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Narcissus: Seeking replacements for 'Fortrol' (cyanazine) and sulphuric acid

Cathy Knott,[1] Pippa Hughes[2] and Gordon R Hanks[2]
[1]Herbicide Consultant and [2]Warwick HRI, University of Warwick

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Project leaders

Gordon R Hanks
Warwick HRI
The Kirton Research Centre
University of Warwick
Kirton
Boston
Lincolnshire PE20 1NN

Tel: 01205 725139 (direct)
Fax: 01205 724957
Email:
Gordon.Hanks@warwick.ac.uk

Cathy Knott
55 Church Street
Werrington
Peterborough
Cambridgeshire
PE4 6QU

Tel: 01733 575001
Fax: 01733 328793
Email:
cathy.knott@btinternet.com

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Key workers:	Gordon R Hanks BSc, MPhil, FIHort, MIBiol, CBiol – Joint Project Leader Cathy Knott BSc - Joint Project Leader Pippa Hughes BSc
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GROWER SUMMARY

Headlines

- Several herbicides and a potential new desiccant were evaluated in a two-year-down crop of narcissus cv. Carlton. The herbicide Boxer (florasulam) was safe and effective at three different growth stages when applied alone or in a tank mix with Stomp or Goltix (applied when leaves were 7-10cm long) or in with Flexidor + Butisan (applied post-flowering).

- Spotlight Plus (a new formulation of carfentrazone-ethyl 60g/L ME), applied 2 weeks before lifting in the second year of the crop, desiccated narcissus leaves, killed broad-leaved weeds including willowherb, and had some herbicidal effect on creeping thistle, but had no effect on grasses. It is therefore a possible replacement for sulphuric acid for the pre-harvest desiccation (defoliation) of narcissus.

- These herbicide and desiccant treatments had no significant adverse side-effects, such as reduced vase-life of field-cropped flowers, reduced bulb yields or reduced performance of bulbs when subsequently forced in a glasshouse, and there were no defects when the bulbs were grown-on in the field for a further year.

Background and expected deliverables

Cyanazine is widely used in narcissus crops but was not supported in the EC Pesticide Review, though there is a derogation for 'Essential Use' on the crop until the end of 2007. As with other minor crops there are very few herbicide recommendations for flower-bulbs, since agrochemical companies do not consider the relatively small economic value of such crops sufficient to justify the high cost of the development and approval process. As a consequence, growers rely heavily on off-label usage, and herbicide applications are often made on the basis of *ad hoc* trials or anecdotal evidence. The aim of this project was to:

- Determine whether Boxer is safe to use on narcissus, and if it could substitute for Fortrol
- Discover appropriate rates, timings and tank-mixes for Boxer on narcissus
- Determine whether it is safe to apply post-flower cropping tank-mix Flexidor 125 + Butisan S after a Boxer application or in tank-mix with Boxer
- Evaluate Spotlight Plus pre-harvest of bulbs as a desiccant/defoliant for narcissus, suitable for replacing sulphuric acid

Summary of the project and main conclusions

<u>Herbicide safety and efficacy in crop-year 1</u>

- In the first year of the trial foliar-acting Boxer (florasulam) was assessed without combination with other herbicide treatments. Boxer appeared to be safe to narcissus at all timings at 50ml/ha (half the normal dose recommended for cereals). It was also safe at the cereal dose (100ml/ha), although this rate was tested only at an early post-crop-emergence timing when leaves were 7-10cm tall. A tank-mix of Flexidor 125 + Butisan S (2.0 + 2.5L/ha), applied post-flowering, was also safe.

- There were no weeds on untreated plots before the post-emergence treatments were applied at the 7–10cm stage, before rapid bud growth, so it was not possible to assess the herbicide efficacy of Boxer in such treatments. A few weeds emerged on all plots

except those treated with Fortrol, during April. It appeared that the residual activity of Fortrol was useful in controlling weeds throughout the flowering period.

- Tank-mix Flexidor 125 + Butisan S, which is mainly residual soil-acting, was not as effective a treatment on emerged weeds as Boxer. Butisan S did not control emerged black bindweed or knotgrass, and the tank-mix did not prevent weeds emerging later (after 6 May). Flexidor 125, with mainly residual activity, did not control emerged weeds. Residual action, however, did not appear to prevent another flush of weeds emerging later in May.

- No damage to the leaves or flowers of narcissus was observed from any herbicide treatment.

Herbicide safety and efficacy in crop-year 2

- As Boxer has only foliar action on weeds, tank-mixes of Boxer with residual herbicides were tested in the second year of the crop.

- The overall pre-crop-emergence treatment, tank-mix CIPC + Linuron, was effective in controlling weeds, with few weeds emerging at the post-emergence timings (leaves 7-10cm tall or before rapid bud growth). However, from experience this is not always the case, though in commercial crops a residual herbicide may not always be applied.

- As there was no weed emergence at the first treatment timing, Boxer alone was applied at the second timing (before rapid bud growth), although only chickweed had emerged. On 28 March, when the flowers were ready to be cropped, some weeds were emerging in the untreated area (chickweed at the cotyledon or young seedling stage, knotgrass at the cotyledon stage). More weeds began to emerge in mid-April, possibly as a result of the soil disturbance that occurs during cropping, and they were at the cotyledon or young seedling stage when weed species were counted on 20 April (prior to the post-flower cropping application on 21 April). The effects from residual treatments with Fortrol, Stomp and Goltix may have lasted until cropping, but soil disturbance due to flower cropping will have reduced such effects. However, Fortrol (which has a relatively short persistence) did not control late flushes of chickweed; Stomp did not control groundsel; and Goltix gave poor control of chickweed and polygonums. This demonstrated that post-flower cropping herbicide application is essential if bulbs are to remain weed-free until bulb lifting.

- Boxer appeared safe to narcissus at all timings at 50ml/ha, either alone or in tank-mix. It was also safe at all timings at the cereal dose (100ml/ha).

- Boxer should be applied after weeds emerge. The weed spectrum for Boxer (see Appendix 1) includes mayweeds, groundsel and volunteer rape; creeping thistle is stunted, but fat-hen and small nettle are resistant. For longer-term control a tank-mix with a residual herbicide is needed at the early post-crop-emergence timing.

- The best control of weeds emerging late in the season was obtained from post-flower cropping treatments: either split-dose Boxer (50 + 50ml/ha), Boxer (100ml/ha), or tank-mix Flexidor 125 (2.0L/ha) + Butisan S (2.5L/ha) + Boxer (50ml/ha).

- Applied when narcissus leaves were 7-10cm tall, tank-mixes of Boxer with the residual soil-acting herbicides Stomp (3.3L/ha) or Goltix (4kg/ha) were safe to narcissus. Limited additional information suggested that other tank-mixes - with Sencorex (0.75kg/ha), Kerb (1.4kg/ha), Pyramin (2.0kg/ha) + Goltix WG (2.0kg/ha), or Skirmish (1.0L/ha) were also safe to narcissus.

- The post-flower cropping tank-mix Flexidor 125 (2.0L/ha) + Butisan S (2.5L/ha) + Boxer (50ml/ha) was also safe to narcissus.

- In the second crop-year no damage to narcissus leaves or flowers was observed as a result of any of the herbicide treatments applied. In a standard test, the vase-life of flowers cropped from the trial was not significantly affected by herbicide treatments.

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Defoliation with Spotlight Plus

- Spotlight Plus is commercially available for use as a herbicide prior to planting any edible or non-edible crop and for weed control and desiccation in potatoes. Spotlight Plus (a new formulation of carfentrazone-ethyl containing 60g/L ME) was applied to narcissus at 1.0L/ha as a single application 2 weeks before bulb lifting, or was followed by 0.6L/ha 7 days later. The application in June 2005 was made under ideal conditions – high temperature and light intensity - and the crop was desiccated in seven days. The follow-up application was not necessary in this case.

- Spotlight Plus desiccated broad-leaved weeds (knotgrass, redshank, black-bindweed, fat-hen and willowherb) and severely damaged creeping thistle. It is known to desiccate volunteer potatoes, oilseed rape, cleavers and nettle, but none of these was present in this trial. It has no effect on grasses.

- After Spotlight Plus treatment, narcissus leaves were easily mechanically detached from the bulbs before or at bulb-lifting.

- Some means of foliage removal is vital for narcissus as the marketing requirements mean that the bulbs must be lifted before the foliage dies down. Spotlight Plus seems to be an effective alternative to sulphuric acid, and does not require a specialist spray contractor.

Bulb yield

- The plots were lifted in July in the second crop-year. There were no statistically significant differences for bulb yields or grade-out between narcissus from herbicide- or desiccant-treated plots and untreated plots.

Quality of bulbs when subsequently forcing or grown-on in the field

- It is important to test herbicide-treated bulbs for the absence of detrimental side effects when they are forced under glass in winter/spring after lifting. Some herbicides are known to damage the flower bud, which in narcissus is initiated in the bulb in May, close to possible herbicide application dates. Desiccants (eg Reglone) can also reduce quality for forcing.

- There were no adverse effects from tank-mix or programme of Boxer with a residual herbicide on bulb quality for forcing.

