Project title:	Narcissus: the use of herbicides, singly and in combination, for the control of volunteer narcissus in winter wheat
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DISCLAIMER

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

AUTHENTICATION

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

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PRACTICAL SECTION FOR GROWERS

Commercial benefits of the project

The work in this project has identified two herbicides which significantly reduced emergence of narcissus volunteers in the year following treatment. However, none of the individual herbicide treatments gave complete control of volunteer narcissus.

Background and objectives

Existing bulb lifting equipment cannot achieve full recovery of narcissus bulbs at harvest, especially of those narcissus cultivars that produce small bulbs as these fall more easily through harvesting equipment. Residual bulb populations in the soil create both a weed problem in following crops (usually winter wheat), and act as a reservoir for stem nematode and large narcissus fly, the two most economically important bulb pests. The problem of pest carry-over is particularly important, as other cultural and chemical control strategies directed at these two pests within the two-year crop production cycle are not fully effective. The wet weather and waterlogged conditions of recent years have aided field spread of stem nematode enormously. Large narcissus fly is near its geographic limits in the UK, and one or two years in which early summer weather conditions are favourable could lead to dramatic increases in the pest population.

The competing demands for good quality agricultural land suitable for large-scale production of a wide range of agricultural and horticultural crops with similar soil requirements to narcissus, has also placed considerable rotational pressures on narcissus production.

The aim of this work was to identify herbicides, used either singly or in formulated mixtures, that effectively kill narcissus after they have flowered in winter wheat. Herbicide treatments also had to give effective control of narcissus within the growth stage range for the safe treatment of winter wheat with those herbicides.

Summary of results

Effects of herbicide treatments on volunteer narcissus in the first year of application

A range of herbicides were selected, all with label recommendations for use in cereals, and were applied at the recommended rate to a crop of winter wheat containing volunteer narcissus. The herbicides selected were Starane 2, Dow Shield, Ally Express, Harmony M, Lorate, Eagle and MSS Mircam Plus (see Table 1). The herbicide treatments were applied on 27 April 2000. This timing was based on the permitted growth stage (GS) range for the wheat crop, for each herbicide (average GS 31). The application of the herbicides occurred between one and seven weeks after narcissus full flower date, depending on cultivar. Hollywood and Ice Follies were at the flower die-back stage while Cheerfulness, a late flowering cultivar, was still in full flower at the time of herbicide application.

***Table 1*:** List of herbicide treatments applied on 27 April 2000 at growth stage 31 of the winter wheat crop

Treatment number	Product	Active ingredient	Rate of product
1	No narcissus volunteers, standard cereal herbicide programme	-	-
2	No herbicide application	-	-
3	Starane 2	fluroxypyr 200g/l	2l ha^{-1}
4	Dow Shield	clopyralid 200g/l	0.35l ha^{-1}
5	Ally Express	carfentrazone-ethyl+metsulfuron-methyl 40:10%w/w	50g ha^{-1}
6	Harmony M	metsulfuron-methyl+thifensulfuron-methyl 7:68 w/w	75g ha^{-1}
7	Lorate	metsulfuron-methyl 20%w/w	30g ha^{-1}
8	Eagle	amidosulfuron 75% w/w	40g ha^{-1}
9	MSS Mircam Plus	dicamba+MCPA+ mecoprop-P 19.5:245:43.3g/l	5l ha^{-1}

Note - Treatments 2 to 9 all contain narcissus volunteers

Phytotoxicity scores were used to measure the ability of the herbicides to control narcissus foliage/growth in the first growing season. Starane 2 had the most pronounced phytotoxic effects in all three cultivars, but particularly for cvs Hollywood and Cheerfulness. Ice Follies was less affected. The other herbicides all caused some phytotoxicity. Dow Shield tended to have the least effect.

Wheat yields were not affected by any of the herbicide treatments. This was to be expected given that each of the herbicides had a label recommendation for use in wheat, and it was applied at the correct growth stage for the crop and rate/ha.

Effects of herbicide treatments on volunteer narcissus in the year following herbicide application

In 2001, work concentrated on assessing the effect of herbicide treatments on the emergence of volunteer narcissus in the field in the year following herbicide treatment in the winter wheat crop.

Effect of herbicide treatment on cultivar growth

Growth was uniform throughout the emergence period.

Effect on herbicide treatment on narcissus emergence

Emergence of all three cultivars tested (Cheerfulness, Ice Follies and Hollywood) was significantly lower in plots treated with Harmony-M and Lorate compared with all other treatments. Treatment with Ally Express also significantly reduced the emergence of Cheerfulness.

Effect of the herbicides on flower development

The residual effect of all the sulfonyl urea herbicides (Lorate, Harmony M and Ally Express) except Eagle resulted in bulbs emerging which either produced no flowers (the commonest result) or which produced deformed flowers. None of the other herbicides (Starane 2, Dow Shield, MSS Mircam Plus) showed any residual effects on flower development.

Residual effect of herbicides on bulb number and weight

No statistically significant effect of herbicide treatment on the number or weight of treated bulbs was found, although there were strong indications that treatment with Lorate and Harmony M in particular, prevented or reduced bulb weight gain. Further work is required to confirm this finding.

