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PRACTICAL SECTION FOR GROWERS

Background and objectives

Many growers producing both narcissus bulbs and ware potatoes have potato storage facilities which could also be used for storing bulbs. However, these storage facilities may be exposed to the potato sprout suppressants CIPC and tecnazene. Bulbs subsequently stored in the facilities could then encounter residues of these sprout suppressants. This may have an adverse effect on bulb growth.

An experiment was conducted to investigate whether narcissus bulbs are sensitive to CIPC or tecnazene. Bulbs were treated once with these chemicals at the rates used to treat ware potatoes, or one-third of this rate. The bulbs receiving one-third the tecnazene rate were also treated a second time at the full rate.

Treated bulbs were used in both a forcing trial and a field trial. In the forcing trial, bulbs were given standard cold treatment, before growing on under commercial forcing conditions. They were then assessed for number of days to flower, plus stem length, flower size and flower count at full flowering. In the field trial, treated bulbs were hot water treated then grown for two years, until harvested. Vigour, flower count and stem length were assessed in spring of the first year. Flower count and stem length were assessed in spring of the second year and yield (bulb number and total bulb weight in 6 size categories) was assessed at harvest.

Summary of results

In the forcing trial, the treatments had little or no adverse effect on the parameters measured. In the first year of the field trial, there was a small tendency for each treatment to reduce flower count, but this did not reach statistical significance. Vigour and stem length were not affected. In the second year of the field trial, flower count was clearly reduced by all treatments except full rate CIPC. The maximum reduction recorded was 7% of the control. The effects on stem length were very small. At harvest, there was an adverse effect of the treatments in one size category only, (14-16 cm circumference). In this category, a maximum 29% reduction in bulb number and 35% reduction in total bulb weight was recorded for the re-treated tecnazene treatment. No effect of the treatments on total yield (all size categories) could be detected. There was a trend for tecnazene to reduce total yield, but this did not reach statistical significance.

Practical and financial benefits from the study

Clear adverse effects of the treatments were not recorded until the second year of the field trial. This suggests these chemicals are damaging to narcissus flower number if present at flower initiation.

The conditions of the experiment differ from those on commercial holdings in two important respects. ADAS has recorded CIPC concentrations in debris in ware potato stores far higher than the concentrations achieved in the bulbs in this experiment. Bulbs placed in such stores are also likely to be exposed to such residues for a prolonged period, in contrast to the brief exposure used in this experiment. Bearing in mind these differences and the adverse effects recorded in this experiment, growers should continue to avoid using ware potato storage facilities for narcissus bulbs, whether for forcing or field production, if the ware potatoes are exposed to sprout suppressants.

SCIENCE SECTION

Introduction

Many Lincolnshire narcissus bulb producers are also potato growers. Potatoes are normally stored in bulk on the floor of buildings or in large, wooden bins, with a forced air system for environmental control. After the crop has been sold, these storage facilities may lie empty for the remainder of the year.

Many bulb plus potato growers view the empty facilities as useful storage for bulbs between bulb harvest and sale or replanting. However, ware potatoes are commonly treated with the sprout suppressants CIPC (chlorpropham) and/or tecnazene (TCNB) whilst in store. These pesticides, in particular CIPC, are known to persist in storage facilities. Dust, ventilation ducting, insulation foam and wood have all been known to become contaminated with CIPC, following its use on stored ware potatoes. ADAS has diagnosed many cases of poor growth in seed potatoes, cereals and grass seed where the seed has been stored in contact with or close to such materials, which have previously come in contact with CIPC from use on ware potatoes. Chitting and emergence are delayed and final yield may be reduced.

There is little information on the risk to bulbs. Enquiries were made at the Dutch Bulb Research Centre at Lisse, as to whether damage had been recorded in Holland. It was reported that, on farms where potatoes were grown together with irises and tulips, serious damage had been found from these chemicals. The sprout suppressants persisted in the floors and walls of storage rooms in which potatoes were treated. Ventilation of the rooms before storing the bulbs was not effective in preventing damage. In experiments, the same effects were obtained with bulbs exposed to CIPC. The damage consisted of a marked retardation of root and sprout formation in iris, tulip and hyacinth. The Dutch did not have experience with narcissus, but expected the same type of damage. Dutch growers are advised to avoid storage of bulbs in rooms in use for potatoes during part of the year.

In a German paper, (Streinbeiss *et al,* 1972)*, treatment of onions with 10 g CIPC/t caused about a 10% reduction in sprouting four months after treatment, though not at later stages or storage.

The manufacturers and suppliers of CIPC and tecnazene have not been able to supply any information on the susceptibility of bulbs or onions to these chemicals. Atlas Interlates CIPC + propham product "Indigo" carries a label warning not to handle, store or dry bulbs "in buildings in which potatoes are being or have previously been treated with Atlas Indigo, as the germination of these seeds can be reduced". However, Atlas have not been able to provide any data on which this warning is based. Zeneca know of no problems with bulbs and tecnazene.

The limited evidence available suggests there is a risk to narcissus bulbs from CIPC residues. Any adverse effects might not be dramatic and could pass unnoticed if a whole batch were to be affected with no fair comparison with unaffected bulbs. No evidence has been found for tecnazene damage to bulbs. The risk with this chemical therefore is theoretical, based on damage to seed potatoes recorded by ADAS and others.