- Spotlight Plus is contact-acting only. In this trial, cracks appeared in soil at the top of the ridges, so it was possible for Spotlight Plus to run down into the bulb: as such, the trial was a stringent safety test for the effects of Spotlight Plus on bulbs.

- These herbicide and desiccant treatments had no significant adverse side-effects, such as reduced performance of bulbs when subsequently forced in a glasshouse (eg reduced

yields, delayed cropping, reduced stem length or flower size, or reduced vase-life). Also, there were no defects in foliage or flowers when the bulbs were grown-on in the field for a further year.

Financial benefits

- Boxer appeared to have a wide margin of safety on narcissus at the dose rates and timings tested. As a cereal herbicide, Boxer is considerably cheaper than Fortrol. However, Fortrol has contact action and not very persistent residual activity, while Boxer has only contact action. In the second year of the trial tank-mixes of the residual herbicides Stomp or Goltix with Boxer were evaluated and were found to be safe to narcissus. Other tank-mixes also appeared to be safe.

- Spotlight Plus seemed to be an effective desiccant or defoliant for narcissus, and treatment with it eased bulb lifting compared with plots defoliated by flailing only. However, Spotlight Plus does not kill grasses. Spotlight Plus is a cheaper alternative to sulphuric acid, and does not require a specialist spray contractor or any extra precautionary measures.

Action points for growers

- Fortrol is widely used as a herbicide for narcissus, but it can no longer be used after 31 December 2007 - so bulb growers will need to alter their weed control strategy. Boxer is foliar-acting only, so is only needed once weeds have emerged. A residual herbicide (e.g. Stomp or Goltix) is important when narcissus leaves are 7-10cm long. Boxer applied (1) alone or in tank-mix with residual herbicide(s) when leaves were 7-10cm long, or (2) alone before rapid bud growth, or (3) post-flower-cropping alone or in tank-mix with Flexidor 125 + Butisan S, appeared safe to narcissus. However, tank-mixes of Boxer with other foliar–acting herbicides were not tested, so should not be used as they may cause damage.

- While noting that the results for Spotlight Plus were obtained from only a single year's trial, Spotlight Plus could be tested (at the grower's risk) on small areas of commercial crops.

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INTRODUCTION

The UK is a world leader in the production of narcissus bulbs and flowers. A high proportion of the output is exported, and the rest supplies a traditional home market that is becoming dominated by multiple retailers. Like other produce in the smaller crop sectors, bulb growers suffer from a shortage of suitable pesticides and approvals, though these are essential for the efficient production of high quality products. Bulb growers aim to achieve a high level of weed control, which:

- Increases yield by eliminating competition from weeds, which can reduce bulb yields by about 10% (or much more when growing under stress in dry conditions)
- Increases flower quality, as the stem does not become weak by excessive elongation trying to outgrow weeds
- Makes bulb lifting and sorting operations more effective by eliminating weeds that clog machinery
- Removes weed hosts of the stem nematode

Herbicides

Numerous narcissus herbicide trials were reported from Rosewarne, Kirton and SCRI in the 1970s and 1980s. The UK findings were incorporated into the former ADAS booklets and leaflets, but these sources are becoming difficult to obtain and out-dated. The HDC funded a project (BOF 35, completed in 1995) aimed specifically at identifying late-season (post-flowering) herbicide treatments. The only other recent UK trials were HDC-funded projects dealing with the control of volunteer potatoes in narcissus and of volunteer narcissus in winter wheat (BOF 46 and 47, both completed in 2002). None of this recent work specifically addressed weed control in the earlier stages of growth (post-shoot-emergence), where Fortrol (cyanazine) has proved so useful.

There are only five active substances in products that specifically state on-label "for use on narcissus": bentazone, chlorpropham, cycloxydim, cyanazine and pentanochlor/chlor-propham. Of these, the last two cannot be used after 31 December 2007. Cyanazine and pentanochlor/chlorpropham have derogations for 'Essential Use' until the end of 2007 on narcissus, and pentanochlor on ornamentals. There are also approvals for narcissus grown for galanthamine production: bentazone (on-label) and pendimethalin and diuron (SOLAs). There are several other active ingredients, including 'total' herbicides, with on-label use for ornamental plant production (see Table 1). Fluroxypyr was on-label for ornamental plant production but could be used post-flowering under the Long Term Arrangements for Extension of Use (LTAEU). Under the current LTAEU, subject to specific restrictions and at their own risk, growers of non-edible crops can also use pesticides approved for any growing crop; however, the LTAEU are under review and this situation will change.

For use on narcissus, herbicide treatments generally fall into three categories:

- *Pre-crop-emergence residual herbicides*
  The aim is to apply a residual as late as possible before shoot emergence, though emergence dates vary greatly between cultivars and there is a danger of missing the ideal spray date. CIPC + Linuron tank-mix is the most widely used herbicide at this stage.
- *Early-post-emergence herbicides*
  Only two of the several available chlorpropham products are recommended for use, at shoot heights of up to 5cm (and one of them expires at the end of 2007). Fortrol is recommended for use at shoot heights of 5-10cm. Because of the variability of

emergence across a field, spray dates have to be judged with care. Later application must be avoided because of the possibility of damage to the flower buds, though this may conflict with a requirement for weed control that persists until after flowering.

- *Post-flowering herbicides*

There are on-label recommendations at this stage for chlorpropham (two products, one expires end of 2007) and bentazone, the latter being contact-acting and for application at or after flowering but not during flower bud formation. Chlorpropham and bentazone would not substitute for the post-emergence role of cyanazine. In an earlier HDC project (BOF 35), trials showed that, of several materials tested, only an isoxaben + metazachlor tank-mix was safe at all application dates, including post-flowering. Isoxaben and metazachlor have mainly residual activity.

Table 1. Active substances for outdoor narcissus (as of October 2006).[1]

Active substance	*Approval status*
Dormant period	
Amitrole	on-label ornamental plant production
Glufosinate-ammonium	on-label ornamental plant production
Glyphosate	on-label ornamental plant production
Paraquat	on-label ornamental plant production
Diquat	on-label ornamental plant production
Dichlobenil	on-label ornamental plant production
Fluroxypyr/Triclopyr	on-label ornamental plant production
Residual pre-crop-emergence	
Chlorpropham	on-label for outdoor narcissus
Chlorpropham/ pentanochlor	on-label for outdoor narcissus
Trifluralin	SOLA ornamental plant production (no decision yet on Annex 1 inclusion, future doubtful)
Lenacil	on-label ornamental plant production
Diuron	on-label ornamental plant production (no decision yet on Annex 1 inclusion, future doubtful)
Oxadiazon	on-label ornamental plant production
Propyzamide	on-label ornamental plant production
Propachlor	on-label ornamental plant production
Simazine	(one product) Essential Use ornamental plant production until 31 December 2007
Post-emergence crop (7-10 cm leaves) and weed	
Cyanazine	Essential Use on-label for outdoor narcissus until 31 December 2007
Pentanochlor	Essential Use on-label for ornamental plant production until 31 December 2007
Post-flowering residual	
Isoxaben	ornamental plant production
Metazachlor	on-label ornamental plant production
Post-flowering foliar acting	
Bentazone	on-label for outdoor narcissus
Clopyralid	on-label ornamental plant production
Grass weed killers post-emergence crop	
Cycloxydim	on-label for outdoor narcissus
Quizalofop-p-tefuryl	on-label ornamental plant production
Fluazifop-P-butyl	SOLA ornamental plant production
Desiccant/foliage destruction	
Sulphuric acid	Commodity substance, bulbs
Carfentrazone-ethyl	LTAEU

[1] Under the LTAEU, subject to the *specific restrictions for extension of use*, pesticides approved for use on any growing outdoor crop may also be used legally (although they may not be safe) on narcissus (outdoor) - but the LTAEU are under review and the situation will soon change.

The triazine herbicide cyanazine (as 'Fortrol' and other cyanazine products) is widely relied on by bulb growers as a post-crop-emergence herbicide with contact and residual action. The Pesticide Usage Survey showed that cyanazine was used on 2,275 spray-ha of bulb crops in 2001, 44% of the crop (Table 2). Cyanazine's derogation for 'Essential Use' in narcissus runs until the end of 2007, with sale and supply ceasing by 30 June 2007. Alternatives were therefore sought in this project.

Table 2. The use of herbicides on outdoor bulbs grown in Great Britain in 2001. Herbicides used on 10% or more of the crop or more are shown in bold. Data from the CSL Pesticide Usage Survey for Defra (2003).