Effect of herbicide treatment on internal damage to bulbs

None of the herbicide treatments significantly affected the proportion of bulbs showing internal damage.

Overall conclusions

- In the year of herbicide application (2000), Starane 2 caused statistically significant severe damage to Cheerfulness and Hollywood. Ice Follies showed no significant differences in damage from any of the herbicide treatments. Dow Shield caused the least amount of damage to all three cultivars.

- The yield of winter wheat was unaffected by any of the herbicide treatments.

- In the year following herbicide treatment (2001), the sulfonyl urea herbicides, particularly Harmony M and Lorate, significantly reduced the emergence of the narcissus bulbs from the wheat stubble. These herbicides also showed indications of preventing or disrupting narcissus flower development and of reducing the weight gain of bulbs one year after treatment. Further work is required to confirm these latter observations.

- None of the herbicides tested gave complete control of narcissus volunteers one year after their application to volunteers in a crop of winter wheat.

Action points for growers

- Paraquat remains the most effective herbicide for controlling volunteer narcissus, but can only be used if the land is left fallow until the following spring after lifting. With competing demands for good quality farm land, this may not be a practical option.

- For the control of volunteer narcissus in winter wheat crops, the sulfonyl urea herbicides Harmony M (75 g/ha) or Lorate (30 g/ha) should be applied post-flowering of narcissus and up to GS 39 of the winter wheat crop. Although these treatments do not effectively kill narcissus in the wheat crop, they do suppress the emergence of narcissus the following year. There is also some evidence that these herbicides interfere with the development of those bulbs and flowers that do emerge.

- Different narcissus cultivars are likely to have differing susceptibilities to herbicides and this will probably be influenced by the stage of development of the plant at herbicide application. In these trials, Hollywood and Ice Follies were at the flower die back stage when the herbicides were applied while Cheerfuless were still in full flower. Ally Express (carfentrazone-ethyl+metsulfuron-methyl), Lorate (metsulfuron-methyl) and Harmony M (metsulfuron-methyl+thifensulfuron-methyl) were equally effective in reducing emergence in Cheerfulness. However, only Lorate and Harmony M were effective in reducing emergence in Hollywood and Ice Follies.

Anticipated practical and financial benefits

In the UK the total saleable output of bulbs is estimated as approximately 30,000 tonnes/year. If 60% (18,000 tonnes) is entered for PHSI Plant Passporting/Export Certification, of which 2% fails due to stem nematode infestation, 360 tonnes would be rejected. Costed at a nominal price of £50/tonne as against a farm-gate price of £350/tonne for healthy stock, this represents a cost to the industry of £108,000 per year in lost sales. If the outcome of this project reduced this problem by only 25%, then the annual saving to the industry would be £27,000. In addition, this work will also assist in greater flexibility in land use with the removal of volunteer narcissus within the field rotation.

SCIENCE SECTION

Introduction

Existing bulb lifting equipment cannot achieve full recovery of narcissus bulbs at harvest, especially of those narcissus cultivars that produce small bulbs as these fall more easily through harvesting equipment. Residual bulb populations in the soil create both a weed problem in following crops (usually winter wheat), and act as a reservoir for stem nematode (*Ditylenchus dipsaci*) and large narcissus fly (*Merodon equestris*), the two most economically important bulb pests. The problem of pest carry-over is particularly important, as other cultural and chemical control strategies directed at these two pests within the two-year crop production cycle are not fully effective. The wet weather and waterlogged conditions of recent years have aided field spread of stem nematode enormously. This has implications for bulb exports as all export consignments have to be verified free of stem nematode infestation by the Plant Health & Seeds Inspectorate (PHSI). Large narcissus fly is near its geographic limits in the UK, and one or two years in which early summer weather conditions are favourable could lead to dramatic increases in the pest population.

Research at Kirton Experimental Horticulture Station in 1978-79 compared the effectiveness of four chemical rogueing agents applied immediately post-flowering. Of these, paraquat and to a lesser extent glyphosate gave some control of narcissus, but neither were fully effective (Miller, 1978). As both paraquat and glyphosate are non-selective, contact herbicides, they can only be used if the land is left fallow until late spring of the year following lifting of narcissus. As there are competing demands for good quality agricultural land suitable for large-scale production of a wide range of agricultural and horticultural crops, leaving land fallow for long periods is not a practical or cost-effective option. There is therefore a need to identify herbicides that can be used in crops following narcissus to control any volunteers that emerge the following spring.

The aim of this work was to identify herbicides, used either singly or in formulated mixtures, that effectively kill narcissus after they have flowered in winter wheat, a crop commonly grown following narcissus production. Herbicide treatments therefore

had to give effective control of narcissus within the growth stage range for the safe treatment of winter wheat with those herbicides.