* Streinbeiss, C.D., *et al.* (1972) *Die Nahrung* **16**, 27-36

In detailed discussions with HDC, the priority for investigation was identified as whether narcissus bulbs are affected at all by CIPC or tecnazene. HDC requested that bulbs should be exposed to the full CIPC and tecnazene rates used to treat ware potatoes. This exposure should be shortly after harvesting the bulbs, when it was judged they would be most absorptive and sensitive to the pesticides. Intermediate exposure treatments, at one-third the ware potato rate for CIPC and tecnazene, should also be included, to help relate experimental results to on-farm conditions, where much lower levels of exposure are likely.

Hence, the objective of the project was to determine whether narcissus bulbs are sensitive to a high concentration of CIPC or tecnazene. If they were found to be so, further work might be required to determine critical levels of exposure.

MATERIALS AND METHODS

Five hundred kg of narcissus cv Yellow Sun were supplied by Lindgarden Ltd., following lifting and hand-grading on 1 July 1995. Bulb roots and necks were fleshy when lifted. Of these, one hundred kg were transported to ADAS Arthur Rickwood and placed in plastic chitting trays in a general purpose building: these constituted the control sample.

The remaining 400 kg were transported to the PMB Experimental Station, Sutton Bridge, for treatment with sprout suppressants. These were applied on 7 July 1995. Two lots of 100 kg were treated in separate 3 tonne controlled environment stores with MSS CIPC 50LF (500 g CIPC/litre), as a thermal fog using a Swingfog applicator. Treatment rates were equivalent to 14mg CIPC/kg bulbs (the full rate for ware potaotes) or one-third this rate. A further two lots of 100kg were treated with Hystore 10 granules (10% tecnazene by weight), after placing the bulbs in paper sacks. Treatment rates were equivalent to 100mg tecnazene/kg or one-third of this rate, sprinkled over the samples, with the bags subsequently sealed.

All four lots were left in the treatment chambers (CIPC) or bags (tecnazene) at approximately 8°C until 10 July 1995, then transported to ADAS Arthur Rickwood, making two separate journeys for the two chemicals to avoid cross contamination. They were then trayed up and placed as four stacks in an open-sided building remote from the control sample, each stack covered with light cotton sheeting to reduce volatilisation. The stacks were positioned approximately 7m apart for different pesticides and 4m for different rates. Sub-samples of 20 bulbs were taken from all five stacks (including control) and sent for pesticide analysis.

The results of the analysis (Table 1) showed no contamination of the control sample, CIPC concentrations typical of those commonly achieved with potatoes, but tecnazene concentrations well below the application rate. Discussions with one manufacturer revealed that the levels found were consistent with tecnazene's mode of action. The granules only release tecnazene slowly, so that sprout suppression is achieved and maintained by maintaining tecnazene gas in the spaces within a potato stack.

Table 1. CIPC and tecnazene concentrations immediately after treatment (10/07/95)

Sample identification	CIPC	Tecnazene
	mg/kg whole bulb	
Control	Less than 0.02	Less than 0.02
CIPC 1/3 rate	5.51	Less than 0.02
CIPC full rate	8.24	0.02
Tecnazene 1/3 rate	0.10	5.51
Tecnazene full rate	0.12	5.89

The two tecnazene treatments also had very similar concentrations of tecnazene. Therefore it was agreed with the HDC that the one-third tecnazene treatment should be re-treated, at a time closer to planting (for the field trial) and the start of cold treatment (for the forcing trial). Consequently, on 13 September 1995, this treatment was re-treated with Hystore 10 granules at 125 mg tecnazene/kg of bulbs, the bulbs being sealed in paper sacks until emptied out on 19 September 1995.

Prior to retreatment, the bulbs to be used for the field trial, (all five treatments), were hot water treated on 24 August by J H Howard & Son. A routine was followed which avoided cross-contamination of different sprout suppressants and of different rates. Bulbs were exposed to a

temperature of 44.4°C for 3 hours. Formalin and the non-ionic wetter "B P Spreader" were added to the water.

Further analysis was conducted on 19 September (Table 2). This was on bulbs which had been hot-water treated for the field trial and not those to be used for the forcing trial. Hence the results are not applicable to the bulbs in the forcing trial, because hot water treatment may have removed some sprout suppressant from the first applications. The results show that retreatment had successfully increased the tecnazene concentration to a level above the original full-rate tecnazene treatment, though the magnitude of the increase was small, probably reflecting the less-absorptive nature of the bulbs by mid-September. The results also show that the effects of time since the original treatments (approximately 10 weeks) plus HWT had led to large decreases in sprout suppressant concentrations, particularly in the case of CIPC.

Table 2. CIPC and tecnazene concentrations of field trial bulbs after HWT and tecnazene re-treatment (19/09/95)

Sample identification	CIPC	Tecnazene
	mg/kg whole bulb	
Control	Less than 0.02	Less than 0.02
CIPC 1/3 rate	0.20	Less than 0.02
CIPC full rate	0.31	Less than 0.02
Tecnazene* re-treated	Less than 0.02	2.59
Tecnazene full rate	Less than 0.02	1.58

* Previously "Tecnazene 1/3 rate".

1. Forcing trial

The non-HWT bulbs, for the forcing trial, were transported to ADAS Wolverhampton at the end of September 1995. Three separate journeys were made, (control, two CIPC and two tecnazene treatments) to avoid cross contamination.

Cold treatment commenced on 6 October 1995. For each of the five treatments, four trays of 35 bulbs were prepared, using new, unused, reinforced carboard trays. The bulbs were stored dry for 6 weeks at 9°C in the dark in Fisons Fi-totron growth cabinets, (see photographs 1 and 2, Appendix 4). These cabinets give a high level of temperature control and permitted the pesticides to be stored separately from each other and from the control, hence minimising pesticide migration. Three cabinets were used, with the two CIPC treatments in one, the two tecnazene treatments in the second and the control in the third. On 17 November, trays were filled with Fisons F2 compost under the bulbs and the bulbs given a further 10 weeks treatment at 9°C for rooting.

