting, and potential release of N from crop residues in the spring.

The risks of basal rot in high residue rotations are likely to be increased following dry winters.

Practical and financial benefits from the study

The project demonstrated that the current recommended practices for nitrogen fertilisation of narcissus crops appear safe, but more attention should be paid to soil nitrogen levels from previous crop residues and especially later in the growing season.

EXPERIMENTAL SECTION

Introduction

Daffodils are relatively unresponsive to fertiliser applications in terms of bulb and flower yields. However, there are accepted MAFF recommendations for the main nutrients needed, based on practical experience and trials. In trials work, yield responses are rarely seen, not only because there is a reserve of nutrients in the bulb, but also because bulbs are often grown in intensive rotations in nutrient-retentive soils with crops which leave large residues of nitrogen. Some surveys have found that bulb growers may apply unnecessarily high rates of fertilisers.

Levels of soil nutrients may, however, affect disease development in daffodils. There are some reports that high levels of nitrogen lead to increased susceptibility to fungal diseases (such as basal rot) and bruising. Thus, in fertiliser trials, McClellen and Stuart (1947) reported that more basal rot occurred when nitrogen was added, and Rikhter (1976) found the highest incidence of fungal disease where a high rate of nitrogen had been applied. Biekart (1930), working on Paperwhite narcissus, reported that continued nitrogen application resulted in many offsets and necrotic bulbs being produced. Wallis (1967) found that, in long-term trials, daffodil bulbs that had received nitrogen were more easily bruised, and showed increased losses due to fungi, than bulbs in other fertiliser treatments.

Basal rot (caused by *Fusarium oxysporum f. sp. narcissi*) is the most serious disease threatening UK bulbs, as recent years have confirmed. The UK bulb industry is experiencing difficulty in controlling basal rot despite, in many cases, the adoption of appropriate fungicide treatments and good bulb handling practices. Lower planting densities, one-year-down growing, and handling bulbs in small units (rather than in bulk) would all be likely to lead to better control of basal rot, but would be uneconomic to apply for other reasons. On the other hand, changes to fertiliser usage could easily be made, if a connection between basal rot and nutrient levels could be proven. The objective of the present study was to see if high nitrogen levels do indeed lead to an increase in basal rot. A small-scale experiment was carried out, so that results could be obtained quickly and economically, before committing to field trials. As high rates of nitrogen were applied, it was considered unlikely that a positive correlation between soil nitrogen levels and increased basal rot would be missed. The work should show whether nitrogen levels could be discounted as a factor in the epidemiology of basal rot, or whether cultural practices could be adjusted to minimise the risks of basal rot, e.g. by reducing fertiliser rates or by avoiding planting susceptible stocks in fields with high nitrogen residues.

Materials and methods

Plant material

Bulbs of *Narcissus* cultivars Golden Harvest and St. Keverne, 10/12 cm grade (circumference, slotted riddle), were taken from stocks grown at HRI Kirton, Lincolnshire. They received standard treatments after lifting in July 1996, including a post-lifting fungicide dip, drying initially on a letter box drying wall at 35°C for three days followed by continued drying and storage at ambient temperatures under fans, hot-water treatment (HWT) in early-August, and continued storage at ambient temperatures under fans until use in the experiment. Both the post-lifting dip and the

HWT tank contained formaldehyde, thiabendazole and non-ionic wetter at the recommended rates. The bulbs were allocated in batches of 10 each, and each batch was weighed.

Fungal inoculum and recovery from soils

Inoculum of *Fusarium oxysporum* f.sp. *narcissi* (isolates GCRI-X and LVBNa2) was prepared by washing spores from ten day old cultures grown on potato sucrose agar into fine talc powder. Equal numbers of plates of each isolate were used. The mixture was stirred until it appeared granular and was then allowed to dry at ambient temperature. Previous work (Linfield & Price, 1986) has shown that after a few weeks any surviving propagules are all chlamydospores. The concentration of propagules in the talc was calculated by suspending 10 g aliquots of the infested talc in 100 ml of 0.1% w/v water agar and plating a dilution series onto Nash medium (Nash & Snyder, 1961). After seven days' incubation at ambient temperature the numbers of colonies on the plates were counted. The talc was found to contain 0.22×10^5 propagules / g. Infested or untreated talc was added to pots of soil as described below (soil and additives)

The number of *Fusarium* propagules present in *ca.* 20 g bulked soil samples taken in November 1996 (see soil and plant analysis) was quantified in replicated samples using the same suspension and dilution plating techniques applied to the talc. An alternative plating medium (Komada, 1975) was used for the soil samples taken in April 1997 because of severe problems with contaminating *Penicillium* colonies when the Nash medium was used. All identified *Fusarium oxysporum*-like colonies were counted.