Active substances	*Spray area (ha)*
Total weeds	
Diquat	147
Diquat/paraquat	**2,043**
Glyphosate	**5,104**
Paraquat	**916**
Grasses	
Fluazifop-P-butyl	469
Broad-leaved weeds	
Bentazone	**1,950**
Chlorpropham	**1,604**
Chlorpropham/linuron[1]	179
Cyanazine[2]	**2,275**
Diuron[3]	**536**
Isoxaben	157
Lenacil	**1,072**
Linuron	**2,680**
Metamitron	**1,911**
Pendimethalin	**531**
Simazine[2]	274
Total area treated with herbicide (ha)	*22,134*
Crop area 2001(ha)	*5,237*
Herbicide applications as % area grown	*422.6*

[1] No longer available
[2] Not supported, or not achieving Annex 1 listing in the EC Review
[3] Inclusion on Annex 1 doubtful but no decision yet (October 2006)

Florasulam, a new triazolopyrimidine herbicide for cereals marketed by Dow AgroSciences as 'Boxer', has shown promise as a post-emergence herbicide on onions and leeks, and appeared to be a useful candidate as a replacement for Fortrol on narcissus. Dow AgroSciences carried out some preliminary trials of florasulam on narcissus, but no information has been made available on suitable rates of use or of its possible subsequent effects on bulbs and flowers (Dow AgroSciences, personal communication).

For the present trial narcissus bulbs were planted in autumn 2003 and, as is normal practice, grown as a 'two-year-down' crop. Dormant season application of glyphosate and pre-emergence application of tank-mix CIPC + linuron were applied as normal across the whole trial area. Boxer was tested as part of the herbicide programme. In crop-year 1, Boxer alone was evaluated for crop tolerance at a range of dose rates and post-emergence timings: (1) when the narcissus leaves were no longer than 7-10cm (the normal application stage for Fortrol), (2) at the late-post-emergence stage (before rapid bud growth), and (3) post-flowering. In the second crop-year tank-mixes of Boxer with residual herbicides were tested. Some herbicides are known to damage the flower bud, which in narcissus is initiated in the bulb in May, close to possible herbicide application dates, so it is important to test herbicide-

treated field-grown bulbs for the absence of detrimental side-effects when they are forced under glass in the winter/spring after lifting.

Desiccants

A related concern of bulb growers is the lack of a suitable desiccant or defoliant for pre-harvest use. Some means of foliage removal is vital, because marketing deadlines mean narcissus bulbs must be lifted before the foliage has died down. The only desiccant approved, sulphuric acid, has the obvious disadvantages of requiring application by a specialist contractor and the taking of stringent precautions. Other methods, such as mechanical defoliation or using a propane burner on the foliage, have disadvantages. Spotlight Plus (sometimes formerly referred to as 'Shark') is commercially available for use as a herbicide prior to planting any edible or non-edible crop and for weed control and defoliation in potatoes. Spotlight Plus (carfentrazone-ethyl, formulated as a 60g/L ME that does not need an added wetter) was, therefore, evaluated in this project.

MATERIALS AND METHODS

Bulbs and husbandry

A crop of the widely grown narcissus cultivar Carlton was used to test herbicides over the period summer 2003 to summer 2005. The trial site was a medium silty marine alluvial soil at The Kirton Research Centre, Kirton, Boston, Lincolnshire, typical of the South Lincolnshire agricultural area where narcissus are widely grown. Prior to setting up the trial, the site was ploughed, cultivated and treated with paraquat + diquat. Standard soil sampling (0-15cm depth) across the site and agricultural soil analysis gave the following results: pH 7.1, P index 4, K index 2-, Mg index 3 and conductivity index 0. Following a winter wheat crop, the nitrogen index was taken as 0. Potash (as sulphate of potash) was applied pre-cultivation at a rate of 150kg K_2O/ha, and nitrogen (as ammonium nitrate) as a top-dressing pre-crop-emergence at a rate of 125kg N/ha.

The trial design was a randomised block with three replicates and 12 treatments (see below). As usual the crop was grown in ridges; each plot consisted of two adjacent ridges 6.6m long, with a guard ridge between each treated plot. The bulbs used were of grade 10-12cm (circumference) and were taken from a stock grown at Kirton for many years using typical husbandry for the area. Following lifting in July 2003 and hot-water treatment in August, bulbs were weighed into lots of 10kg each. Each 10kg-lot was placed evenly in 6.6m-long lengths of tubular nylon netting. At planting, the trials area was 'ridged out' (ridges at 0.76m centre-to-centre) and the positions of the 6.6m-long plots marked in. One net of bulbs was laid in each 6.6m-long section, giving a planting density of 20t/ha. Similar bulbs, but loose rather than netted, were placed at the same planting density in the guard plots. Growing narcissus bulbs in netting does not impede growth but ensures complete recovery of plots for recording purposes. The ridges were 'split-back', using a ridging body, to cover the bulbs. During each growing season the trial received a standard fungicide programme, with five sprays in year 1 and three in year 2. No further pesticide sprays or fertilisers were applied, and no irrigation was given. Following common commercial practice, flowers were picked in the second crop-year only.

Herbicide treatments

The test herbicide treatments formed part of an overall herbicide programme. All plots received 'dormant season' and pre-crop-emergence herbicides as follows:

- 'Dormant season' glyphosate (as 2.0L/ha 'Roundup' in 250L water/ha)
- Pre-crop-emergence tank-mix CIPC + linuron (as 4.2L/ha MSS CIPC40 EC + 1.68L/ha Alpha Linuron 50 SC in 450L water/ha)

The experimental treatments in crop-year 1 comprised various rates and timings of Boxer and a standard treatment of Fortrol applied at early post-crop-emergence stage (Table 3). All experimental herbicide and desiccant treatments were applied in 250L/ha of water using a precision sprayer ('Oxford') fitted with 02/F80 nozzles.

In crop-year 2, using the finding from the first year that Boxer appeared safe, tank-mixes of Boxer plus residual herbicides Stomp or Goltix (both known to be safe at the early post-crop-emergence stage), were applied at this timing; the highest dose of Boxer was also tested at a later stage (before rapid bud growth and post-flowering) (Table 4). The timings for foliar-acting Boxer were later because, as in the previous year, no weeds emerged earlier. Boxer was also used added to the Flexidor + Butisan tank-mix. Spotlight Plus was applied as a pre-harvest desiccant at the end of the second year's growth only. Some additional treatments with tank-mixes of Boxer and other residual herbicides were assessed for crop safety only on an adjacent crop area in the second crop-year only (Table 5). Information on the status of all herbicides used is given in Table 6. The key dates for the trial (including all application dates)

are shown in Table 7. Meteorological data for the Kirton site are summarised in Figure 1; they showed that the growing seasons in both 2004 and 2005 were generally warmer but less sunny than the long-term average for the site, while rainfall was near-average overall.

Table 3. Post-emergence and post-flowering herbicide treatments used in crop-year 1. All treatments were preceded by dormant season application of glyphosate and pre-crop-emergence application of tank-mix CIPC + Linuron.

	Treatments with application rates (product/ha)		
	Standard early post-crop-emergence stage (leaves 7-10cm long)	*Late-post-emergence stage (before rapid bud growth)*	*Post-flower-cropping stage*
1.	Untreated control	-	-
2.	Hand-weeded control	-	-
3.	Fortrol (5.2L)	-	-
4.	Boxer (25ml)	-	-
5.	Boxer (50ml)	-	-
6.	Boxer (100ml)	-	-
7.	-	Boxer (50ml)	-
8.	Boxer (25ml)	Boxer (25ml)	-
9.	Boxer (50ml)	-	Boxer (50ml)
10.	Boxer (50ml)	-	Flexidor 125 (2.0L) + Butisan S (2.5L)
11.	Boxer (50ml)	-	-
12.	Boxer (50ml)	-	-

Table 4. Post-emergence and post-flower cropping herbicide treatments and desiccant treatments used in crop-year 2. All treatments were preceded by dormant season application of glyphosate and pre-crop-emergence application of tank-mix CIPC + linuron.

	Treatment with application rates (product/ha) and defoliation method			
	Standard early-post-crop-emergence stage	*Late-post-emergence stage*	*Post-flower-cropping stage*	*Pre-harvest defoliation*
1.	Untreated control	-	-	Flailing
2.	Hand-weeded control	-	-	Flailing
3	Fortrol (5.2L)	-	-	Flailing
4.	Stomp (3.3L) + Boxer (50ml)	-	-	Flailing
5.	-	Boxer (50ml)	-	Flailing
6.	-	Boxer (100ml)	-	Flailing
7.	-	-	Boxer (100ml)	Flailing
8.	Goltix (4kg) + Boxer (50ml)	-	-	Flailing
9.	-	Boxer (50ml)	Boxer (50ml)	Flailing
10.	-	Boxer (50ml)	Flexidor 125 (2.0L) + Butisan S (2.5L) + Boxer (50ml)	Flailing
11.	-	Boxer (50ml)	-	Spotlight Plus (1.0L)
12.	-	Boxer (50ml)	-	As 11 + 0.6L 7 days later

Table 5. Additional treatments tested for crop safety only in crop-year 2 at early-post-crop-emergence stage (leaves 7-10cm long).

	Herbicide (product/ha)
13.	Skirmish (1.0L) + Boxer (50ml)
14.	Sencorex (0.75kg) + Boxer (50ml)
15.	Kerb (1.4kg) + Boxer (50ml)
16.	Pyramin DF (2kg) + Goltix WG (2kg) + Boxer (50ml)

Table 6. Status of the herbicides used in this project (as at October 2006).