On 12 January 1996 the trays were transported to O A Taylor and Sons Ltd property at Holbeach and set out in a heated greenhouse, (approximately 15°C), for final forcing. Treatments were randomised in four blocks. Sixteen whole bulbs (including tops and roots) were taken from each treatment and sent for analysis. The results (Table 3) show that residues of both chemicals persisted through cold treatment but that the two rates of each chemical had declined to roughly similar concentration. No detectable contamination of the control treatment had occurred. Comparison of Tables 2 (field trial bulbs after HWT) and 3 (non-HWT bulbs after cold treatment) also indicates that HWT must have removed a large proportion of the CIPC originally present.

Table 3. CIPC and tecnazene concentrations on completion of cold treatment (12/01/96)

Sample identification	CIPC	Tecnazene
	mg/kg whole bulb	
Control	Less than 0.02	Less than 0.02
CIPC 1/3 rate	0.31	Less than 0.02
CIPC full rate	0.34	Less than 0.02
Tecnazene* re-treated	Less than 0.02	1.16
Tecnazene full rate	Less than 0.02	1.34

The bulbs were grown on to full flowering, (as assessed by ADAS staff), then were assessed for number of days to full flowering, flower stem length at full flowering, flower size, marketable flower count and abnormalities. Statistical analysis was conducted on all these parameters except abnormalities.

2. Field trial

The field trial was planted on 25 September 1995, on a site provided by O A Taylor & Sons Ltd., at Green Lane, Holbeach. The design was randomised blocks with four replicates (20 plots total, arranged as four blocks of five). Each plot consisted of 50 bulbs, selected in two lots of 25, each lot weighing 1.850 kg (± 0.005 kg). Each plot was planted with two rows of 25 bulbs 0.92m apart. Adjacent blocks were separated by pathways 0.92m wide. The ends of the blocks were separated from the surrounding commercial crop by one guard row and the two outermost sides of the blocks by 0.92m wide paths. The bulbs were planted under ideal soil conditions. Standard field operations were conducted by O A Taylor & Sons Ltd.

Between February and April 1996 assessments were made of emergence date, date of full flowering, flower stem length at full flowering, flower count, vigour assessment (1-10) and abnormalities. Statistical analysis was conducted on stem length, flower count and vigour. Similar assessments except vigour, were made between February and March in 1997.

The bulbs were lifted on 7 July 1997. They were stored under cover to dry at the ADAS Siltland Centre, Holbeach St Marks, until grading and weighing at ADAS Arthur Rickwood on 13 August. Grading was conducted using a commercial long-slot narcissus riddle. Bulb numbers and weights in kilograms were recorded for the following categories of circumference in cm: less than 8; 8-10; 10-12; 12-14; 14-16; greater than 16; total. Statistical analysis was conducted on both bulb number and weight.

RESULTS

1. Forcing trial

Table 4 shows the mean values for the four variates analysed statistically: days to full flowering from first placing in the glasshouse, (days to flower); flower stem length at full flowering (stem length); flower size measured as diameter across widest point and marketable flower count per tray of 35 bulbs (flower count).

Table 4. Mean values of variates

Treatment	Days to flower	Stem length (cm)	Flower size (cm)	Flower count
Control	19.3	46.8	11.0	62.5
CIPC 1/3 rate	21.4	47.6	11.1	60.0
CIPC full rate	21.9	46.8	11.0	60.5
Tecnazene re-treated	20.4	46.6	11.0	60.3
Tecnazene full rate	20.0	47.2	10.8	60.5

Analysis of variance (see appendix 1) showed that only days to flower and flower size reached significance, ($P = <0.001$ and 0.030 respectively). These two variates were further analysed using a Dunnett's test (see Appendix 1). In this analysis, the Dunnett's test statistic was not exceeded at the 5% level and so the difference between the control and the other treatments are considered not to be significant.

In the Dunnett's test, the control is compared to each of the other treatments. In a statistical analysis, as more comparisons (or tests) are made, the probability of wrongly concluding that two means are different increases. The Dunnett's test addresses this and hence results which reach significance in the analysis of variance can prove to be non-significant using the Dunnett's test.

Abnormalities took the form of split trumpets and torn or jagged petals. There were few of these and marketable flower counts showed no significant differences as a result of the treatments.

Hence, the results show no significant effects of the four treatments were detected, compared to the control. There was, however, a trend for the treatments to increase days to full flowering.

2. Field trial

a. Year 1 (1996)

The crop attained 50% emergence on 15 February 1996. No differences were apparent between treatments. 100% emergence was reached on 14 March. No differences were noted between treatments in the stage of growth and no leaf abnormalities were recorded. By 8 April the flower stems had reached 20% at gooseneck stage and were showing colour. There were no differences between treatments, no evidence of HWT damage and no short flower stems. Vigour assessments (scored 1-10) were made on this date. Full flowering was reached on 19 April.

Flower counts (number per plot) and stem length were recorded on 23 April. Very few flower rogues or virus symptoms were noted. There was no evidence of any disease and weed control was excellent.

Table 5. Mean values of flower count (no. per plot) and stem length (cm), (Year 1).

Treatment	Flower count	Stem length
Control	96.8	37.6
CIPC 1/3 rate	85.8	38.6
CIPC full rate	86.3	37.7
Tecnazene re-treated	86.8	37.8
Tecnazene full rate	88.3	37.9

Table 5 shows the mean values of flower count and stem length at full flowering. Analysis of variance, (see Appendix 2), showed no significant differences between the control and the other treatments for either parameter. Mean flower count was appreciably higher for the control, but the difference was not significant (P = 0.073).