In the first year of this project, bulbs of three cultivars (Cheerfulness, Ice Follies and Hollywood) were planted (October 1999) into plots subsequently sown with winter wheat (November 1999). A range of herbicides were then applied post-flowering of the emerged narcissus the following spring (2000). Of the five herbicides tested, only Starane 2 (fluroxypyr) caused significant damage incuding twisting and yellowing of two of the cultivars (Hollywood and Ice Follies). The sulfonyl-urea herbicides Ally Express (carfentrazone-ethyl+metsulfuron-methyl), Harmony M (metsulfuron-methyl+thifensulfuron-methyl), Lorate (metsuluron-methyl) and Eagle (amidosulfuron) had caused no phytotoxic symptoms in 2000. Dow Shield (clopyralid) did not cause any significant damage. Assessments of winter wheat plant populations and yield indicated that these treatments did not adversely affect the growth of the wheat crop.

The specific objective of the work done in 2001 reported here was to assess the residual effects of the herbicide treatments applied in 2000 on the emergence, flower development and weight of the narcissus bulbs.

Materials and methods

Experiment location

The experiment was done at ADAS Arthur Rickwood on a peaty soil with 25% organic matter content. The site had not been treated with sulfonyl-urea herbicides in the previous 12 months prior to planting.

Herbicide treatments

The herbicide treatments applied in 2000 are given in Table 1. Herbicides were all applied once on 27 April 2000 post-flowering of the narcissus when the wheat was at growth stage 31 in accordance with the label recommendations. At this time, Hollywood and Ice Follies were at the flower dieback stage, but Cheerfulness was still in flower.

***Table 1*:** List of treatments applied on 27 April 2000 at growth stage 31 of the winter wheat crop

Treatment number	Product	Active ingredient	Rate of product
1	No narcissus volunteers, standard cereal herbicide programme	-	-
2	No herbicide application	-	-
3	Starane 2	fluroxypyr 200g/l	2l ha^{-1}
4	Dow Shield	clopyralid 200g/l	0.35l ha^{-1}
5	Ally Express	carfentrazone-ethyl+metsulfuron-methyl 40:10%w/w	50g ha^{-1}
6	Harmony M	metsulfuron-methyl+thifensulfuron-methyl 7:68 w/w	75g ha^{-1}
7	Lorate	metsulfuron-methyl 20%w/w	30g ha^{-1}
8	Eagle	amidosulfuron 75% w/w	40g ha^{-1}
9	MSS Mircam Plus	dicamba+MCPA+ mecoprop-P 19.5:245:43.3g/l	5l ha^{-1}

Note - Treatments 2 to 9 all contain narcissus volunteers

Narcissus cultivars

The narcissus cultivars chosen for the experiment were Hollywood, Ice Follies and Cheerfulness, and represented early, middle and late flowering cultivars, respectively.

Experiment design

The experiment was laid out as a randomised block split-plot design with four replicates. Each plot measured 2 m by 10 m. The main plots were the narcissus cultivars, and the split-plots were the herbicides. The three cultivars were planted in ridges (October 1999) in separate rows, at two different depths (25 cm and 10 cm), at a rate of 2.0 tonne per ha. The grade used was 8-10 cm bulbs. This was done to simulate a volunteer population in the wheat. The herbicide treatments (Table 1) were applied on 27 April 2000. At this time, Hollywood and Ice Follies were at the flower dieback stage but Cheerfulness was still in flower. The wheat crop was sown in November 1999 and then harvested on 23 August 2000. The experimental area was left as stubble for the second year of the experiment.

Assessments

1. Emergence counts of narcissus were done on three occasions during February and March 2001 by counting all emerged plants in each plot.

2. Narcissus growth assessments were done on six occasions between 20 February and 26 March 2001, by measuring the height in cm of 10 plants for each cultivar.

3. Phytotoxicity assessments were made during flowering in spring 2001. Each emerged plant in untreated and herbicide-treated plots was assessed for presence or absence of a flower stem, number of petals, 'ballooning' of the flower and flower deformity.

4. Bulbs from each treatment were lifted, weighed and counted post-flowering.

5. After lifting, the bulbs were stored for 5 weeks prior to the final phytotoxicity

assessments. Each bulb was cut open to enable assessment of any internal damage to be made. Where damage was evident, it was classed as slight, moderate or severe.

6. The number of bulbs with fork damage was also recorded to determine how much damage was sustained at lifting.

Data analysis

The data were analysed using analysis of variance (ANOVA). Treatment 1 (no narcissus volunteers, standard cereal herbicide programme) has been omitted from all data analysis for the current year's results to enable a valid analysis without data transformation. Where the ANOVA resulted in a significant F-test, Duncan's Multiple Range Test was used to assess pair-wise differences between treatments. In this test, treatment means are calculated for each treatment and these are ordered in ascending order together with their standard error. Duncan's test then systematically makes a pair-wise comparison of these ordered means and places treatments in the same (assigned the same suffix letter) or a different group depending on whether the treatment pair is judged to be statistically significantly different or otherwise. This test can be regarded as a 'batting order' for treatment effects but a real assessment of any two treatments can only properly be assessed using a trial designed for this purpose.

Percentage data has been included in Tables 5 to 7 and 9 to 11 to allow the reader to better understand the findings. It should be noted that the percentage data has not been subjected to statistical analysis.

Results

Emergence and lifting dates

Emergence began in early February 2001. All cultivars had emerged by late February. Ice Follies and Hollywood began to flower in late March and were at full-flower on 2 April 2001. Cheerfulness began flowering in mid April, and was at full-flower on 30 April 2001.