Product name	*a.i. and formulation*	*Marketing company*	*EC Review of a.i.*	*Approval on other crops or narcissus*
Fortrol	cyanazine 500g/L SC	Makhteshim etc.	Not supported, revoked	Essential Use narcissus until 31 December 2007
Flexidor 125	isoxaben 125g/L SC	Landseer etc.	Supported	UK ornamentals
CIPC 40 EC	chlorpropham 400g/L EC	Nufarm etc.	Annex 1	UK narcissus
Alpha Linuron 50SC	linuron 500g/L SC	Makhteshim etc.	Annex 1	UK some vegetables / LTAEU
Butisan S	metazachlor 500g/L SC	BASF etc.	Supported	UK brassicas, ornamentals
Boxer	florasulam 50g/l	Dow	Annex 1	UK cereals / LTAEU
Spotlight Plus	carfentrazone-ethyl 60g/L ME	Belchim	Annex 1	UK potato haulm destruction and cereals / LTAEU
Sulphuric acid	Sulphuric acid soluble concentrate	Commodity substance	Supported, round 4 review	Unlikely to continue?
Stomp 400 SC	pendimethalin 400g/L SC	BASF etc.	Annex 1	UK SOLA daffodils for galanthamine production / LTAEU
Goltix Flowable	metamitron 700g/L SC	Makhteshim etc.	Supported	UK approval sugarbeet / LTAEU
Skirmish	terbuthylazine/ isoxaben 420/75g/L SC	Syngenta	Supported	UK approval peas / LTAEU
Sencorex WG	metribuzin 70% w/w WDG	Bayer	Supported	UK approval potatoes / LTAEU
Kerb Flo	propyzamide 400g/L SC	Dow	Annex 1	UK approval for bush fruit, roses / LTAEU
Pyramin DF	chloridazon 65% w/w WG	BASF	Supported	UK approval for sugar beet etc./ LTAEU

Table 7. Diary of operations and sprays.

Operation	*Date*	*Temp. (°C)* [1]	*Growth stage – crop*	*Growth stage - weeds*
Crop-year 1 (2003-2004)				
Narcissus planted	26 Sep 2003	-	-	-
Glyphosate on all plots	9 Dec 2003	5.2	Pre-emergence	-
Pre-crop-emergence CIPC + Linuron on all plots	7 Jan 2004	6.6	Pre-emergence	-
Mean shoot emergence date	18 Jan 2004	-	-	-
Standard early post-crop-emergence treatments	9 Feb 2004	3.3	Leaves average 7cm tall (range 2-15cm)	No weeds
Late-post-crop-emergence (before rapid bud growth) treatments	24 Feb 2004	3.6	Stem extended but not at rapid bud growth	No weeds
Post-flowering treatments	6 May 2004	9.8	Post-flower-cropping, seed heads, 70% crop cover	Very few weeds; knotgrass 2TL[2]
Crop-year 2 (2004-2005)				
Glyphosate on all plots	11 Nov 2004	6.5	-	-
Pre-crop-emergence CIPC + Linuron on all plots	9 Dec 2004	5.0	-	-
Mean shoot emergence date	6 Jan 2005	-	-	-
Standard early post-crop-emergence treatments	4 Feb 2005	6.5	Leaves 4-10cm tall	No weeds
Additional early post-crop-emergence treatment (Table 5)	11 Feb 2005		Leaves 4-10cm tall	No weeds
Late-post-crop-emergence (before rapid bud growth) treatment	7 Mar 2005	3.8	Stem extended but not at rapid bud growth	Low number; chickweed cotyledon stage
Narcissus cropped for vase-life test	18 Mar 2005		Buds	-
Rest of flowers cropped	29–30 Mar 2005	-	-	-
Post-flower-cropping treatment	21 Apr 2005	8.7 (soil moist)	-	Thistles established, chickweed small, groundsel, black-bindweed and knotgrass at C/1TL
Pre-harvest defoliation Spotlight Plus (treatments 11 and 12)	20 Jun 2005	20.6 (sunny)	Narcissus leaves wilted, beginning to senesce	Chickweed senescing
Pre-harvest defoliation Spotlight Plus (treatment 12)	27 Jun 2005	18.4 (sunny)	Narcissus leaves wilted, beginning to senesce	Chickweed senescing
Flailing (remaining treatments) and lift bulbs	14 Jul 2005	-	-	-
Bulbs graded and bulbs allocated for forcing placed at 9°C	4 Aug 2005	-	-	-
Forced bulbs to glasshouse	15 Nov 2005	-	-	-

[1] Mean daily values
[2] 2TL = two true leaf stage; C/1TL = cotyledon to one true leaf stage

Records

The following assessments were made in each crop-year:

- Crop and weed stage of development at the time of treatments
- Crop tolerance (based on phytotoxic symptoms and crop stand) at the following crop growth stages: buds visible, leaves 20cm high, buds showing, late-bud stage, 50% flowers open, seed heads, 70% crop cover, mid flower die-down and late flower die-down. The following tolerance scores were used:

Crop tolerance score	*% Phytotoxicity*
0	Complete kill
1	80 – 95% damage
2	70 – 80% damage
3	60 – 70% damage
4	50 – 60% damage
5	40 – 50% damage
6	25 – 40% damage
7	20 – 25% damage (considered unlikely to cause reduction in yield or quality at cropping)
8	10 – 20% damage
9	5 – 10% damage
10	No damage (as untreated controls)

In crop-year 2 the following assessments were also made:

- Weed cover was assessed as the percentage of the soil area on the ridge covered by weeds.
- Numbers of each weed species present were counted in six random 0.17m^2 quadrats per plot at appropriate intervals after each application. For English and Latin weed names, see Table A1 of Appendix 1.
- Flower quality was assessed starting 18 March 2005. Ten stems were sampled at random from each plot at the 'upright fat pencil' stage. They were stored dry and flat for 3 days at 2°C. Each lot of 10 stems was then placed in a 1.0L vase containing 0.6L plain tap-water and was placed in a vase-life test room. In the test room conditions were 20°C and 60% relative humidity under daylight fluorescent lamps on for 12 hours per day and giving *ca*. 1000 lux at flower height. Flowers were examined daily and individual stems were discarded as they reached the end of vase-life (taken as the start of withering of the petal tips).
- At bulb lifting the ease of lifting was noted.
- Bulb yield (number and weight of bulbs per plot) was recorded in size grades following bulb-lifting, surface-drying and cleaning. Bulbs were then allocated for further tests (see below).
- Bulb of grade 12-14cm (circumference) were allocated for forcing over winter 2005/2006. From 4 August 2005 these were stored at 9°C. 80 bulbs from each plot were planted in peat in a standard forcing tray in mid-September and returned to the 9°C store. On 15 November 2005 trays were moved to a glasshouse heated to 15°C and ventilated at 18°C. Flowers were cropped daily as they reached the 'split spathe' stage and numbers were recorded in each length grade (<35, 35-40, 40-45, 45-50 and >50cm). At the median cropping date for each tray, 10 stems were sampled from each tray and stored dry and flat for 3 days at 1°C and 90% relative humidity, after which a vase-life test was carried out as described above. In addition, the flower diameter of each was recorded when individual flowers were fully open, and flowers carefully examined for any defects.
- Further lots of bulbs (100 mixed sizes from each plot) were re-planted in the field in September 2005. At flowering in spring 2006 the crop was carefully walked to check for any abnormal or damaged foliage or flowers.

Statistical analysis

Except for those noted below, data presented in this report are the means of the three replicates of each herbicide treatment. Weed records and crop tolerance scores were generally consistent across replicates and were not formally analysed. Other data were subjected to the analysis of variance and treatment effects were judged statistically significant at the $P \leq 0.05$ level. Where the treatment factor was not significant, means and analysis of variance tables have not been presented.

Data on additional tank-mixes (see Table 5) were means of two replicate plots each. These data were analysed using 'missing values' for the missing third replicates; whilst not strictly valid, this provided a convenient approximation, and the finding that treatment effects were not significant in this case was borne out by the obviously similar means obtained for all treatments.

RESULTS AND DISCUSSION

Crop tolerance to herbicides, crop-year 1

No crop damage was observed at any growth stage from any herbicide treatment. Boxer appeared to be safe to narcissus at all timings at 50ml/ha (half the normal dose rate recommended for cereals). It was also safe at the cereal dose (100ml/ha) when tested at the early timing when leaves were 7cm tall. Tank-mix Flexidor + Butisan (2.0 + 2.5L/ha), applied post-flowering, was also safe.

Weed assessments, crop-year 1

Weed distribution was uneven over the trial area, and, overall, weed numbers were low. The overall pre-crop-emergence treatment, tank-mix CIPC + Linuron, was effective in controlling weeds. Although a few seedlings began to appear at the beginning of February, they later died as a result of frost. There were no weeds on untreated plots before post-crop-emergence treatments were applied on 9 and 24 February 2004. It was not possible to assess the herbicide efficacy of contact-acting Boxer applied on 9 or 24 February because no weeds were present. A few weeds emerged on all plots, except those treated with Fortrol, during April. In this case it appeared that the residual activity of Fortrol was useful in controlling weeds throughout the flowering period.