Soil and additives

The soil used was a coarse silty marine alluvial soil from HRI Kirton ("Jessops 1" field), with an initial analysis (glasshouse soil analysis) of 14 mg/litre nitrate, 43 mg/litre phosphorus, 131 mg/litre potassium, 201 mg/litre magnesium, conductivity 2135 µS and a pH value of 7.75. An adequate supply of the soil was taken from the field in late-September 1996, using only the top 20 cm, and was mixed well.

Seven batches of soil, each 400 litre (sufficient to fill 100, 4 litre (21 cm diameter) pots), were mixed with laboratory-grade ammonium nitrate in a compost mixer. For five batches, ammonium nitrate was added to give nitrogen rates equivalent to 0, 50, 100, 200 or 300 kg N/ha in the field. The amount of N added was calculated on an area basis, scaling down a field application of, say, 100 kg N/ha to the surface area of a 21 cm diameter pot. In the experiment, of course, this N would be confined to the depth of the pot (16.5 cm). For a sixth batch, ammonium nitrate was added to give a 150 kg N/ha rate, further ammonium nitrate being added later at the same rate to give a split-dose application (see below). For a seventh batch, ammonium nitrate was added at the 100 kg N/ha rate, along with 4 kg brassica residue per 400 litres soil (the residue was the remains of a summer cabbage crop left in the field and collected in late-September). We estimated that this residue delivered N at *ca.* 180 kg/ha, somewhat higher than a typical cabbage residue of about 135 kg N/ha.

Each batch of amended soil was dispensed into 4 litre (20 cm diameter) plastic flower pots, making 78 pots for each nitrogen treatment. Twenty-six pots of each had 35 g fungal inoculum in talc mixed into each pot, and a further 26 had 105 g inoculum in talc mixed in, making low and high

inoculum rates; a further 26 pots of each had 35 g plain talc added as a control. The low and high inoculum rates were equivalent to 0.76×10^6 and 2.2×10^6 propagules per pot, respectively.

On 7 October 1996, for each of the 21 treatment combinations (7 nitrogen rates x 3 inoculum rates), 12 pots were each planted with a pre-weighed batch of 10 bulbs of cv Golden Harvest, 12 with bulbs of cv St. Keverne, and two were left unplanted as controls to measure the loss of nutrients by immobilisation and denitrification.

Crop husbandry and further treatment

The pots were placed in a glasshouse with frost-protection heating (minimum maintained temperature of 3°C) and automatic ventilation at 15°C. Each pot was placed on a saucer to preclude loss of nutrients by leaching, and was watered (into the saucer) as required. Where weed seedlings appeared, they were uprooted and laid on the soil surface to die down. Flower heads were removed after anthesis, to prevent rotting. The non-planted pots were treated in the same way as those planted with bulbs.

For pots in the split-dose treatment, a top dressing of ammonium nitrate (1.3 g per pot, equivalent to a 150 kg N/ha rate) was added to each pot and worked into the surface on 10 April 1997.

After the beginning of foliar senescence, water was withheld and the pots were allowed to dry off. They were taken from the glasshouse and stored at 17°C on 6 June 1997 (Golden Harvest) or 25 June (St. Keverne).

Soil and plant analysis

Four weighed samples of bulbs of each cultivar (six bulbs each) were taken at the start of the experiment (8 October 1996). Two of each were used for the determination of nitrate-nitrogen and two for organic nitrogen.

Duplicate samples (*ca.* 1 kg) of each of the seven nitrogen soil mixtures were taken (from unused surplus soil) on 4 November 1996 for the analysis of ammonium- and nitrate-nitrogen. On the same date samples (*ca.* 20 g) were taken of soils to which a low or high rate of fungal inoculum, or of plain talc, had been added. This was done by bulking small samples from several pots to include the range of nitrogen treatments. These samples were used to re-isolate *Fusarium oxysporum* f.sp. *narcissi* and determine the levels of the pathogen present (see below).