The vigour assessment scores were analysed using Friedman's non-parametric analysis, (see Appendix 2). This is an analysis of variance test used for discrete data, which ranks the scores and assesses the order of values. There was no significant difference between the control and the other treatments.

b. Year 2 (1997)

Foliage began emerging around 30 January. By 3 March leaf density and quality were excellent, with only one or two shoots showing smoulder. On 17 March the crop was at advanced gooseneck stage with 5% of flowers nearly fully open. No differences in growth, flowering or vigour were evident. By 21 March 90-95% of full flowering had been achieved. Assessments were made at full flower on 25 March.

A check on 2 May found all plots to be in full leaf, showing good vigour and health, with no obvious signs of leaf diseases. Weed cover was negligible and there were no signs of senescence.

Flower counts and stem length were recorded on 25 March.

Table 6. Mean values of flower count (no. per plot) and stem length (cm), (Year 2)

Treatment	Flower count	Stem length
Control	155.3	37.9
CIPC 1/3 rate	144.3	38.5
CIPC full rate	154.5	37.5
Tecnazene re-treated	144.0	37.1
Tecnazene full rate	144.0	37.5

Table 6 shows the mean values of flower count and stem length at full flowering. Analysis of variance, (see Appendix 3), showed there was a statistically significant treatment effect for both variates, (P = 0.032 and 0.0101 for flower count and stem length respectively).

The ANOVA data were further analysed using Duncan's multiple range test at the 5% level and by Dunnett's test at the same level. The first of these tests groups the treatment means in ascending order of magnitude and then groups the means into statistically homogeneous groups, allowing treatments to be compared with each other. Dunnett's test compares the mean of the control treatment with each of the other treatments. The results are shown in Tables 7 and 8.

Table 7. Statistical grouping - flower count

Treatment	Mean flower count	Homogenous groups
Tecnazene re-treated	144.0	a
Tecnazene full rate	144.0	a
CIPC 1/3 rate	144.3	a
CIPC full rate	154.5	b
Control	155.3	b

Table 8. Statistical grouping - stem length

Treatment	Mean stem length (cm)	Homogenous groups
Tecnazene re-treated	37.1	a
Tecnazene full rate	37.5	a b
CIPC full rate	37.5	a b
Control	37.9	b c
CIPC 1/3 rate	38.5	c

Table 7 shows that the tecnazene re-treated, tecnazene full rate and CIPC 1/3 rate were in a lower group for mean flower count than the control. The Dunnett's test confirmed this (see Appendix 3), with these three treatments being significantly different to the control. The maximum reduction was approximately 7% of the control.

Table 8 indicates that the treatment means for stem length can be ranked statistically into three groups: shortest - tecnazene re-treated, tecnazene full rate and CIPC full rate; intermediate - tecnazene full rate, CIPC full rate and control; longest - control and CIPC 1/3 rate. However, the groups overlap and only tecnazene re-treated and CIPC 1/3 rate were statistically distinct from each other in the Duncan's test. Using Dunnett's test (Appendix 3), which specifically tests treatment means against the control, no significant differences were found. This suggests that if there is a statistically significant effect, it is likely to be small. Examination of the means in Table 8 shows a maximum difference in stem length of 1.4 cm, or 4% of the longest.

Mean values for bulb numbers and total weights in the six categories plus the overall totals at harvest are shown in Tables 9 and 10 respectively.

Table 9. Mean bulb numbers in six size categories

Treatment	Circumference (cm)						
	<8	8-10	10-12	12-14	14-16	>16	Total
Control	61.5	35.7	43.7	37.5	37.2	27.5	243.3
CIPC 1/3 rate	64.5	39.0	51.7	40.0	29.0	22.3	246.5
CIPC full rate	65.0	36.5	49.2	35.2	36.2	22.8	245.0
Tecnazene re-treated	66.0	36.7	45.2	44.2	26.3	21.0	239.5
Tecnazene full rate	56.0	33.5	42.5	37.0	31.5	26.0	226.5

Table 10. Mean bulb total weights (kg) in six size categories

Treatment	Circumference (cm)						
	<8	8-10	10-12	12-14	14-16	>16	Total
Control	1.24	1.11	2.07	2.54	3.27	3.09	13.31
CIPC 1/3 rate	1.33	1.15	2.36	2.57	2.43	2.57	12.40
CIPC full rate	1.30	1.11	2.25	2.34	3.05	2.51	12.56
Tecnazene re-treated	1.34	1.07	2.10	2.84	2.15	2.46	11.94
Tecnazene full rate	1.19	0.99	2.00	2.46	2.64	3.11	12.39

Analysis of variance for the yield data is shown in Appendix 3. There were no significant treatment effects on total yield, either bulb number or total bulb weight, though there was a trend for both tecnazene treatments to reduce yield, especially bulb number. Studying the individual size categories, the only one in which there was a significant effect of the treatments on yield was 14-16 cm. This effect was present for both number of bulbs and total weight, ($P = 0.028$ and 0.006 respectively). These two data sets were further subjected to Duncan's multiple range test and Dunnett's test, to identify which treatments form statistically homogenous groups and which treatments were significantly different to the control. The rankings and resulting statistical groupings using the Duncan's test are shown in Tables 11 and 12.