Weed assessments on 3 May showed that, as expected, Fortrol, with its residual activity, was the most effective treatment, persisting until the 11 June assessment (Table 8). There were no weeds on two of the three replicates of this treatment. Boxer was shown to be as effective as Fortrol when used at either the 100ml/ha rate or as a split-dose application (2 x 50ml/ha), the other Boxer treatments being less effective.

Table 8. Weed numbers in crop-year 1 (in 2004) before (3 May) and after (11 June) the post-flower cropping herbicide applications.

	Herbicide timing and dose rate/ha		*Weed numbers /m²*	
Leaves 7-10 cm (9 Feb.)	*Before rapid bud growth (24 Feb.)*	*Post-flower cropping (6 May)*	*3 May*	*11 June*
1 Untreated	-	-	24	20
2 Handweeded	-	-	0	0
3 Fortrol 5.2L	-	-	2	5
4 Boxer 25ml	-	-	13	22
5 Boxer 50ml	-	-	8	22
6 Boxer 100ml	-	-	4	12
7 -	Boxer 50ml	-	14	12
8 Boxer 25ml	Boxer 25ml	-	8	18
9 Boxer 50ml	-	Boxer 50ml	-	5
10 Boxer 50ml	-	Flexidor 2.0L + Butisan 2.5L	-	12

The weed species present on 3 May and 11 June 2004 are shown in Tables 9 and 10, respectively. Before post-flowering treatments were applied (6 May), weed populations remained very low, with only 24/m^2 on untreated plots, mainly black bindweed and knotgrass. After post-flowering treatments had been applied a few weeds emerged. Assessments on 11 June showed that Boxer (at 50ml/ha) applied on 5 May was effective in controlling black bindweed but not knotgrass, and the remaining weeds numbered less than 5/m^2. Tank-mix Flexidor + Butisan was not as effective on emerged weeds, 12/m^2 remaining. Butisan did not control emerged black bindweed and knotgrass, and Flexidor, with mainly residual activity, did not control emerged weeds. Residual action did not appear to prevent another flush of

weeds emerging later in May. It was proposed in 2005 to add another residual herbicide, either as a tank-mix or in a programme with Boxer.

Table 9. Weed numbers in crop-year 1 of each species and total numbers (means of three replicates) on 3 May 2004.

Herbicide timing and rate/ha		*Weed numbers/m²*							
Leaves 7-10cm (9 Feb.)	*Before rapid bud growth (24 Feb.)*	*Black-bindweed*	*Knotgrass*	*Speedwell*	*Groundsel*	*Chickweed*	*Mayweeds*	*Red dead-nettle*	*Total*
1 Untreated	-	6	7	1	2	4	4	0	24
2 Hand-weeded	-	0	0	0	0	0	0	0	0
3 Fortrol 5.2L	-	2	0	0	0	0	0	0	2
4 Boxer 25ml	-	4	2	1	3	0	2	1	13
5 Boxer 50ml	-	1	4	3	0	0	0	0	8
6 Boxer 100ml	-	1	3	0	0	0	0	0	4
7 -	Boxer 50ml	4	4	4	1	0	1	0	14
8 Boxer 25ml	Boxer 25ml	4	4	0	0	0	0	0	8
9 Boxer 50ml	-	9	9	0	0	0	1	0	19
10 Boxer 50ml	-	2	7	0	0	0	0	0	9

Table 10. Weed species present and percentage weed cover in crop-year 1 on 11 June 2004.

Herbicide timing and dose rate/ha			*Weed assessments*	
Leaves 7-10cm (9 Feb.)	*Before rapid bud growth (24 Feb.)*	*Post-flower cropping (6 May)*	*Main weed species*	*% cover*
1 Untreated	-	-	Black-bindweed, knotgrass, chickweed, redshank, groundsel, nettle, mayweeds, shepherd's purse	20
2 Hand-weeded	-	-	None	0
3 Fortrol 5.2L	-	-	Black-bindweed, knotgrass	<3
4 Boxer 25ml	-	-	As untreated	12
5 Boxer 50ml	-	-	As untreated	10
6 Boxer 100ml	-	-	As untreated	5
7 -	Boxer 50ml	-	Black-bindweed, knotgrass	5
8 Boxer 25ml	Boxer 25ml	-	As untreated	7
9 Boxer 50ml	-	Boxer 50ml	As untreated	<5
10 Boxer 50ml	-	Flexidor 2.0L+ Butisan 2.5L	As untreated	8

Crop tolerance to herbicides, crop-year 2

Narcissus shoots began to emerge on 6 January 2005. Narcissus were assessed for crop damage on several occasions (18 February, 3 March, 15 March, 28 March, 20 April and 8 May) after each herbicide application. No crop damage was observed at any growth stage from any herbicide treatment. At the early timing (leaves 7cm tall) Boxer at 50ml/ha in tank-mix with Stomp or Goltix or with other residuals (Sencorex, Kerb and Pyramin + Goltix) appeared to be safe. It was also safe at 50 ml/ha or when used at the cereal dose (100ml/ha) when applied before rapid bud growth. No crop damage was seen when Boxer was applied post-flowering at 100ml/ha, or at 50ml either alone or in tank-mix with Flexidor + Butisan (2.0 + 2.5L/ha).

Weed assessments crop-year 2

In 2005 no weeds had emerged by the early post-crop-emergence application (leaves 7-10cm long) on 4 February, so foliar-acting Boxer was applied at the second timing on 7 March. Subsequently, the weed distribution was uneven over the trial area and weed numbers were much higher on all plots than in the first year.

The second application on 7 March (before rapid bud growth) was a week before severe frosts and snow, when a few tiny cotyledon weeds (chickweed) were seen along with some creeping thistle and willowherb. The frost and snow may have killed some emerging weeds.

On 28 March, when the narcissus were at the open flower stage, more weeds were emerging on the untreated plots: chickweed (cotyledon to seedling stage) and knotgrass and other species (cotyledon stage), but these were too small to identify or count.

Another flush of weeds emerged in mid-April, possibly as a result of soil disturbance during cropping. These weeds were at the cotyledon to seedling stage when counted on 20 April, before the post-flower cropping application (21 April). The effects from residual treatments - Fortrol, Stomp and Goltix - may have lasted until cropping, but were difficult to judge because of late weed emergence; soil disturbance from flower cropping will have reduced their long-term effects. However, Fortrol, which has relatively short persistence, did not control late flushes of chickweed, Stomp did not control groundsel, and Goltix gave poor control of chickweed and polygonums. This suggests that post-flower-cropping herbicide application is essential if narcissus crops are to remain weed-free until harvest.

Assessments on 20 April (Table 11) showed that Boxer applied on 7 March (treatments 5, 6, 9, 10, 11 and 12) at a 50 or 100ml dose affected thistles, which became chlorotic, the damage remaining visible by 9 May although the shoots did not die. Boxer applied on 7 March killed emerged chickweed and some knotgrass, but would have had no effect on weeds emerging later. The herbicide treatments in the previous year also had an impact: in 2004 weed numbers were low and weeds emerged late, and knotgrass was not well controlled by Boxer treatments, Fortrol performing better. The remaining knotgrass spread and its seeds further infested the plots.

On 21 April, chickweed was at small plant stage, and groundsel, black-bindweed and knotgrass were at the cotyledon to 1 true-leaf stage. There were also some large shoots of creeping thistle and a few willowherb, which became chlorotic and stunted by Boxer. Weed counts were made on 8 May (Table 11). The herbicide label claims that knotgrass is only moderately susceptible to Boxer, but here Boxer gave good control when applied to small seedling weeds. Boxer alone, in a programme or in tank-mix, also controlled groundsel, chickweed and black-bindweed. All post-flower-cropping treatments were very effective.

The additional treatments (see Table 5) were assessed on 18 February (7 days after application), 3 March and 28 March 2005. No damage was observed from any treatment. There were no weeds at application since tank-mix CIPC + linuron had been effective. All the residual herbicides in the tank-mixes gave good weed control, and there were very few weeds on 28 March, while on 20 April only a few chickweed escaped control on all plots except those treated with tank-mix Pyramin + Goltix + Boxer, which were weed-free (Table 12). Assessment on 3 July, four days before lifting, showed there was negligible weed cover on treated plots: only an uneven distribution of a very few willowherb remained.

Weed control scores are shown in Table 13, and illustrate the need for post-flower-cropping treatments to keep bulbs weed-free until harvest. All treatments post-flower-cropping were very effective and also appeared safe to the crop.

The narcissus crop and herbicides together had a considerable effect on weed suppression. By 4 June the narcissus leaves had wilted. Weed cover (Table 14) on untreated plots was mainly chickweed, which had emerged early and was controlled by Boxer applied on 7 March. The post-flower-cropping treatments (treatments 7, 9 and 10) all gave excellent control of small weeds that had emerged after soil disturbance during cropping three weeks earlier 29-30. There were a few creeping thistles over the trial area, and these were severely stunted by the post-flower-cropping treatments with Boxer. Fortrol, which is less persistent, had less effect on chickweed than Stomp or Goltix. Stomp did not control groundsel, but this species produced little ground cover. An uneven distribution of redshank had begun to emerge on some plots by 4 June.