On 8 April 1997, one replicate of each cultivar was used to provide plant and soil samples for nitrogen analysis and a further soil sample for testing for *Fusarium*. The methods used were as previously.

Further bulb and soil samples were taken from storage for nitrogen analysis on 17 July 1997. On the basis of previous results, only samples from the 0 and 300 kg N/ha treatments and from the split-dose treatment were analysed.

Crop monitoring and recording

The crops were checked at frequent intervals in the glasshouse. Shoot emergence in spring 1997 was 100% in both cultivars, with no evidence of losses due to bulb rots. The number of plants with disease symptoms (e.g. early senescence or smoulder) was recorded in May 1997.

Because it was not known whether treatment effects would become clear during the first year of the experiment, it was decided to sample half of the replicates in summer 1997, and, on the basis of these results, to take a decision whether to sample the remaining replicates in 1997 and complete the experiment, or to grow them on for a further year before examination. Hence, five replicates of the pots of each cultivar (taken at random) were moved from 17°C storage to a store at 25°C with 60% relative humidity on 24 June 1997 (Golden Harvest) and 11 July 1997 (St. Keverne). This was done to encourage any *Fusarium* bulb rots to develop. On 22 July 1997 bulbs of these five replicates were extracted from their pots and the number and weight of bulbs from each pot was recorded. Bulbs were then cut lengthwise to record the number of bulbs with rots (recorded as whole-bulb, basal or neck rots).

The remaining six replicate pots of each treatment were kept in storage at 17°C. Following consideration of the first set of results by the HDC Bulbs and Outdoor Flowers Panel in September 1997, it was decided to examine these remaining replicates without further growing-on. The bulbs were assessed for yield and rots on 15-16 October 1997.

Experimental design and statistical analysis

Each cultivar was grown in a separate glasshouse compartment, each being set out as 13 replicate blocks (including one block to be used for plant and soil samples in April 1997, and one block of unplanted pots for checking the loss of nitrogen).

Data were subjected to analysis of variance. Harvested bulb weights were analysed after adjustment for planted weight as a covariate.

As explained above, the replicates were examined in two batches. The results presented in this report are the means for both sets of samples combined. The statistical analysis used allowed for consideration of the effects of the two sample dates, but these were generally not statistically significant (other than for showing self-evident effects, such as the development of basal rot into whole-bulb rot, and the loss of bulb weight due to desiccation, between samples one and two).

Results

Organic and nitrate-nitrogen in bulbs

Results of nitrogen analysis of bulbs before planting, during the growing season after flowering, and after lifting, are shown in Table 1.

Levels of organic nitrogen fell from 14-15 g/kg in October (in bulbs pre-planting) to (in the various treatments) 6-12 g/kg in plants after flowering in April. In plants grown in substrates with

increasing levels of nitrogen fertiliser added, organic nitrogen levels in April increased from 6.3 (in 0 kg N/ha treatments) to 10.3 g/kg (in 300 kg N/ha treatments) in St. Keverne and from 8.1 to 11.6 g/kg in Golden Harvest. Levels were higher in bulbs sampled after harvest (July 1997), generally about 12-13 g/kg; levels had not increased in plants which had received a second application of nitrogen as part of the split-dose treatment, compared with the other treatments.

Levels of nitrate-nitrogen in bulbs generally fell between October and April in Golden Harvest but increased in St. Keverne, but there were no clear trends with increasing amounts of nitrogen added. In April samples, the highest levels of nitrate-nitrogen were seen in plants grown with added brassica residues. Levels of nitrate-nitrogen in bulbs after harvest were higher than in the previous samples, in all treatments tested.

Ammonium- and nitrate-nitrogen in soil

Soil analyses are shown in Table 2. Levels of ammonium-nitrogen were low, with few clear trends showing.

In soil samples taken two weeks after the start of the experiment, levels of nitrate-nitrogen increased with increasing amounts of nitrogen applied, indicating that the required gradient of nitrogen levels was being achieved. The levels achieved ranged from <10 mg/kg to about 140 mg/kg. Where brassica residue had been added, nitrate-nitrogen levels were equivalent to those achieved by applying 100-200 kg/ha rates of nitrogen. By April, nitrate-nitrogen levels had fallen to 3-10 mg/kg in all treatments. In soil from unplanted pots, nitrate-nitrogen levels were slightly greater than those in planted pots, but much lower than in November samples. Nitrate-nitrogen levels remained low in soil sampled again in July, although levels in the treatment receiving the second part of a split-dose nitrogen application had increased from 4 mg/kg to 10-13 mg/kg.