All cultivars were lifted on 21 June 2001.

Effect of herbicide treatment on emergence

Significantly fewer narcissus bulbs of Hollywood and Ice Follies emerged in plots treated in 2000 with Harmony-M and Lorate compared with other treatments (Tables 2 and 3). The emergence of Cheerfulness bulbs was significantly reduced by Harmony M, Lorate and Ally Express (Table 4).

Effect of herbicide treatment on cultivar growth

Growth was measured from emergence (20 February) until flowering of Hollywood commenced (26 March). Growth was uniform throughout the emergence period (Figure 1).

Effect of the herbicides on flower development

Assessments for residual phytotoxic effect of herbicide treatment on emerged plants were made on 5 April 2001 for Hollywood and Ice Follies, and on 30 April 2001 for Cheerfulness. The results are given in Tables 5 (Hollywood), 6 (Ice Follies) and 7 (Cheerfulness). In all cases, the number of plants with either no flower stem or with deformed flowers was significantly reduced by Harmony M and Lorate and to a lesser extent by Ally Express for Cheerfulness (Table 7). However, this difference in the number of plants with no flower stem or with deformed flowers, can largely be

accounted for by the poor emergence caused by these treatments.

Examination of the percentage data does, however, suggest that a high proportion of plants that emerged in the Lorate, Harmony M and Ally Express treatments also produced no flower stem or deformed flowers. This effect was particularly marked for Hollywood and Ice Follies, neither of which produced any undeformed flowers when treated with Lorate or Harmony M, but less so for Cheerfulness. Only a very low proportion of bulbs across all treatments produced a flower stem but no flower, or showed evidence of 'ballooning' flowers.

Effect of the herbicides on narcissus bulb yield

No significant effect of herbicide treatment on the weight or number of harvested bulbs was found (Table 8). However, there was some evidence that weight of bulbs treated with Harmony M and Lorate had not increased (and in some cases had decreased) over the life of the experiment. This effect was particularly marked in cv. Hollywood.

Internal damage at lifting.

In general, the number and proportions of bulbs showing internal damage were low making statistical analysis of the data impractical. The proportion of healthy bulbs recovered was not significantly reduced by any herbicide treatment in any of the cultivars (Tables 9 to 11). However, both Hollywood and Ice Follies had a moderate proportion (25-40%) of slightly damaged bulbs in Lorate and Harmony M treated plots. This may partially explain the relatively poor emergence shown by bulbs receiving this treatment.

Figure 1. Growth of narcissus cultivars during emergence in 2001.

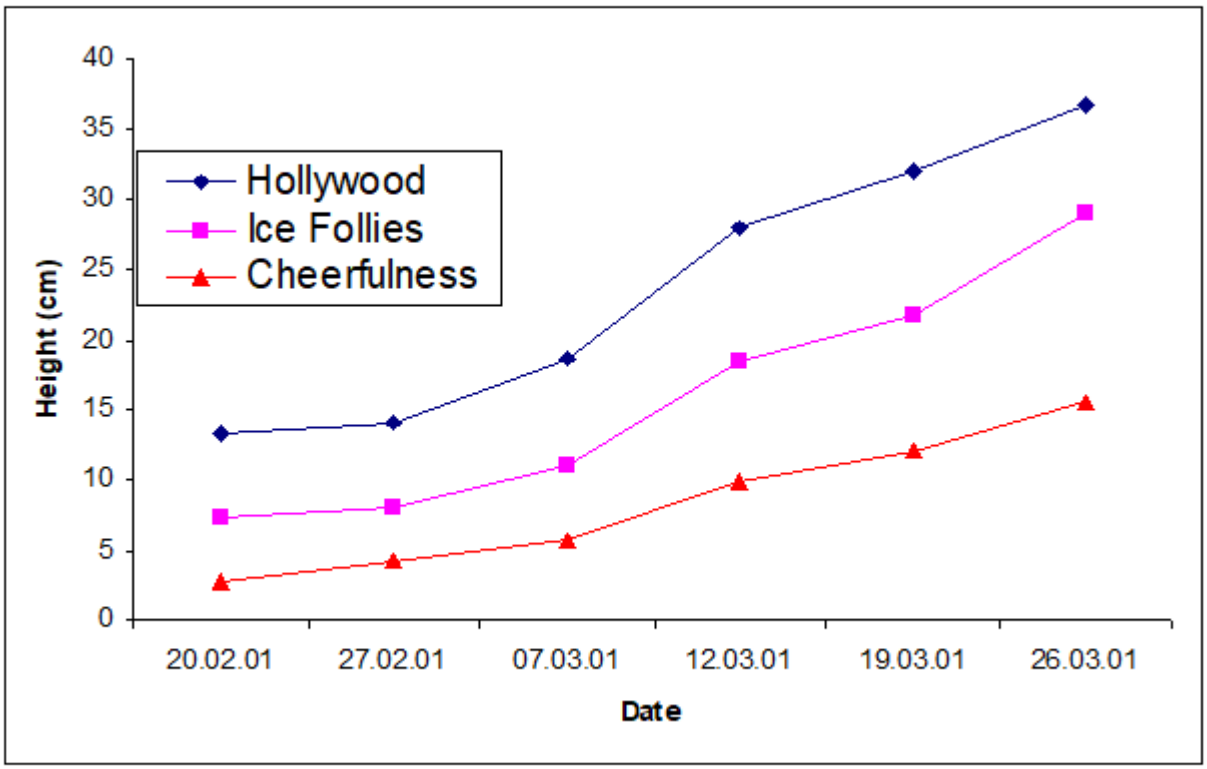

Table 2. Mean number of emerged shoots per plot on sequential dates for cv. Hollywood (Duncan's Multiple Range Test suffixes are in parenthesis. Values within the same column followed by a common letter do not differ significantly at *P*=<0.05).