Table 11. Number of weeds in crop-year 2 on 20 April 2005 and (in italics, for treatments 7, 9 and 10) 8 May 2005, 18 days after the post-flower-cropping application.

	Leaves 7-10cm long 4 Feb	*Before rapid bud growth 7 March*	*Post-flower-cropping 21 April*	*Chickweed*	*Black-bindweed*	*Knotgrass*	*Groundsel*	*Willowherb*	*Total*
1.	Untreated	-	-	66.7	9.3	43.3	17.3	1.3	137.9
2.	Hand-weeded	-	-	-	-	-	-	-	-
3.	Fortrol 5.2L	-	-	37.3	11.3	3.3	6.7	3	61.6
4.	Stomp 3.3L + Boxer 50ml	-	-	13.3	-	1.3	8.7	-	22.6
5.	-	Boxer 50ml	-	4.7	3.3	36.7	1.3	0.7	48.1
6.	-	Boxer 100ml	-	8	4.7	17.3	-	0.7	36
7.	-	-	Boxer 100ml	36.7 *0*	8.7 *0.7*	31.3 *5.7*	10 *0*	0.7 *0*	83.4 *6.4*
8.	Goltix 4kg + Boxer 50ml	-	-	20	6.7	12	-	1.3	50
9.	-	Boxer 50ml	Boxer 50ml	8 *0*	14 *3*	34.7 *3*	- *0*	3.3 *0*	60 *6*
10.	-	Boxer 50ml	Flexidor 2.0L + Butisan 2.5L + Boxer 50ml	8 *0*	3.3 *0*	16.7 *1.0*	0.7 *0*	- *0*	28.7 *1.0*
11.	-	Boxer 50ml	-	2	11.3	37.3	-	-	56.6
12.	-	Boxer 50ml	-	4.7	9	30	0.7	-	39.7

Table 12. Number of weeds and weed control score in crop-year 2 on 20 April 2005.

	Herbicide timing and dose rates/ha Leaves 10 - 15 cm long (applied 11 February)	*Chickweed*	*Small nettle*	*Knotgrass*	*Groundsel*	*Total*	*Weed control score*[1] *28 Mar*
1.	Untreated	50	4	0	2	56	0
13	Skirmish 1.0L + Boxer 50ml	8	1	0	0	9	9.5
14	Sencorex 0.75kg + Boxer 50ml	7	0	1	0	8	9.5
15	Kerb 1.4kg + Boxer 50ml	3	0	0	0	3	9.5
16	Pyramin DF 2kg + Goltix WG 2kg + Boxer 50ml	0	0	0	0	0	10.0

[1] 0, no control, to 10, complete control

Table 13. Weed control scores[1] (excluding creeping thistle) in crop-year 2 on 20 April, 8 May 2005 (treatments 7, 9 and 10, 18 days after post-flower-cropping application) and 3 July (after Spotlight Plus treatment).

	Leaves 7-10cm long 4 Feb	*Before rapid bud growth 7 March*	*Post-flower-cropping 21 April*	*Pre-harvest defoliation[2] 20 & 27 June*	*20 April*	*8 May*	*3 July*
1.	Untreated	-	-	-	0	0	0
2.	Hand-weeded	-	-	-	0	0	0
3	Fortrol 5.2L	-	-	-	5	5	3
4.	Stomp 3.3L + Boxer 50ml	-	-	-	9	9	4
5.	-	Boxer 50ml	-	-	5	5	4
6.	-	Boxer 100ml	-	-	7	7	6
7.	-	-	Boxer 100ml	-	0	9	9
8.	Goltix 4kg + Boxer 50ml	-	-	-	6	6	5
9.	-	Boxer 50ml	Boxer 50ml	-	5	9	9
10.	-	Boxer 50ml	Flexidor 2.0L + Butisan 2.5L + Boxer 50ml	-	8	10	10
11.	-	Boxer 50ml	-	Spotlight Plus 1.0L	5	5	10
12.	-	Boxer 50ml	-	As 11 + 0.6L 7 days later	6	6	10

[1] 0, no control, to 10, complete control
[2] Creeping thistles severely stunted – no stem elongation

Table 14. Percentage weed cover by species and in total in crop-year 2 on 4 June 2005.

	Leaves 7-10cm long 4 Feb	*Before rapid bud growth 7 March*	*Post-flower-cropping 21 April*	*Chickweed*	*Black-bindweed*	*Knotgrass*	*Groundsel*	*Speedwell*	*Willowherb*	*Total % weed cover*
1.	Untreated	-	-	50	2	3	5	2	<1	70
2.	Hand-weeded	-	-	50	2	3	5	2	1	63
3	Fortrol 5.2L	-	-	8	1	0	1	0	2	10
4.	Stomp 3.3L + Boxer 50ml	-	-	4	0	0	4	0	1	5
5.	-	Boxer 50ml	-	0	0	1	0	0	0	2
6.	-	Boxer 100ml	-	0	0	0	0	0	0	1
7.	-	-	Boxer 100ml*	0	0	0	0	0	0	0
8.	Goltix 4kg +Boxer 50ml	-	-	2	1	0	0	0	2	4
9.	-	Boxer 50ml	Boxer 50ml*	0	0	0	0	0	0	0
10.	-	Boxer 50ml	Flexidor 2.0L + Butisan 2.5L + Boxer 50ml*	0	0	0	0	0	0	0
11.	-	Boxer 50ml	-	1	1	1	0	0	0	2
12.	-	Boxer 50ml	-	0	0	1	0	1	0	2

*creeping thistles severely stunted – no stem elongation

Spotlight Plus: defoliation and weed control prior to lifting

The crop foliage had begun to wilt by 4 June and was senescing by 20 June. Weeds on untreated plots, mainly chickweed, were also beginning to senesce by that time. Spotlight Plus (1.0L/ha) was applied under ideal conditions, high light intensity and high temperature (20°C), on 20 June 2005, and took effect within seven days. It completely controlled all annual broad-leaved weeds (in this case chickweed, knotgrass, black-bindweed and sow-

thistle) and severely scorched large, established willowherb and creeping thistle. Spotlight Plus had no effect on the low numbers of annual meadow grass. As planned, the second Spotlight Plus treatment was applied seven days later, although it did not appear to be needed. The percentage weed cover and predominant weed species were assessed on 3 July, in advance of lifting the crop on 14 July (Table 15). Where chickweed was not well controlled, this species made the greatest contribution to weed cover. The effect of Fortrol, Stomp and Goltix tank-mixes applied in February did not persist until lifting, and failed to control willowherb. All the post-flower-cropping herbicides performed better than earlier applications.

One application of Spotlight Plus completely desiccated the crop within 7 days. The desiccated narcissus leaves were easily and cleanly detachable from the bulb. All other plots were defoliated mechanically by flailing on 14 July, just before lifting. As judged by the operator, the lifting of bulbs appeared easier in Spotlight Plus-treated plots than in mechanically defoliated plots.

Table 15. Percentage weed cover and species remaining on 3 July before lifting (5 July), crop-year 2.

	Leaves 7-10cm long 4 Feb	*Before rapid bud growth 7 March*	*Post-flower-cropping 21 April*	*Pre-harvest defoliation* 20 & 27 June*	*% weed cover 3 July*	*Weed species (main ones in **bold** text)*
1	Untreated	-	-	-	100	**Chickweed**** knotgrass redshank groundsel willowherb field speedwell
2.	Hand-weeded	-	-	-	100	**Chickweed** knotgrass groundsel willowherb field speedwell
3.	Fortrol (5.2L)	-	-	-	30	**Willowherb chickweed** black-bindweed redshank
4.	Stomp 3.3L + Boxer 50ml	-	-	-	25	**Groundsel** sow-thistle chickweed black-bindweed willowherb
5.	-	Boxer (50ml)	-	-	20	**Knotgrass** willowherb
6.	-	Boxer (100ml)	-	-	10	Knotgrass
7.	-		Boxer (100ml)	-	5	Knotgrass
8.	Goltix 4kg + Boxer 50ml	-	-	-	25	**Chickweed** willowherb black-bindweed redshank knotgrass
9.	-	Boxer (50ml)	Boxer (50ml)	-	0	-
10.	-	Boxer (50ml)	Flexidor 125 (2.0L) + Butisan S (2.5L) + Boxer 50ml	-	0	-
11.	-	Boxer (50ml)	-	Spotlight Plus (1.0L)	0	-
12.	-	Boxer (50ml)	-	As 11 + 0.6L 7 days later	0	-

* Flailing was carried out on treatments 1 to 10 after this assessment, on 14 July just before lifting
** Chickweed on all plots was senescing

Crop quality

Vase-life assessment of field-cropped flowers
The analysis of variance showed there was no significant effect of herbicide treatment on the vase-life of stems cropped from the field in crop year 2.

Bulb yields and size grades
There was no statistically significant effect of herbicide treatment on the total yield of bulbs (either numbers or weight lifted per plot) or on the numbers and weights of bulbs in each size grade. After grading these bulbs were forced in a glasshouse or grown-on in the field to look for any after-effects of the herbicide treatments compared with untreated controls.