Table 11. Statistical grouping - bulb number, 14-16 cm

Treatment	Mean bulb no.	Homogenous groups
Tecnazene re-treated	26.3	a
CIPC 1/3 rate	29.0	a b
Tecnazene full rate	31.5	a b c
CIPC full rate	36.3	b c
Control	37.3	c

Table 12. Statistical grouping - total bulb weight, 14-16 cm

Treatment	Mean total weight (kg)	Homogenous groups
Tecnazene re-treated	2.15	a
CIPC 1/3 rate	2.43	a
Tecnazene full rate	2.64	a b
CIPC full rate	3.05	b c
Control	3.27	c

Table 11 shows three over-lapping groups for bulb number, 14-16 cm circumference. The control produced the highest number and this effect was statistically significant compared to tecnazene re-treated, using the Dunnett's test (see appendix 3) and borderline for CIPC 1/3 rate. (Borderline is a situation where the treatment mean is not significantly different at the 5% level, but approaches the 5% level). The reduction in the tecnazene re-treated treatment was equivalent to 29% of the control. Table 11 also shows that tecnazene re-treated was in a lower bulb number group than CIPC full rate for this size group.

Table 12 also shows three over-lapping groups for total weight, 14-16 cm circumference. The control produced the highest weight. The maximum reduction, in the tecnazene re-treated treatment, was equivalent to 34% of the control. In the Duncan's test, CIPC full rate also had a higher yield than CIPC 1/3 rate and tecnazene re-treated. Dunnett's test (Appendix 3) showed that CIPC 1/3 rate and

tecnazene re-treated were significantly different from the control and tecnazene full rate was borderline.

Note: In all the ANOVA, the distribution of the residuals were examined to determine if transformations of the data (eg. logarithmic transformations) were necessary and that the ANOVA was valid. In all the ANOVA results cited in Year 2, no transformations of the data were considered necessary.

DISCUSSION

The forcing trial found no significant treatment effects, with only a trend for the treatments to increase days to flowering. In the first year of the field trial, again no significant treatment effects were found, though there was a clear trend for the treatments to reduce flower count compared to the control. In the second year of the field trial significant effects were found. All treatments except CIPC full rate caused a significant reduction in flower count, compared to the control. There was a trend for all treatments except CIPC 1/3 rate to reduce stem length, though the differences were small and not statistically significant. There were no significant effects of the treatments on total yield, either bulb number of total bulb weight, though there was a trend for tecnazene to have an adverse effect. For individual size categories, a significant effect of the treatments was found for both bulb number and total weight in the 14-16 cm category. In this category, the control had the highest yield: this was significantly greater in bulb number than the tecnazene re-treated treatment and - in total bulb weight - than the tecnazene re-treated and CIPC 1/3 rate treatments. There was a non-significant trend for the treatments, except tecnazene full-rate, to reduce both yield parameters in the >16 cm size category. There was also a non-significant trend for CIPC to increase the number and total weight of smaller bulbs (all categories <14cm), compared to the control.

Both CIPC and tecnazene had adverse effects on the parameters recorded. The results do not produce a clear picture of which chemical was worst. In year 2 of the field trial, CIPC full rate had least effect on flower count compared to the control and CIPC 1/3 rate had least effect on stem length. Also, the tecnazene treatments tended to reduce total yield compared to the control, though the effects were not statistically significant. Hence there is an indication that the tecnazene treatments used may have been more damaging than the CIPC treatments, but the experiment did not find a clear difference. This would need further investigation.

The tecnazene re-treated treatment had a greater adverse effect on bulb yield than tecnazene full rate in the 14-16 cm size category, but this difference was not apparent elsewhere in the trial.

CIPC 1/3 rate had a significant adverse effect on the second year flower count and bulb total weight in the 14-16 cm size category, whereas CIPC full rate did not. This inconsistency cannot readily be explained, though the CIPC concentrations recorded for the two treatments (Tables 1, 2 and 3) were never very different.

The concentrations of CIPC and tecnazene to which the bulbs were exposed initially were high. It is not known whether the wood of potato crates or the fabric of buildings would contain similar or greater concentrations of these chemicals. The effects of the single-exposure treatments used in this study might be taken to suggest these sprout suppressants had a relatively minor effect on bulb growth: the forced bulbs showed least effect; a slight effect on flower count was observed in the first year of the field trial; this became a significant effect in the second year, with an effect on yield of one size category. These results might be explained as follows. The first year's flowers would already have formed within the bulbs at the time of the exposure. The residues declined quite rapidly after treatment, but the concentrations in the field trial bulbs after HWT (Table 2) and the forcing bulbs at the end of forcing (Table 3) were still well above the minimum concentrations found to be detrimental to seed potatoes at planting, (approximately 0.05 mg/kg for CIPC and 0.15 mg/kg for tecnazene). Hence the first year flowers may be less sensitive than potato shoots, because they have formed before exposure and the sensitive dividing cell tissue is in a more protected location. Nevertheless, if the original contamination is great enough for residues to persist until second year flower formation, a more marked effect occurs. Flower initiation is affected in some way, though the reduction in flower number was only 7% in this study.

However, there are reasons to suppose that such conclusions underestimate the risks from sprout suppressants and it would not be safe to conclude that potato storage facilities can be used safely for narcissus bulb storage, from the results of this experiment. The concentration of sprout suppressants absorbed within building materials in potato stores, such as wood, is not known: this requires further investigation. It is known that extremely high concentrations of CIPC in particular can be found in dust and debris in potato stores, especially around ventilation ducts and fans. CIPC concentrations exceeding 3000 mg/kg in dust have been found by ADAS. Crystals around ducts have been found to contain in excess of 50% CIPC. Not only are the potential concentrations high, but exposure of bulbs could be long-term, continuing for weeks or months, unlike the single-episode exposure of the current study. In many other biological studies, for example pesticide toxicity to animals, it is known that the magnitude of effect depends on not only concentration, but also length of exposure. Taking the effects recorded in the current study and the potentially greater exposure to contamination of potato stores, every effort should continue to be made to avoid storing bulbs in potato storage facilities treated with sprout suppressants.