Treatment	5 Feb 2001	20 Feb 2001	19 March 20001
No herbicide application	72.5	109.2 (d)	109.2 (d)
Starane 2 at 2l ha^{-1}	74.2	109.5 (d)	109.5 (d)
Dow Shield at 0.35l ha^{-1}	76.5	111.5 (d)	111.5 (d)
Ally Express at 50g ha^{-1}	17.8	27.5 (b)	28.3 (b)
Harmony-M at 75g ha^{-1}	0.0	0.2 (a)	0.2 (a)
Lorate at 30g ha^{-1}	0.5	1.0 (a)	1.8 (a)
Eagle at 40g ha^{-1}	79.0	106.7 (d)	107.0 (d)
MSS Mircam Plus at 5l ha^{-1}	32.5	67.2 (c)	67.2 (c)
SED (62df)	-	4.99	5.99
P-value (for treatments)	skewed data	<0.001	<0.001

***Table 3*.** Mean number of emerged shoots per plot on sequential dates for cv. Ice Follies (Duncan's Multiple Range Test suffixes are in parenthesis. Values within the same column followed by a common letter do not differ significantly at *P*=<0.05).

Treatment	5 Feb 2001	20 Feb 2001	19 March 20001
No herbicide application	25.8	103.2 (d)	108.0 (e)
Starane 2 at 2l ha^{-1}	19.0	98.5 (d)	101.2 (e)
Dow Shield at 0.35l ha^{-1}	24.8	99.7 (d)	97.0 (de)
Ally Express at 50g ha^{-1}	8.8	42.2 (b)	45.7 (b)
Harmony-M at 75g ha^{-1}	0.0	0.0 (a)	4.0 (a)
Lorate at 30g ha^{-1}	0.0	0.0 (a)	2.0 (a)
Eagle at 40g ha^{-1}	15.8	83.2 (c)	85.2 (cd)
MSS Mircam Plus at 5l ha^{-1}	7.5	39.7 (b)	77.5 (c)
SED (62df)	-	4.99	5.99
P-value (for treatments)	skewed data	<0.001	<0.001

Table 4. Mean number of emerged shoots per plot on sequential dates for cv. Cheerfulness (Duncan's Multiple Range Test suffixes are in parenthesis. Values within the same column followed by a common letter do not differ significantly at *P*=<0.05).

Treatment	5 Feb 2001	20 Feb 2001	19 March 20001
No herbicide application	2.2	20.8 (b)	75.5 (d)
Starane 2 at 2l ha^{-1}	4.2	31.0 (b)	72.0 (d)
Dow Shield at 0.35l ha^{-1}	1.3	24.8 (b)	81.7 (d)
Ally Express at 50g ha^{-1}	2.0	4.8 (a)	15.5 (b)
Harmony-M at 75g ha^{-1}	0.0	0.5 (a)	3.7 (ab)
Lorate at 30g ha^{-1}	0.0	1.0 (a)	1.8 (a)
Eagle at 40g ha^{-1}	6.0	23.0 (b)	76.7 (d)
MSS Mircam Plus at 5l ha^{-1}	3.7	22.0 (b)	52.7 (c)
SED (62df)	-	4.99	5.99
P-value (for treatments)	skewed data	<0.001	<0.001

Table 5. Effect of herbicide treatment on flower development in narcissus, cv. Hollywood (mean number of bulbs showing the symptoms indicated in the column headings are given; percentage data are given in parenthesis, ns = not significant).

Treatment	Flower stem, but no flower	No flower stem	Deformed	Balloon	Undamaged flowers
No herbicide application	2.0 (1.7)	48.7 (43.6)	0.5 (0.5)	0.0 (0.0)	60.5 (54.1)
Starane 2 at 2l ha^{-1}	3.0 (2.7)	55.5 (49.3)	0.0 (0.0)	0.0 (0.0)	54.0 (48.0)
Dow Shield at 0.35l ha^{-1}	3.0 (2.6)	49.0 (43.2)	0.3 (0.3)	0.0 (0.0)	61.2 (53.9)
Ally Express at 50g ha^{-1}	1.0 (3.4)	14.5 (49.5)	0.5 (1.7)	0.3 (1.0)	13.0 (44.4)
Harmony-M at 75g ha^{-1}	0.0 (0.0)	0.8 (100.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Lorate at 30g ha^{-1}	0.0 (0.0)	2.0 (100.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Eagle at 40g ha^{-1}	2.0 (1.8)	52.2 (49.5)	4.3 (3.9)	0.3 (0.3)	53.0 (52.6)
MSS Mircam Plus at 5l ha^{-1}	3.0 (3.8)	31.8 (40.6)	2.3 (2.9)	0.3 (0.4)	41.0 (47.7)
SED (62 df)	-	7.38	1.30	-	10.14
P-value	Skewed	<0.05	<0.05	Skewed	ns

Table 6. Effect of herbicide treatment on flower development in narcissus, cv. Ice Follies (mean number of bulbs showing the symptoms indicated in the column

headings are given; percentage data are given in parenthesis, ns = not significant).