Recovery of *Fusarium*

In soil samples taken in November 1996, the mean numbers of Fusarium propagules recovered per gram of dry soil were 50 and 100 in controls (plain talc added) for Golden Harvest and St Keverne, respectively. For the low rate of inoculum the corresponding figures were 1700 and 2300, and for the higher rate, 2300 and 3000.

In samples taken in April 1997, there were no consistent differences between the numbers of propagules per gram of soil with no added nitrogen and with the highest rate of added nitrogen, so the values were bulked and meaned. For Golden Harvest, the mean numbers of propagules per gram were 154, 97 and 217 with no, low or high inoculum added. For St Keverne, the corresponding figures were 84, 62 and 67. The variation between replicates suggested that these differences were unlikely to be statistically significant. These results showed a considerable loss of inoculum between November and April. In contrast, isolations from surplus talc inoculum, stored at ambient room temperatures from October 1996 to January 1998, showed that there had been no loss of activity here.

Bulb diseases and rots

Few foliar symptoms of fungal diseases were seen during the growing period of the crop in the glasshouse. Premature senescence of the leaf tip, probably associated with smoulder (caused by *Botrytis narcissicola*) or basal rot (caused by *Fusarium oxysporum* f.sp. *narcissi*), was seen in only 0.2% of plants of each cultivar, and no effects of treatment could be determined at such low rates.

In cv Golden Harvest (basal rot-susceptible), 9.4% of lifted bulbs, overall, had some type of bulb rot. This was either a whole-bulb or basal rot (rarely a neck rot). There was a clear effect of *Fusarium* treatments on the number of bulbs with rot (Table 3): overall, 1% of bulbs showed rots where no *Fusarium* had been applied to the substrate but 8 and 19%, respectively, where *Fusarium* had been added at the low or high rate. The effects of nitrogen treatment were also statistically significant: although there was no clear dose-response to increasing rates of nitrogen, the highest rates of rotting were found where nitrogen had been applied as a split-dose treatment. The amounts of rotting where brassica residues had been incorporated were similar to other nitrogen treatments. There was a significant interaction between the *Fusarium* and nitrogen treatments (Table 4). The amount of bulb rots increased where split-dose nitrogen had been used in conjunction with a low rate of *Fusarium*. Where the high rate of inoculum had been used, although the amount of bulb rots was generally high, it varied in different nitrogen treatments: relatively less rotting was found at the higher nitrogen rates (100 to 300 kg/ha applications).

There were few statistically significant effects of *Fusarium* and nitrogen treatments on the amount of bulb rots in cv St Keverne (basal rot-resistant). Rots occurred only at a very low level (only 0.7% of bulbs, overall, showed any rots). However, the highest amount of rotting was found where the higher rate of *Fusarium* had been applied and where nitrogen had been applied as a split-dose treatment (3.7% in this treatment, compared with 0 to 2.0% in all other treatments), this interaction being significant at the 5 per cent level of probability (Table 5). There was a suggestion of increased rotting where the lower rate of *Fusarium* had been used with 300 kg/ha or split-dose nitrogen, but levels were too low to be regarded as statistically significant. A few bulbs of St Keverne (0.9% overall) showed a superficial, *Penicillium*-like mould, but no trends with treatments could be detected at this low level of occurrence.

Bulb yields

The weight of harvested bulbs of cv Golden Harvest decreased markedly as the amount of *Fusarium* inoculum was increased, and was lower in the split-dose treatment than in other nitrogen treatments (Table 6). The interaction between *Fusarium* and nitrogen treatments was not significant. There were no significant effects of treatments on the number of bulbs lifted.

In St Keverne the weight of bulbs lifted was more when a high rate of *Fusarium* had been added than in the control, and yields were lowest when a split-dose nitrogen treatment had been applied (Table 6). There were, in this variety, significant effects of treatments on the number of bulbs lifted (Table 7). There were more bulbs (more splitting of offsets) where the higher rates (>50 kg/ha) of nitrogen had been used, and where higher rates of nitrogen (200 or 300 kg/ha rates or split-dose) had been combined with a low rate *Fusarium* application. This was reflected in the mean individual bulb weights, which were lower with higher nitrogen rates and especially where this was combined with a low rate *Fusarium* treatment.