CONCLUSIONS

The potato sprout suppressants CIPC and tecnazene were both found to have adverse effects on the growth of narcissus. The magnitude of the effects were relatively minor, not reaching statistical significance during the forcing trial or the first year of the field trial. Statistically significant adverse effects were recorded on flower count, plus yield in one size category, during the second year of the field trial.

More marked adverse effects than those recorded in this trial may be encountered on commercial holdings, because there is the potential for both the level and duration of exposure to these sprout suppressants to be higher.

GLOSSARY

CIPC)
chlorpropham) = 1-methylethyl (3-chlorophenyl) carbamate

tecnazene)
TCNB) = 1,2,4,5-tetrachloro-3-nitrobenzene

APPENDIX 1: Forcing trial

Analysis of variance

1. Days to flowering

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block	3	56.76	18.92	1.50	0.264
Treatment	4	1242.60	310.65	24.66	<0.001
Residual	12	151.19	12.60	2.15	

Standard errors of differences of means

Block	Treatment
0.270	0.302

CV% (12 df) 2.1

2. Stem length

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block	3	382.10	127.37	4.62	0.023
Treatment	4	164.63	41.16	1.49	0.265
Residual	12	330.62	27.55	2.02	

Standard errors of differences of means

Block	Treatment
0.400	0.447

CV% (12 df) 1.3

3. Flower size

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block	3	16.150	5.383	6.32	0.008
Treatment	4	13.158	3.289	3.86	0.030
Residual	12	10.214	0.851	0.87	

Standard errors of differences of means

Block	Treatment
0.070	0.079

CV% (12 df) 1.0

Appendix 1: Forcing trial - continued

4. Flower count

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block	3	5.750	1.917	0.25	0.860
Treatment	4	24.800	6.200	0.81	0.543
Residual	12	92.000	7.667		

Standard errors of differences of means

Block	Treatment
1.751	1.958

CV% (12 df) 4.5

Dunnett's Test

1. Days to flower

	Treatment mean	Control mean	Difference	Residual mean square error	Root mean square	Standard error	Dunnett's test statistic
CIPC 1/3 rate	21.439	19.286	2.153	12.599	3.550	2.510	0.858
CIPC full rate	21.875	19.286	2.583				1.032
Tecnazene re-treated	20.351	19.286	1.065				0.424
Tecnazene full rate	19.980	19.286	0.694				0.277

2. Flower size

	Treatment mean	Control mean	Difference	Residual mean square error	Root mean square	Standard error	Dunnett's test statistic
CIPC 1/3 rate	11.116	11.01	0.106	0.851	0.923	0.652	0.162
CIPC full rate	11.047	11.01	0.037				0.057
Tecnazene re-treated	10.969	11.01	-0.041				-0.063
Tecnazene full rate	10.824	11.01	-0.186				-0.285

Dunnett's test statistic critical value for 5 treatments, 12 degrees of freedom and a two-sided test at the 5% level (from reference tables) = 2.81.

APPENDIX 2: Field trial, year 1

1. Flower count

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block	3	43.75	14.58	0.49	0.693
Treatment	4	334.00	83.50	2.83	0.073
Residual	12	354.00	29.50	2.83	

Standard errors of differences of means

Block	Treatment
3.44	3.84

CV% (12 df) 6.1

2. Stem length

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block	3	369.04	123.01	2.86	0.081
Treatment	4	242.23	60.56	1.41	0.290
Residual	12	515.79	42.98	5.15	

Standard errors of differences of means

Block	Treatment
0.411	0.459

CV% (12 df) 1.7

3. Vigour

Treatment	Estimated sum of median	Ranks
Control	9.10	10.0
CIPC 1/3 rate	10.00	13.5
CIPC full rate	10.00	14.0
Tecnazene re-treated	9.60	12.5
Recnazene full rate	9.30	10.0

Grand median = 9.60

APPENDIX 3: Field trial, Year 2

ANOVA

1. Flower count

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block	3	539.20	179.73	4.89	0.019
Treatment	4	560.30	140.07	3.81	0.032
Residual	12	441.30	36.78		

Standard errors of differences of means

Block	Treatment
3.84	4.29

CV% (12 df) 4.1

2. Stem length

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block	3	721.27	240.42	8.74	0.002
Treatment	4	598.94	149.73	5.44	0.010
Residual	12	330.56	27.55	2.80	

Standard errors of differences of means

Block	Treatment
0.286	0.319

CV% (12 df) 1.2

3. Bulb yield

Less than 8cm, bulb number

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block.Wplot stratum					
Block	3	118.80	39.60	0.53	0.667
Treat	4	262.80	65.70	0.89	0.501
Residual	12	889.20	74.10		

Standard errors of differences of means

Block	Treatment
5.44	6.09

CV% (12 df) 13.8

Appendix 3: Field trial, year 2 - continued

ANOVA

Less than 8cm, total bulb weight

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block.Wplot stratum					
Block	3	0.7208	0.02403	0.84	0.497
Treat	4	0.06035	0.01509	0.53	0.718
Residual	12	0.34297	0.02858		

Standard errors of differences of means

Block	Treatment
0.1069	0.1195

CV% (12 df) 13.2

8-10 cm, bulb number

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block.Wplot stratum					
Block	3	25.00	8.33	0.11	0.953
Treat	4	62.70	15.67	0.20	0.931
Residual	12	918.50	76.54		