Treatment	Flower stem, but no flower	No flower stem	Deformed	Balloon	Undamaged flowers
No herbicide application	1.0 (0.8)	44.2 (37.0)	1.3 (1.1)	0.0 (0.0)	73.0 (61.1)
Starane 2 at 2l ha^{-1}	1.7 (1.5)	48.0 (41.5)	0.8 (0.7)	0.0 (0.0)	65.2 (56.4)
Dow Shield at 0.35l ha^{-1}	2.2 (1.9)	46.5 (40.4)	0.3 (0.3)	0.0 (0.0)	66.2 (42.5)
Ally Express at 50g ha^{-1}	3.2 (6.0)	19.0 (35.8)	0.3 (0.6)	0.3 (0.6)	30.3 (42.9)
Harmony-M at 75g ha^{-1}	1.0 (11.8)	5.0 (58.8)	2.5 (29.4)	0.0 (0.0)	0.0 (0.0)
Lorate at 30g ha^{-1}	0.7 (21.9)	2.5 (78.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Eagle at 40g ha^{-1}	0.5 (0.5)	38.2 (36.1)	8.8 (8.3)	0.0 (0.0)	58.2 (44.9)
MSS Mircam Plus at 5l ha^{-1}	3.8 (3.6)	32.5 (30.6)	1.6 (1.5)	1.3 (1.2)	67.5 (36.4)
SED (62df)	-	7.38	1.302	-	10.14
P-value	skewed	<0.05	<0.05	Skewed	ns

Table 7. Effect of herbicide treatment on flower development in narcissus, cv. Cheefulness (mean number of bulbs showing the symptoms indicated in the column headings are given; percentage data are given in parenthesis, ns = not significant).

Treatment	Flower stem, but no flower	No flower stem	Deformed	Balloon	Undamaged flowers
No herbicide application	0.0 (0.0)	19.8 (22.5)	1.5 (1.7)	1.3 (1.5)	65.2 (74.3)
Starane 2 at 2l ha^{-1}	1.5 (1.5)	29.5 (30.3)	3.0 (3.1)	0.3 (0.3)	63.0 (64.7)
Dow Shield at 0.35l ha^{-1}	0.3 (0.3)	22.3 (22.9)	2.0 (2.1)	1.5 (1.5)	71.0 (73.1)
Ally Express at 50g ha^{-1}	4.0 (11.6)	14.8 (42.7)	0.8 (2.3)	0.5 (1.5)	14.5 (41.9)
Harmony-M at 75g ha^{-1}	0.8 (8.0)	6.0 (60.0)	0.0 (0.0)	0.0 (0.0)	3.2 (32.0)
Lorate at 30g ha^{-1}	0.5 (8.3)	3.7 (61.7)	0.0 (0.0)	0.0 (0.0)	1.8 (30.0)
Eagle at 40g ha^{-1}	0.5 (0.5)	22.0 (23.9)	2.0 (2.2)	1.0 (1.1)	66.5 (72.3)
MSS Mircam Plus at 5l ha^{-1}	0.5 (0.8)	13.5 (21.2)	1.8 (2.8)	0.3 (0.5)	47.5 (74.7)
SED (62df)	-	7.38	1.302	-	10.14
P-value	skewed	<0.05	<0.05	Skewed	ns

Table 8. Mean weight (kg) and number of bulbs recovered at harvest in June 2001 (ns = not significant). Figures in parenthesis are the increase or decrease (%) in yield from the average planted weights.

Treatment	Hollywood		Ice Follies		Cheerfulness	
	Weight (kg %)	Number	Weight (kg %)	Number	Weight (kg %)	Number
No herbicide application	3.66 (+161)	51.0	6.32 (+351)	62.2	3.83 (+173)	73.7
Starane 2 at 2l ha^{-1}	4.30 (+207)	54.7	6.44 (+360)	63.8	4.30 (+207)	82.5
Dow Shield at 0.35l ha^{-1}	4.30 (+207)	52.5	6.37 (+355)	60.8	4.27 (+205)	81.0
Ally Express at 50g ha^{-1}	1.72 (+22)	31.3	3.25 (+132)	43.2	1.47 (+5)	46.5
Harmony-M at 75g ha^{-1}	1.11 (-21)	26.8	1.29 (-8)	33.5	2.46 (+75)	41.2
Lorate at 30g ha^{-1}	1.13 (-19)	28.8	1.57 (+12)	36.7	2.19 (+56)	42.0
Eagle at 40g ha^{-1}	4.09 (+192)	51.5	5.12 (+265)	57.0	4.05 (+189)	79.2
MSS Mircam Plus at 5l ha^{-1}	2.02 (+44)	44.0	3.34 (+138)	54.5	2.69 (+92)	52.7
SED (62 df)	1.016	10.05	1.016	10.05	1.016	10.05
P-value	ns	ns	ns	ns	ns	ns

Table 9. Effect of herbicide treatment on the mean number of damaged cv. Hollywood bulbs (percentage data in parenthesis, ns = not significant).