During grading, bulbs from the various treatments were examined to see if there were any obvious differences in their softness, which might lead to easier bruising. No differences could be detected.

Discussion

In this experiment bulbs were subjected to a wide range of nitrate-nitrogen levels in the period after planting in September. By the following April, nitrate-nitrogen in the soil had fallen to similar, low levels in all treatments, but the levels of organic nitrogen in the plants reflected the earlier differences in soil nitrogen levels. At this time, plants grown with added brassica residues exhibited the highest level of nitrate-nitrogen. By the end of the growing season (July), organic nitrogen levels in bulbs had increased, presumably due to translocation of nitrogen from the leaves. The application of the second part of the split-dose nitrogen application produced an increased nitrate-nitrogen level in the soil, compared with other treatments, but it had not resulted in a rise in organic nitrogen levels in the bulbs.

The arrangements adopted for the experiment, including standing the plant pots on saucers and watering into the saucers, should have ensured that no leaching losses could occur. In some 'control' pots, which were filled with soil and kept watered but in which no bulbs were planted, a large reduction in nitrogen levels did take place. This was probably due to increased denitrification as a result of the wet soil conditions (with no crop to use the water).

In the basal rot-susceptible cultivar Golden Harvest, very few bulbs developed rots when no *Fusarium* inoculum had been added, indicating an inherently healthy stock. Rotting increased when inoculum had been added to the soil, in proportion to the amount added, and despite the fact that isolations showed a considerable loss of inoculum between November and the following April. The incidence of bulb rots increased where nitrogen had been applied as a split-dose treatment, even when inoculum had been added at the lower rate. Reduced bulb yield, in this cultivar, was directly related to an increase in bulb rots.

In the basal rot-resistant cultivar St Keverne, there was a relatively low incidence of bulb rots. As in the case of Golden Harvest, however, losses were increased where the split-dose nitrogen application had been added along with the higher rate of inoculum. In St Keverne, bulb rots and bulb yields were not as obviously related as in Golden Harvest. Higher rates of nitrogen appeared to lead to more bulb splitting (a greater number of bulbs harvested), as observed in Paperwhite narcissus by Biekart (1930). There is no obvious explanation for the slightly greater yields obtained, on average, where a high rate of *Fusarium* inoculum had been added.

The basal rot fungus infects narcissus bulbs via roots or wounds in the basal plate, either soon after planting when new roots are emerging, or when the roots are senescing in early-summer. In the present experiment, bulbs presented with a wide range of soil nitrogen levels in the autumn/winter period failed to show an increased incidence of basal rot as a result. In Golden Harvest, only bulbs which had a high level of soil nitrogen in the following spring, due to the second part of the split-dose application, showed an increased number with rots where *Fusarium* inoculum had been applied at a low rate (with the high rate of inoculum, levels of bulb rots were high generally). This suggests that the usual pre-planting (August-September) or pre-emergence (December) nitrogen applications practised by growers are unlikely to lead to an increased basal rot problem. As shown

by the split-dose treatment, however, high nitrogen levels can, in some circumstances, lead to more basal rot. This could be a problem when susceptible cultivars of daffodils are planted after a previous high-residue crop such as brassicas. It is interesting to note that, in the experiment, rots increased even in St Keverne, where nitrogen had been applied late.

The results indicated that narcissus should be planted after low-residue crops like cereals, not after high-residue crops like brassicas, where high spring levels of nitrogen could occur following a dry winter with little leaching.

Further research

It is stressed that these conclusions are based on data from a single experiment. It is important to understand fully the interaction between nitrogen levels and basal rot, since the disease continues to be the major concern of UK bulb growers. A clear strategy for nitrogen use in susceptible crops is needed. Three approaches are suggested for further work:

- testing the 'high nitrogen, more basal rot' hypothesis in a further pot-grown experiment with more rates of spring nitrogen top-dressing
- carrying out field experiments following cereal crops, but with different rates of brassica residue added
- surveying spring mineral nitrogen levels and bulb rots in field-grown stocks

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Table 1 Analysis of organic and nitrate-nitrogen in narcissus bulbs or plants before, during and after growing in soil with different nitrogen additions. Values are means of duplicate samples.