Crop performance in subsequent bulb forcing
During the glasshouse period foliage, stems, buds and flowers were checked visually for any abnormalities. Plants from all treatments, including the Spotlight treatments, presented a normal appearance. In the vase-life test also, no damage or abnormalities were seen in any treatment. The flowers were normal for early-season forced 'Carlton', with some 'notching' of the petal margins and some small 'star-like' flowers. The analysis of variance showed that there were no significant effects of herbicide treatment on mean cropping date, duration of the cropping period, numbers of flowers obtained in total or in different length grades, flower diameter or vase-life.

Crop performance in subsequent field growing
At flowering foliage and flowers were checked for any abnormalities or damage. None was seen: plants in all treatments were of a normal appearance.

CONCLUSIONS

Herbicides

The overall pre-crop-emergence treatment, tank-mix CIPC + Linuron, was effective in controlling weeds in both crop years, few weeds emerging at the post-crop-emergence applications. However, this is not always the case and in commercial crops a residual herbicide may not always be sprayed.

In the first year of the trial Boxer (a.i. florasulam), a foliar-acting herbicide, was assessed on its own. No weeds emerged before post-crop-emergence treatments were applied on 9 and 24 February 2004 and it was not possible to assess the herbicide efficacy of Boxer. Weed numbers were very low, but weeds emerged on all plots, except those treated with Fortrol, during April. Fortrol, with residual activity, was the most effective treatment, controlling weeds throughout the flowering period, but this herbicide will not be available after December 2007. A tank-mix or programme of Boxer with residual herbicides was therefore necessary, and these were assessed in the next year.

In the second crop-year there was a similar pattern of weed emergence, with none at the first timing, and Boxer alone was applied at the second timing (before rapid bud growth) even though only chickweed had emerged. More weeds emerged at the end of March, by flower cropping time, and a further flush appeared in mid-April, possibly as a result of soil disturbance during cropping. The latter were at the cotyledon to seedling stage when weeds were counted on 20 April before the post-flower cropping application. The effects from the residual treatments, Fortrol, Stomp and Goltix, may have lasted until cropping, when soil disturbance will have reduced their effects. However, Fortrol, which has relatively short persistence, did not control late flushes of chickweed, Stomp did not control groundsel, and Goltix gave poor control of chickweed and polygonums. This demonstrates that a post-flower-cropping herbicide application is essential if bulbs are to remain weed-free until harvest.

In summary:

- Boxer appeared to be very safe to narcissus at all timings at 50ml/ha (half the normal dose rate recommended for cereals) either alone or in tank-mix. It was also safe at the cereal dose (100ml/ha), at all timings.
- Boxer should be applied after weeds emerge. It controls mayweeds, groundsel and volunteer rape and stunts creeping thistle, but fat-hen and small nettle are resistant (Appendix 1). For longer term control a tank-mix with a residual herbicide is needed at the early post-crop-emergence timing
- The best weed control, if weeds emerge late, was from the post-flower-cropping treatments: split dose Boxer 50 + 50ml, or 100ml, or tank-mix Flexidor 125 (2.0L) + Butisan S (2.5L) + Boxer (50ml).
- Applied when narcissus leaves were 7-10cm long, tank-mixes of Boxer with residual soil-acting herbicides Stomp (3.3L/ha) and Goltix (4kg/ha) were safe to narcissus. Further limited information suggests that tank-mixes with Sencorex (0.75kg/ha), Kerb (1.4kg/ha), Pyramin (2.0kg/ha + Goltix WG 2.0kg/ha) or Skirmish (1.0L/ha) were also safe.
- The post-flower cropping tank-mix Flexidor 125 (2.0L) + Butisan S (2.5L) + Boxer (50ml) was crop-safe.

Narcissus are usually grown as two- (or more) year-down crops, and it is important to test herbicide-treated bulbs for the absence of detrimental side-effects when they are forced under glass in winter following lifting from the field. Some herbicides are known to damage the flower bud, which in narcissus is initiated in the bulb in May, close to possible herbicide application dates. None of the herbicides tested adversely affected vase-life in field-cropped flowers, bulb yield or grade-out, foliage and flower appearance in the field in either year (or

subsequently in forcing or in field planting), or performance of forced bulbs (cropping date, flower yield, stem length, flower size or vase-life).

Pre-harvest desiccation

Some means of foliage removal is necessary when growing narcissus, since marketing requirements mean the bulbs must be lifted before the foliage has died down. The only desiccant approved, sulphuric acid, has the obvious disadvantages of requiring application by a specialist contractor and the stringent precautions that are necessary, while mechanical defoliation or burning have the disadvantages of being slow, causing damage to the remaining shoots just below ground level, and requiring specific equipment. Spotlight Plus is commercially available for use as a herbicide prior to planting any edible or non-edible crop and for weed control and defoliation in potatoes.

In the second crop-year of this project Spotlight Plus (a new formulation of carfentrazone-ethyl, 60g/L ME, that does not require the addition of a wetter) was applied at 1.0L/ha under ideal conditions and it was quick to take effect. In seven days it completely desiccated the crop and annual broad-leaved weeds and severely scorched large, established plants of willowherb and creeping thistle (often problem weeds in narcissus crops). Spotlight Plus may be less effective on chickweed (Belchim, personal communication), but in this trial chickweed was already senescing. Spotlight Plus had no effect on the few grass weeds present. The second Spotlight Plus application, 0.6L/ha seven days later, did not appear to be needed under the extant weather conditions. Narcissus leaves desiccated by Spotlight Plus were easily and cleanly detachable from the bulb, and bulb lifting was judged as improved, in comparison with flailing.

Spotlight Plus would appear to be an effective, cheaper alternative to sulphuric acid. It does not have the disadvantage of requiring application by a specialist contractor. However, it will not kill grasses.

Desiccants might affect flower quality when the bulbs are forced. As is commonplace, cracks appeared in the soil surface at the tops of ridges late in the season, so it would have been possible for Spotlight Plus to run down onto the bulbs. However, treatment with Spotlight Plus did not adversely affect bulb yield or grade-out, foliage and flower appearance in subsequent forcing or field planting, or performance of forced bulbs (cropping date, flower yield, stem length, flower size or vase-life).

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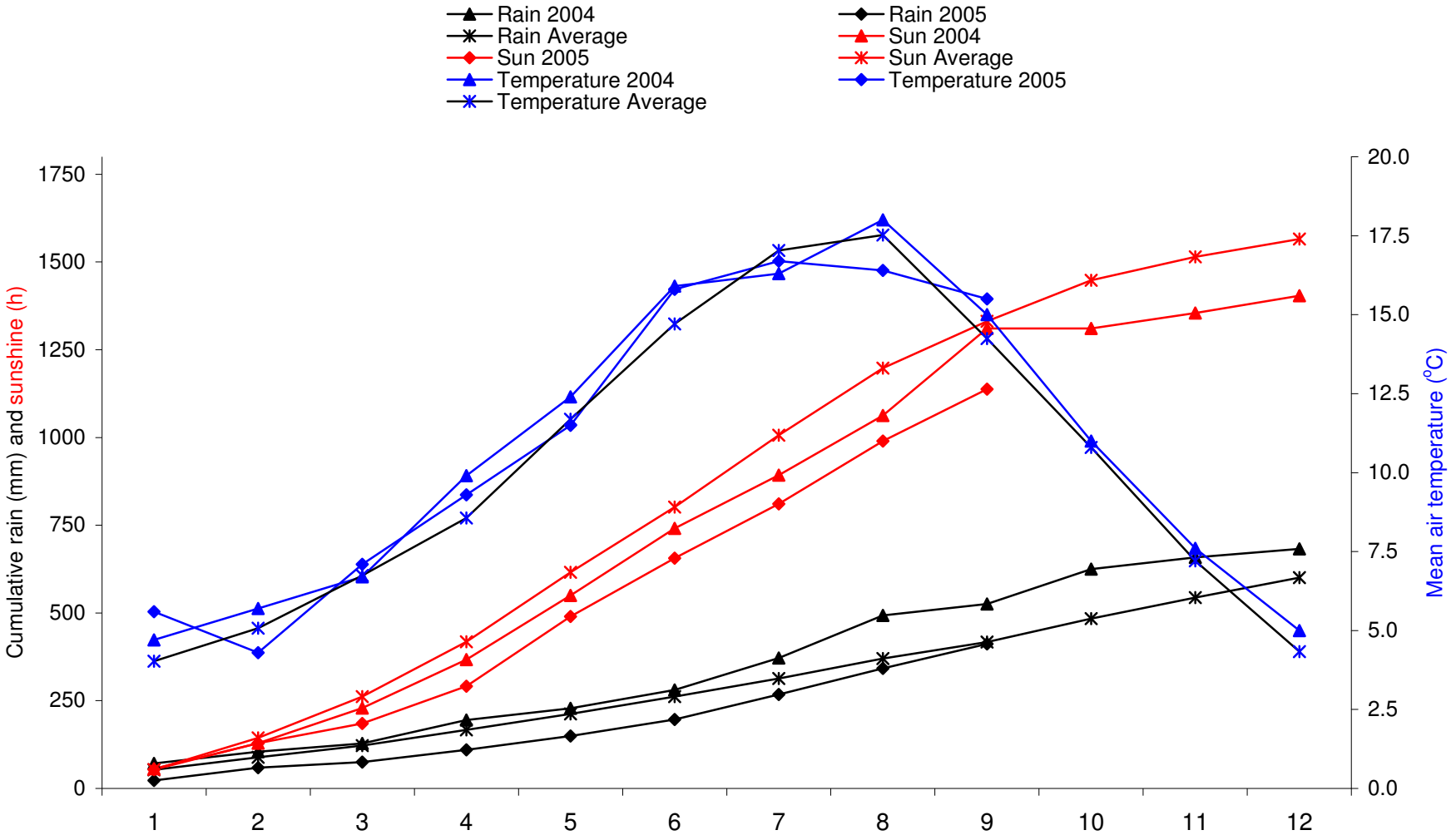
Figure 1. Monthly weather for 2004 and 2005 and 10-year averages (1993-2002)