Treatment	Rots	Slight	Moderate	Severe	Fork	Total damaged	Healthy
No herbicide application	2.0 (3.9)	1.5 (2.9)	0.3 (0.6)	1.5 (2.9)	3.8 (7.4)	9.0 (17.8)	42.0 (82.2)
Starane 2 at 2l ha^{-1}	3.0 (5.5)	2.8 (5.1)	1.5 (2.7)	0.8 (1.5)	3.5 (6.4)	11.5 (21.2)	43.2 (78.8)
Dow Shield at 0.35l ha^{-1}	1.8 (3.4)	1.5 (2.9)	1.5 (2.9)	0.3 (0.6)	4.8 (9.1)	9.8 (18.8)	42.7 (81.2)
Ally Express at 50g ha^{-1}	1.8 (5.8)	5.0 (16.0)	1.5 (4.8)	0.0 (0.0)	2.0 (6.4)	10.3 (32.9)	21.0 (67.1)
Harmony-M at 75g ha^{-1}	2.0 (7.4)	6.8 (25.3)	2.3 (8.6)	0.5 (1.9)	0.5 (1.9)	12.0 (45.0)	14.8 (55.0)
Lorate at 30g ha^{-1}	3.5 (12.1)	8.3 (28.7)	3.0 (10.4)	0.5 (1.7)	0.3 (1.0)	15.5 (54.0)	13.3 (46.0)
Eagle at 40g ha^{-1}	2.3 (4.5)	2.2 (4.3)	0.8 (1.6)	0.3 (0.6)	3.5 (6.8)	9.0 (17.6)	42.5 (82.4)
MSS Mircam Plus at 5l ha^{-1}	1.8 (4.1)	0.5 (1.1)	1.3 (2.9)	0.3 (0.7)	1.0 (2.3)	4.8 (11.1)	39.2 (88.9)
SED (62df)	1.433	-	1.117	-	-	3.927	9.25
P-value	ns	skewed	ns	skewed	skewed	<0.05	ns

Table 10. Effect of herbicide treatment on the mean number of damaged cv. Ice Follies bulbs (percentage data in parenthesis, ns = not significant).

Treatment	Rots	Slight	Moderate	Severe	Fork	Total damaged	Healthy
No herbicide application	2.0 (3.2)	5.0 (8.0)	3.0 (4.8)	0.3 (0.5)	3.5 (5.6)	13.8 (22.2)	48.5 (77.8)
Starane 2 at 2l ha^{-1}	1.8 (2.8)	1.8 (2.8)	0.5 (0.8)	0.0 (0.0)	3.8 (6.0)	7.8 (12.2)	56.0 (87.8)
Dow Shield at 0.35l ha^{-1}	1.5 (2.5)	1.0 (1.6)	2.8 (4.6)	0.0 (0.0)	2.0 (3.3)	7.2 (11.9)	53.5 (88.1)
Ally Express at 50g ha^{-1}	2.5 (5.8)	3.8 (8.8)	0.8 (1.9)	0.3 (0.7)	3.3 (7.6)	10.5 (24.3)	32.7 (75.7)
Harmony-M at 75g ha^{-1}	2.8 (8.4)	9.8 (29.3)	2.0 (6.0)	0.5 (1.5)	0.5 (1.5)	15.5 (46.3)	18.0 (53.7)
Lorate at 30g ha^{-1}	2.5 (6.8)	14.8 (40.2)	0.3 (0.8)	0.3 (0.8)	1.3 (3.5)	22.0 (59.8)	14.8 (40.2)
Eagle at 40g ha^{-1}	3.3 (5.8)	4.8 (8.4)	1.8 (3.2)	0.3 (0.5)	2.3 (4.0)	12.3 (21.6)	44.7 (78.4)
MSS Mircam Plus at 5l ha^{-1}	1.5 (2.8)	4.3 (7.9)	1.8 (3.3)	0.5 (0.9)	2.5 (4.6)	10.5 (19.3)	44.0 (80.7)
SED (62 df)	1.433	-	1.117	-	-	3.927	9.25
P-value	ns	skewed	ns	skewed	skewed	<0.05	ns

Table 11. Effect of herbicide treatment on the mean number of damaged cv. Cheefulness bulbs (percentage data in parenthesis, ns = not significant).