Standard errors of differences of means

Block	Treatment
5.53	6.19

CV% (12 df) 24.1

8-10 cm, total bulb weight

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block.Wplot stratum					
Block	3	0.01704	0.00568	0.11	0.951
Treat	4	0.05893	0.01473	0.29	0.878
Residual	12	0.60831	0.05069		

Standard errors of differences of means

Block	Treatment
0.1424	0.1592

CV% (12 df) 20.7

Appendix 3: Field trial, Year 2 - continued

ANOVA

10-12 cm, bulb number

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block.Wplot stratum					
Block	3	127.40	42.47	1.00	0.427
Treat	4	241.00	60.25	1.42	0.287
Residual	12	510.60	42.55		

Standard errors of differences of means

Block	Treatment
4.13	4.61

CV% (12 df) 14.0

10-12 cm, total bulb weight

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block.Wplot stratum					
Block	3	0.30716	0.10239	1.40	0.290
Treat	4	0.35213	0.08803	1.21	0.358
Residual	12	0.87539	0.07295		

Standard errors of differences of means

Block	Treatment
0.1708	0.1910

CV% (12 df) 12.5

12-14 cm, bulb number

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block.Wplot stratum					
Block	3	34.80	11.60	0.37	0.776
Treat	4	194.70	48.67	1.55	0.249
Residual	12	375.70	31.31		

Standard errors of differences of means

Block	Treatment
3.54	3.96

CV% (12 df) 14.4

Appendix 3: Field trial, Year 2 - continued

ANOVA

12-14 cm, total bulb weight

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block.Wplot stratum					
Block	3	0.2547	0.0849	0.57	0.645
Treat	4	0.5355	0.1339	0.90	0.494
Residual	12	1.7863	0.1489		

Standard errors of differences of means

Block	Treatment
0.2440	0.2728

CV% (12 df) 15.1

14-16 cm, bulb number

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block.Wplot stratum					
Block	3	2.55	0.85	0.04	0.989
Treat	4	351.70	87.93	3.96	0.028
Residual	12	266.70	22.23		

Standard errors of differences of means

Block	Treatment
2.98	3.33

CV% (12 df) 14.7

14-16 cm, total bulb weight

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block.Wplot stratum					
Block	3	0.0068	0.0023	0.02	0.997
Treat	4	3.3141	0.8285	6.09	0.006
Residual	12	1.6322	0.1360		

Standard errors of differences of means

Block	Treatment
0.2333	0.2608

CV% (12 df) 13.6

Appendix 3: Field trial, Year 2 - continued

ANOVA

Greater than 16 cm, bulb number

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block.Wplot stratum					
Block	3	109.80	36.60	0.65	0.597
Treat	4	119.30	29.82	0.53	0.716
Residual	12	674.70	56.23		

Standard errors of differences of means

Block	Treatment
4.74	5.30

CV% (12 df) 31.4

Greater than 16 cm, total bulb weight

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block.Wplot stratum					
Block	3	2.7083	0.9028	0.97	0.440
Treat	4	1.6919	0.4230	0.45	0.769
Residual	12	11.2123	0.9344		

Standard errors of differences of means

Block	Treatment
0.611	0.684

CV% (12 df) 35.2

Appendix 3: Field trial, Year 2 - continued

ANOVA

Total bulb number

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block.Wplot stratum					
Block	3	260.5	86.8	0.79	0.522
Treat	4	1040.8	260.2	2.37	0.111
Residual	12	1319.2	109.9		

Standard errors of differences of means

Block	Treatment
6.63	7.41

CV% (12 df) 4.4

Total weight of bulbs

Source of Variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Block.Wplot stratum					
Block	3	3.5964	1.1988	2.66	0.096
Treat	4	3.9866	0.9966	2.21	0.129
Residual	12	5.4125	0.4510		