Cultivar and N treatment	Organic nitrogen analysis		Nitrate-nitrogen analysis	
	N (g/kg)	% water in bulb	N (mg/kg)	% water in bulb
Pre-planting bulb analysis (October 1996)				
Golden Harvest	15.27	65.45	59.60	66.15
St. Keverne	14.43	60.60	42.40	61.85
Post-flowering plant analysis (April 1997)				
Golden Harvest				
0 kg/ha	8.05	67.70	46.1	61.2
50 kg/ha	8.58	67.20	38.3	66.8
100 kg/ha	10.33	71.35	43.8	71.2
200 kg/ha	9.81	71.00	44.7	65.7
300 kg/ha	11.56	71.30	43.1	62.6
150+150 kg/ha (split dose)	8.93	68.55	40.2	66.9
100+ brassica residue	10.51	71.20	55.9	70.0
St. Keverne				
0 kg/ha	6.30	63.65	51.1	66.5
50 kg/ha	8.05	66.20	43.1	67.8
100 kg/ha	8.41	68.70	54.0	64.8
200 kg/ha	9.63	70.05	49.4	65.3
300 kg/ha	10.33	69.75	55.7	66.2
150+150 kg/ha (split dose)	6.65	68.50	53.4	62.0
100+ brassica residue	8.05	69.20	57.7	65.2
Post-harvest bulb analysis (July 1997)				
Golden Harvest				
0 kg/ha	12.61	68.30	67.80	65.30
300 kg/ha	12.26	65.80	63.50	65.30
150+150 kg/ha (split dose)	12.09	64.15	71.00	65.75
St. Keverne				
0 kg/ha	12.61	64.65	55.10	63.60
300 kg/ha	15.76	65.10	67.20	66.50
150+150 kg/ha (split dose)	13.14	66.00	58.90	64.50

Table 2 Analysis of ammonium and nitrate-nitrogen in soil with different nitrogen additions. The values in parenthesis are for pots of soil only (no bulbs planted). Values are means of duplicate samples

Cultivar and N treatment	Ammonium nitrate (mg/kg)	Nitrate-nitrogen (mg/kg)	% moisture
November 1996			
Golden Harvest			
0 kg/ha	0	6.74	16.95
50 kg/ha	0	19.47	18.00
100 kg/ha	1.50	26.21	16.10
200 kg/ha	1.62	53.51	18.10
300 kg/ha	0.53	141.42	19.90
150+150 kg/ha (split dose)	1.47	58.92	18.75
100+ brassica residue	0	39.63	18.55
St. Keverne			
0 kg/ha	0	4.41	17.30
50 kg/ha	0.92	24.40	16.25
100 kg/ha	0	41.59	15.50
200 kg/ha	0	80.99	17.55
300 kg/ha	0	111.56	17.35
150+150 kg/ha (split dose)	0	55.88	18.15
100+ brassica residue	0	47.84	16.45
April 1997			
Golden Harvest			
0 kg/ha	0.64 (0.62)	3.86 (7.70)	12.85 (20.15)
50 kg/ha	0	8.58	11.80
100 kg/ha	0.55 (0)	4.53 (11.64)	11.85 (21.70)
200 kg/ha	0	10.26	11.85
300 kg/ha	0 (1.82)	3.64 (12.48)	11.45 (15.30)
150+150 kg/ha (split dose)	0	3.56	13.35
100+ brassica residue	1.47	7.00	13.90

(continued)

Cultivar and N treatment	Ammonium nitrate (mg/kg)		Nitrate-nitrogen (mg/kg)		% moisture	
St. Keverne						
0 kg/ha	0	(0.52)	2.88	(4.13)	14.80	(18.75)
50 kg/ha	1.06		3.98		13.90	
100 kg/ha	0	(1.64)	3.68	(7.57)	14.25	(18.70)
200 kg/ha	0		3.40		13.40	
300 kg/ha	0.57	(1.25)	7.26	(8.30)	14.15	(15.65)
150+150 kg/ha (split dose)	0.74		3.75		14.05	
100+ brassica residue	1.15		5.08		14.45	
July 1997						
Golden Harvest						
0 kg/ha	0.66		1.39		4.00	
300 kg/ha	1.08		2.82		3.05	
150+150 kg/ha (split dose)	0.79		13.09		2.70	
St. Keverne						
0 kg/ha	0		1.96		7.05	
300 kg/ha	0.30		8.54		4.90	
150+150 kg/ha (split dose)	1.83		9.66		4.30	

Table 3 The percentage of lifted bulbs with rots in narcissus cv Golden Harvest, following *Fusarium* and nitrogen treatments. The figures given are marginal means for *Fusarium* and nitrogen treatments (see Table 4 for full treatment means).