Treatment	Rots	Slight	Moderate	Severe	Fork	Total damaged	Healthy
No herbicide application	3.8 (5.2)	1.0 (1.4)	1.8 (2.4)	1.0 (1.4)	3.5 (4.7)	11.0 (14.9)	62.7 (85.1)
Starane 2 at 2l ha^{-1}	3.0 (3.6)	2.0 (2.4)	1.8 (2.2)	1.3 (1.6)	3.0 (3.6)	11.0 (13.3)	71.5 (86.7)
Dow Shield at 0.35l ha^{-1}	4.3 (5.3)	0.8 (1.0)	1.3 (1.6)	2.3 (2.8)	4.3 (5.3)	12.8 (15.8)	68.2 (84.2)
Ally Express at 50g ha^{-1}	2.5 (5.4)	0.0 (0.0)	0.3 (0.6)	0.0 (0.0)	3.0 (6.5)	5.8 (12.5)	40.7 (87.5)
Harmony-M at 75g ha^{-1}	2.3 (5.6)	1.0 (2.4)	0.5 (1.2)	0.3 (0.7)	2.8 (6.8)	6.8 (16.5)	34.5 (83.5)
Lorate at 30g ha^{-1}	1.5 (3.6)	2.0 (4.8)	0.5 (1.2)	0.0 (0.0)	1.3 (3.1)	5.2 (12.4)	36.7 (87.6)
Eagle at 40g ha^{-1}	2.5 (3.2)	3.3 (4.2)	1.8 (2.3)	3.0 (3.8)	3.5 (4.4)	14.0 (17.7)	65.2 (82.3)
MSS Mircam Plus at 5l ha^{-1}	2.8 (5.3)	2.5 (4.7)	1.0 (1.9)	1.3 (2.5)	1.8 (3.4)	9.3 (17.6)	43.5 (82.4)
SED (62df)	1.433	-	1.117	-	-	3.927	9.25
P-value	ns	skewed	ns	skewed	skewed	<0.05	ns

Discussion

The results clearly demonstrate that sulfonyl-urea herbicides, particularly Lorate (a contact and residual material) and Harmony M (a contact, residual and translocated material), suppressed the emergence of narcissus bulbs treated with these herbicides in the previous year. Of the plants that did emerge following these treatments, most produced no flowers, while a few plants produced a flower stem with no flowers, or deformed flowers. There is also evidence that these treatments reduced or eliminated bulb weight gain, but further work is required to substantiate this.

There was some evidence that different cultivars may vary in their susceptibility to different sulfonyl urea herbicides. This variation could be attributed to the different stages of growth and flower development of the narcissus plants at the time of application of the herbicides. Hollywood and Ice Follies represent early and mid-season flowering cultivars and were in the flower dieback stage when the herbicides were applied. However, Cheerfulness flowers later in the season and in this experiment was in full flower when the herbicides were applied.

Ally Express (carfentrazone-ethyl+metsulfuron-methyl), Lorate (metsulfuron-methyl) and Harmony M (metsulfuron-methyl+thifensulfuron-methyl) were equally effective in reducing emergence in Cheerfulness. However, only Lorate and Harmony M was effective in reducing emergence in Hollywood and Ice Follies.

Cheerfulness seemed to be less susceptible to residual sulfonyl urea herbicide phytotoxic effects on flower development, than either Hollywood or Ice Follies. Again, this effect may be due to the stage of development of the plants at treatment. Eagle (amidosulfuron) did not significantly affect any of the cultivars.

The other herbicide tested, Starane 2 (fluroxypyr) caused significant levels of foliage distortion when applied to narcissus growing in the wheat crop in 2000, but this had no residual affect on the viability of the bulbs which emerged in 2001. Dow Shield and MSS Mircam Plus did not show any significant residual effects on narcissus bulb emergence or flower development.

Overall conclusions

Effects within the year of herbicide application (2000)

- Starane 2 caused statistically significant severe damage to Hollywood and Cheerfulness.
- Ice Follies showed no significant differences in damage from any of the herbicide treatments.
- Dow Shield caused the least amount of damage to all three cultivars.
- The wheat yield was unaffected by any of the herbicide treatments.

Effects one year after herbicide application (2001)

- Sulfonyl urea herbicides, particularly Harmony M and Lorate, significantly reduced the emergence of the narcissus bulbs from the wheat stubble.
- Sulfonyl urea herbicides, particularly Harmony M and Lorate, showed indications of preventing or disrupting narcissus flower development.
- Sulfonyl urea herbicides, particularly Harmony M and Lorate, showed indications of reducing the weight gain of bulbs one year after treatment. Further work is required to confirm this observation.

None of the herbicides tested gave complete control of narcissus volunteers, and as little work has been done in this area, there is scope for further studies to confirm and refine these findings, possibly testing of a wider range of cereal herbicides.

TECHNOLOGY TRANSFER

The project was outlined at the HDC Narcissus Seminar, Springfields Restaurant, Spalding Lincs on the 21st November 2000.

Presentation at the HDC Narcissus Seminar, Cornwall on 15 November 2001.

Presentation at the ADAS National Bulb Consultancy Centre meeting on 21 March 2002.

HDC News feature article, June 2001.

Planned Grower's Walks for 2001 were cancelled due to the Foot & Mouth Disease outbreak.

REFERENCE

Miller, R M (1978). Narcissus and tulip, chemical roguing: Effectiveness of several chemical bulb roguing agents. *ADAS Results of Experiments at the Experimental Horticulture Stations. Bulbs and Allied Flower Crops* 1978 pp 28-29.