Standard errors of differences of means

Block	Treatment
0.425	0.475

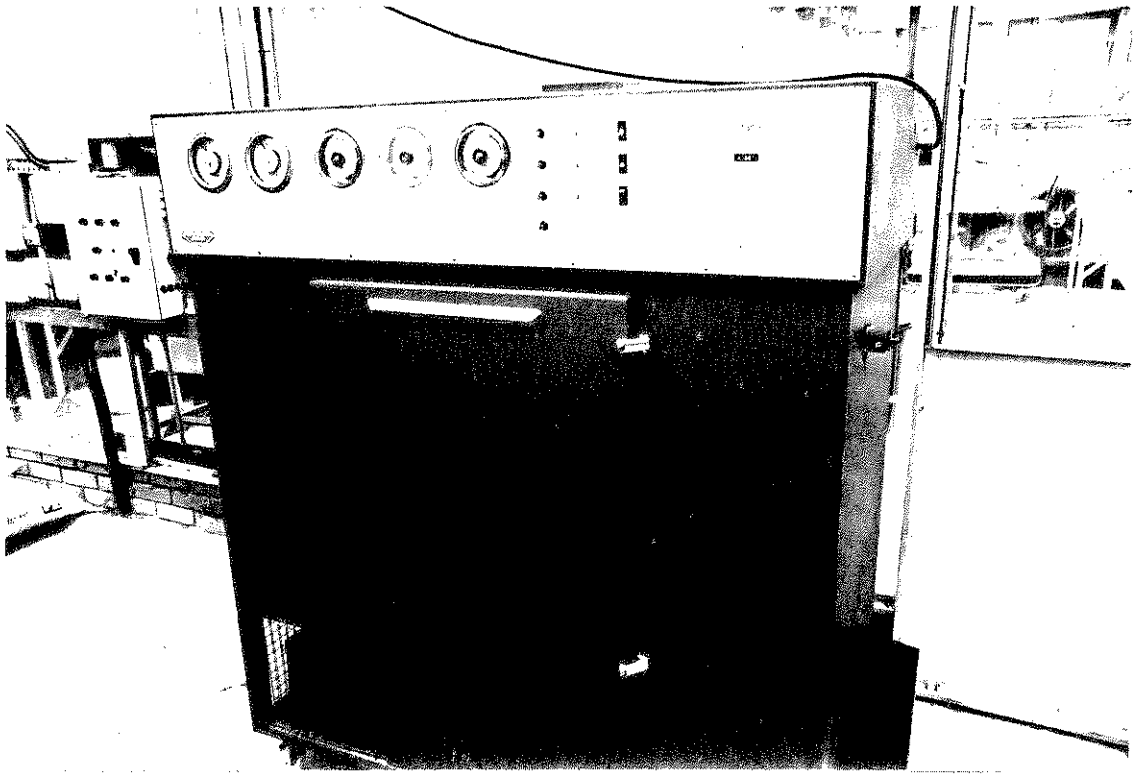
CV% (12 df) 5.4

APPENDIX 3: Field trial, year 2 - continued

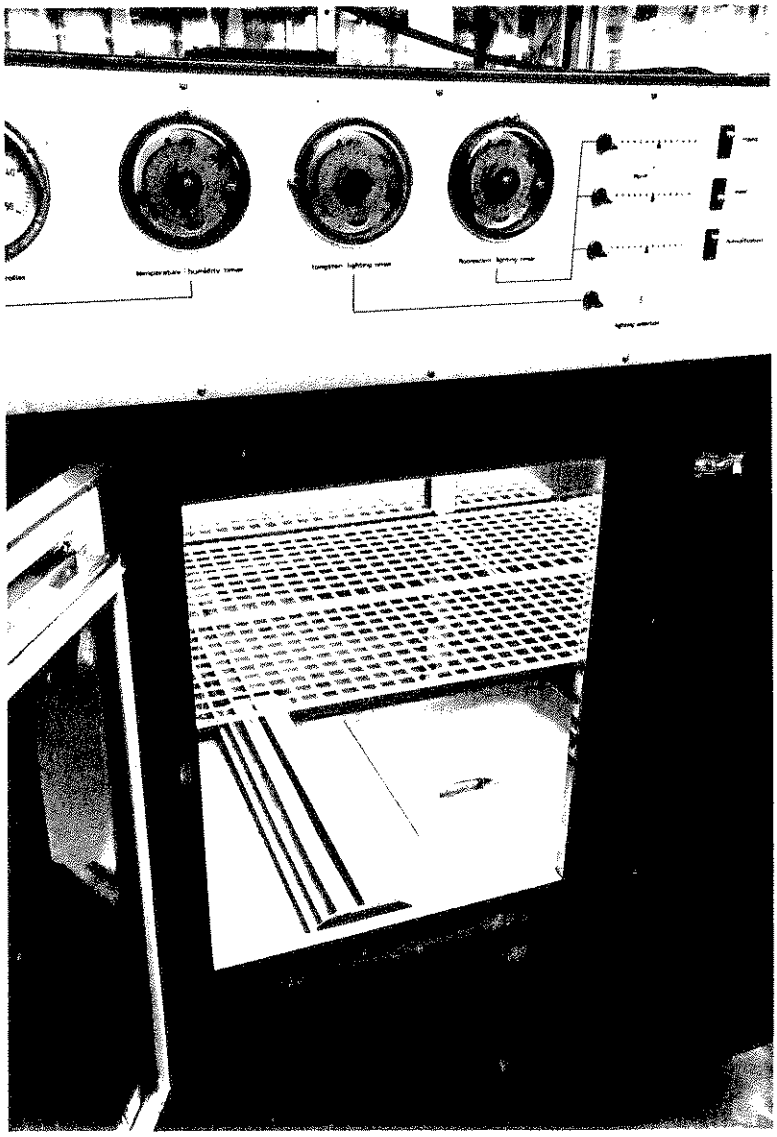
Dunnett's test

Variate / Treatment	Treatment mean	Control mean	Difference	Residual mean square error	Root mean square	Standard error	Dunnett's test statistic
Stem length							
CIPC 1/3 rate	38.482	37.901	0.581	27.547	5.249	3.711	9.328
CIPC full rate	37.547	37.901	-0.354				
Tecnazene re-treated	37.067	37.901	-0.834				
Tecnazene full rate	37.521	37.901	-0.380				
Flower number							
CIPC 1/3 rate	144.3	155.3	-11.0	36.78	6.065	4.288	10.778
CIPC full rate	154.5	155.3	-0.8				
Tecnazene re-treated	144.0	155.3	-11.3				
Tecnazene full rate	144.0	155.3	-11.3				
Bulb no., 14-16							
CIPC 1/3 rate	29.0	37.2	-8.2	22.23	4.715	3.334	8.379
CIPC full rate	36.2	37.2	-1.0				
Tecnazene re-treated	26.3	37.2	-10.9				
Tecnazene full rate	31.5	37.2	-5.7				
Bulb wt., 14-16							
CIPC 1/3 rate	2.425	3.265	-0.84	0.1360	0.369	0.261	0.655
CIPC full rate	3.050	3.265	-0.215				
Tecnazene re-treated	2.145	3.265	-1.120				
Tecnazene full rate	2.643	3.265	-0.622				

APPENDIX 4: PHOTOGRAPHS - FORCING TRIAL



Photograph 1: Fisons Fi-totron growth cabinet



Photograph 2: Growth cabinet showing interior

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