APPENDIX 1: Weed susceptibility

Table A1. Weed susceptibility to pre-emergence herbicides (S = susceptible; MS = moderately susceptible; R = resistant; MR = moderately resistant).

Common name	*Latin name*	*Fortrol*	*Stomp*	*Stomp*	*Flexidor*	*Butisan*	*CIPC + linuron*	*Goltix*
	Dose rate L or kg/ha	*5.2*	*5.0*	*3.3*	*2.0*	*2.5*	*4.2+1.7*	*4.0kg*
Bindweed, black	*Fallopia convolvulus*	S	S			MS		S
Bugloss	*Anchusa arvensis*							
Charlock	*Sinapis arvensis*	S			S	MR	S	S
Chickweed, common	*Stellaria media*	S	S	S	S	S	S	S
Cleavers	*Galium aparine*		S		MR	MS	S	R
Corn marigold	*Chrysanthemum segetum*		S	S	S	S	S	S
Corn spurrey	*Spergula arvensis*				S	MS		S
Crane's-bill, cut-leaved	*Geranium dissectum*					MR		
Dead-nettle, henbit	*Lamium amplexicaule*		S	S				
Dead-nettle, red	*Lamium purpureum*	S	S	S	S	S	S	S
Dock, broad-leaved	*Rumex obtusifolius*							
Fat-hen	*Chenopodium album*	MS	S	S	S	MS	S	S
Fool's parsley	*Aethusa cynapium*	MR						S
Forget-me-not, field	*Myosotis arvensis*	S	S	S	S	S		S
Fumitory, common	*Fumaria officinalis*	MS	MS	MS		R	S	S
Gallant-soldier	*Galinsoga parviflora*							
Groundsel	*Senecio vulgaris*	S		R	MS	S	S	S
Hemp-nettle, common	*Galeopsis tetrahit*	S	S	S		MR	S	S
Knotgrass	*Polygonum aviculare*	MS	S	S	S	R	S	S
Mayweed, scented	*Matricaria recutita*	S	MS	MS	S	S	S	S
Mayweed, scentless	*Tripleurospermum inodorum*	S	MS	MS	S	S	S	S
Nettle, small	*Urtica urens*	S		S	S	MS	S	S
Nightshade, black	*Solanum nigrum*	MR	S				S	
Orache, common	*Atriplex patula*	S		S	S		S	S
Pansy, field	*Viola arvensis*	MS	S	S	S	MR		S
Parsley piert	*Aphanes arvensis*	S	S	S	S	S		S
Pennycress, field	*Thlaspi arvense*					R		S
Persicaria, pale	*Persicaria lapathifolia*	S						S
Pimpernel, scarlet	*Anagalis arvensis*	S	S	S	S		S	
Pineappleweed	*Matricaria discoidea*	S	MS	MS	S	S	S	S
Poppy, common	*Papaver rhoeas*	S	S	S	S	S		S
Redshank	*Persicaria maculosa*	S	S		S	MS	S	S
Shepherd's-purse	*Capsella bursa-pastoris*	S	S	MS	S	S	S	S
Sow-thistle, smooth	*Sonchus oleraceus*		S	S				S
Speedwell, field	*Veronica persica*	S	S	S		S	S	S
Speedwell, ivy-leaved	*Veronica hederifolia*	S	S	S	S	S	S	S
Sun spurge	*Euphorbia helioscopia*							
Thistle, creeping	*Cirsium arvense*							
Wild radish	*Raphanus raphanistrum*	S			S			
Annual meadow-grass	*Poa annua*	S	S	S		S	S	S
Black-grass	*Alopecurus myosuroides*	MS	S	S		S	S	
Brome, barren	*Anisantha sterilis*	S				MS		
Wild-oat	*Avena fatua*	R				MR	S	
Volunteer OSR		R	MS	MS	S	R		
Volunteer potatoes					S			

Table A2. Weed susceptibility to herbicides applied post-emergence (S = susceptible; MS = moderately susceptible; R = resistant; MR = moderately resistant)

Common name	*Boxer*	*Boxer*	*Sencorex*	*Sencorex*	*Basagran*	*Goltix**
Rate L or kg/ha:	*0.1*	*0.05*	*0.5kg*	*0.5kg*	*1.65kg*	*1.0 kg*
Bindweed, black	S		S	S	MS	MR
Bugloss			S	S		
Charlock	S	S	S	S	S	MS
Chickweed, common	S	S	S	S	S	S
Cleavers	S	S	R	R	S	R
Corn marigold	S		MS post-em	MS	S	S
Corn spurrey			S	S	S	S
Crane's-bill, cut-leaved					S	
Deadnettle, henbit			S	S	MS	
Dead-nettle, red			S	S	MS	MS
Dock, broad-leaved						S
Fat-hen	R		S	S	MS	S
Fool's parsley					S	S
Forget-me-not, field	S		S	S	S	S
Fumitory, common			S	S	MS	MS
Gallant-soldier						
Groundsel	S		S	S	MS	S
Hemp-nettle, common	S		S	S	MR	S
Knotgrass	MS		MS	MS	MR	S
Mayweed, scented	S	S	S	S	S	S
Mayweed, scentless	S	S	S	S	S	S
Nettle, small	R		S	S	S	S
Nightshade, black	S		MS	S	S	MR
Orache, common			S	S	MS	S
Pansy, field			MS	MS	R	S
Parsley piert	S				-	
Pennycress, field			S	S	S	S
Persicaria, pale			S	S	S	MS
Pimpernel, scarlet			S	S	S	MR
Pineappleweed	S				S	S
Poppy, common	MR				MS	S
Redshank			S	S	S	MS
Shepherd's-purse			S	S	S	S
Sow-thistle, smooth			MS	MS	MS	
Speedwell, field			S	S	MS	S
Speedwell, ivy-leaved			S	S	MR	MS
Sun spurge					-	S
Thistle, creeping			R		suppr	R
Wild radish			S	S	S	MR
Annual meadow-grass	S		S	S	R	S
Black-grass			MS	MS	R	
Brome, barren					R	
Wild-oat					R	
Volunteer oil-seed rape	S	S	S	S	S	
Volunteer potatoes						

* Applied early to weeds at cotyledon to 1 true-leaf stage

Table A3. Boxer and Spotlight Plus efficacy data.

Boxer (florasulam): susceptible weeds at 50ml product/ha*
Cleavers - up to 10cm
Chickweed - six true-leaves
Mayweeds - rosette stage
Volunteer OSR - four true-leaves
Charlock - four true-leaves.
*At 25ml product/ha the weed spectrum would be similar, though the weed sizes controlled would be smaller.
Boxer (florasulam): susceptible weeds at 100ml product/ha (the supported rate in cereals)
Cleavers – 20cm
Chickweed - flowering
Hedge mustard – 10cm
Mayweeds - flower buds visible
Shepherd's purse – 10cm
Volunteer OSR - flower buds visible
Runch – 10cm
Black-bindweed – 10cm
Black-nightshade – 5cm
Charlock - before flower buds visible
Corn marigold – up to rosette stage
Clover – 10cm
Forget-me-not – 10cm
Groundsel – 5cm
Hemp nettle - four true-leaves
Parsley piert – 10cm
Shepherd's needle – 10cm
Sow-thistle (annual) – 10cm
Thale cress - six true-leaves
Wild carrot - six true-leaves
Volunteer peas – 10cm
Weed beet - six true-leaves
Boxer (florasulam): resistant weeds at 100ml product/ha*
Fat-hen - R
Small (annual) nettle - R
Common poppy - MR
Knotgrass - MS
**R, resistant; MR, moderately resistant; MS, moderately susceptible)*
Spotlight Plus: susceptible weeds at desiccation stage
Fat-hen
Knotgrass
Redshank
Black-bindweed
Speedwells
Cleavers
Volunteer OSR
Volunteer potatoes (suppressed, but tubers not destroyed)
Spotlight Plus: resistant weeds at desiccation stage
Grasses