	Percentage of bulbs with rots			
	Whole bulb rots	Basal rot	Neck rot	Combined rots
Fusarium treatments				
None	0.2	0.1	0.6	1.0
Low-rate	5.3	2.2	0.6	8.0
High-rate	11.2	7.3	0.7	19.2
SED	1.20	0.78	0.32	1.62
Significance (189df)	***	***	NS	***
Nitrogen treatments				
0 kg/ha rate	5.0	3.7	0.5	9.1
50 kg/ha rate	6.3	4.2	0.4	10.8
100 kg/ha rate	4.9	1.6	0.7	7.2
200 kg/ha rate	3.4	3.6	0.7	7.7
300 kg/ha rate	3.1	1.8	0.5	5.3
150+150 kg/ha rate (split dose)	10.3	5.1	1.2	16.5
100+ brassica residues	6.1	2.5	0.5	9.1
SED	1.84	1.19	0.49	2.47
Significance (189df)	**	*	NS	***

In this and subsequent tables statistical significance is indicated by NS, not significant, and *, ** and ***, significant at the 5, 1 and 0.1% levels of probability, respectively

Table 4 The percentage of lifted bulbs with rots (combined total with whole-bulb, basal or neck rots) in narcissus cv Golden Harvest, following *Fusarium* and nitrogen treatments.

	Nitrogen treatment (kg/ha)						
Fusarium treatment	0	50	100	200	300	150+150	100+ brassica residues
None	2.0	0.5	1.2	0.5	1.0	1.0	0.9
Low-rate	5.1	3.9	6.3	4.6	5.6	23.3	7.1
High-rate	20.2	27.9	14.0	18.0	9.3	25.3	19.2
SED	4.28						
Significance (189df)	**						

Table 5 The percentage of lifted bulbs with rots (combined total with whole-bulb, basal or neck rots) in narcissus cv St Keverne, following *Fusarium* and nitrogen treatments.

	Nitrogen treatment (kg/ha)						
Fusarium treatment	0	50	100	200	300	150+150	100+ brassica residues
None	0	0	1.5	0	0.4	0	0
Low-rate	0.6	0.4	0.8	0	2.0	1.4	0
High-rate	0.5	1.9	0	0.4	0	3.7	0.9
SED	0.95						
Significance (189df)	**						

Table 6 Bulb yields in narcissus cv Golden Harvest and St Keverne, following *Fusarium* and nitrogen treatments. The figures given are marginal means for *Fusarium* and nitrogen treatments. Values are adjusted for variations in planting weight by using planting weight as a covariate.

	Golden Harvest		St Keverne	
	Weight lifted (g)	% weight increase	Weight lifted (g)	% weight increase
Fusarium treatment				
None	458	22	476	5
Low-rate	443	18	483	8
High-rate	425	14	493	9
SED	5.0	1.3	5.2	1.1
Significance (188df)	***	***	**	**
Nitrogen treatments				
0 kg/ha rate	447	19	492	9
50 kg/ha rate	441	18	483	7
100 kg/ha rate	445	19	490	10
200 kg/ha rate	452	21	491	9
300 kg/ha rate	445	19	475	6
150+150 kg/ha rate (split dose)	422	13	466	4
100+ brassica residues	440	18	489	9
SED	7.6	2.0	7.9	1.7
Significance (188df)	**	**	**	**

Table 7 The percentage increase in bulb numbers from planting in narcissus cv St Keverne, following *Fusarium* and nitrogen treatments.

	Nitrogen treatment (kg/ha)						
Fusarium Treatment	0	50	100	200	300	150+150	100+ brassica residues
None	76	67	118	100	85	91	96
Low-rate	65	113	65	130	132	136	72
High-rate	57	66	124	105	107	81	122
SED	12.1						
Significance (189df)	***						