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OUTDOOR FLOWERS:
AN EVALUATION OF HERBICIDES

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Grower Summary

BOF 51

Outdoor flowers: An evaluation of herbicides

Headline

- **Centium + Stomp showed promise as an effective pre-emergence herbicide on a range of cut-flower species**
- **Goltix and Betanal (or Betanal Flow) showed potential for post-emergence use on cut-flower crops**
- **Ronstar or Raft were useful pre-transplanting soil treatments for flower crops**

Background and expected deliverables

Discussions with flower growers almost invariably highlight a need for advice on herbicides. There are very few herbicide recommendations for outdoor flower crops, since agrochemical companies do not consider the relatively small economic value of such specialist crops sufficient to justify the 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. The aim of this project is to identify herbicides suitable for use on a range of annual, seed-raised cut-flower species grown in the field.

Summary of the project and main conclusions

China aster (drilled)

- Pre-emergence Centium + Stomp gave good weed control without causing any crop damage.
- Post-weed-emergence Goltix and Betanal were safe for the crop, though in this instance weed control was poor.
- These results suggest that a programme needs to be developed, based on pre-emergence Centium + Stomp followed by a Betanal and (or) Goltix application on cotyledon-stage weeds, possibly using a higher rate of Betanal.

Cornflower (drilled)

- Pre-emergence Flexidor gave good weed control with no significant crop damage. Pre-emergence Centium + Stomp gave good weed control, initially causing crop damage from which the crop only partly recovered.
- Post-weed-emergence Goltix was very safe, prosulfocarb, Betanal and Linuron also gave reasonable or good weed control without serious crop damage.
- This suggests a programme based on pre-weed-emergence Flexidor, and possibly Stomp or Kerb mixtures, followed by Goltix. Cornflowers suppress weeds, thus a further herbicide application may not be necessary if good initial control is achieved.

Zinnia (drilled)

- Pre-emergence Centium + Stomp (tank mix) and Flexidor (alone) gave good weed control without crop damage. Kerb was also safe, but controlled only a limited weed spectrum.
- All post-weed-emergence treatments either failed to achieve good weed control or caused crop damage.
- This suggests using pre-weed-emergence Centium + Stomp, or Flexidor/Kerb mixtures, but an alternative post-weed-emergence is still needed.

Larkspur (drilled)

- Pre-emergence Centium + Stomp gave good weed control with negligible crop damage.
- Post-weed-emergence Betanal Flow application gave very little crop damage, but there was poor weed control due to weather conditions and late application.
- A useful programme would consist of pre-weed-emergence Centium + Stomp, followed by post-weed-emergence Betanal (or perhaps Goltix, which was not evaluated in this trial).

Bupleurum (drilled)

- Except for Centium + Stomp and Sencorex + Stomp (both Centium and Sencorex caused some crop damage), the pre-weed-emergence treatments gave good weed control without significant crop damage. Stomp + other partners could be considered.
- The post-weed-emergence treatments either failed to achieve good weed control or caused crop damage.
- Several materials could be used for pre-weed-emergence treatments, though CIPC 40 + Linuron is cheap and effective. Bupleurum is a vigorous plant and may suppress weeds, a further herbicide application may not be necessary if good initial control is achieved

China aster (transplanted)

- Both Ronstar and Raft pre-transplanting applications were safe and effective.
- Goltix and Betanal, applied early post-weed-emergence to small weeds, were safe and effective.
- Ronstar followed by Betanal would be a useful programme.

Snapdragon (transplanted)

- Both Ronstar and Raft pre-transplanting applications were effective and safe, causing only slight spotting on lower leaves after rain-splash.
- Of the pre-weed-emergence treatments evaluated, only Venzar was both safe to the crop while giving good weed control.
- Post-weed-emergence Goltix and Betanal were both damaging.
- Ronstar followed by Venzar would be a useful programme.

Stock (transplanted)

- Both Ronstar and Raft pre-transplanting applications were safe and effective.
- Pre-weed-emergence Decimate and Dacthal + Butisan and others were safe and effective, but Simazine caused severe crop damage

- Applied post-weed-emergence, Betanal caused more damage than Goltix. Goltix damage was at an acceptable level.
- There were slight (2 – 3cm) reductions in bunch length when Raft (pre-planting), Simazine or Stomp (post-transplanting), Goltix or Betanal Flow (post-emergence) were used, though several of these herbicides caused other crop damage.
- Ronstar pre-transplanting and Goltix post-weed-emergence would be a useful programme, with the addition of a pre-weed-emergence herbicide – the safest were Decimate and Dacthal + Butisan).

Delphinium (transplanted)

- Ronstar applied pre-transplanting was acceptably safe and effective.
- Decimate, Stomp and Stomp + Centium caused minor crop effects, but other materials were more damaging. All materials tested (except CIPC 40 + Linuron, and Simazine) showed a loss of weed control later in the season.
- Applied post-weed-emergence, Goltix or Betanal caused only slight crop damage and achieved good weed control, despite the relatively advanced stage of weed development. Boxer achieved effective weed control despite the low rate used but was too damaging.
- A suitable programme would be Ronstar pre-transplanting, Stomp (with or without Centium) or Decimate pre-weed-emergence, and Goltix and (or) Betanal post-weed-emergence.

Phlox (transplanted)

- Ronstar pre-transplanting caused minor crop damage and gave poor weed control.
- None of the materials applied pre- or post-weed-emergence was safe, and only CIPC 40 + Linuron produced effective weed control. Goltix and Betanal Flow were applied later than recommended because of adverse weather conditions.
- Phlox appeared to be a difficult species to treat, and further investigations are needed.

Financial benefits

While a full assessment of the benefits of this project must await the results of the second year's work, in which successful herbicide treatments will be incorporated into overall herbicide programmes, it is clear that several of the herbicides tested have the potential to ease weed problems in cut-flower crops.

Action points for growers

While noting that these results are the product of only one year's trial, a number of the crop/herbicide combinations could be tested (at the grower's risk) on small areas of commercial flower crops.

INTRODUCTION

The UK demand for cut-flowers is growing rapidly, and the production of flowers under low-cost polythene tunnels provides a real opportunity for UK growers. However, the lack of technical information for the wide diversity of traditional and novel species being grown is a major factor limiting expansion of the sector. Discussions with flower growers almost invariably highlight a need for advice on herbicides. There are very few herbicide recommendations for outdoor flower crops, since agrochemical companies do not consider the relatively small economic value of such specialist crops sufficient to justify the 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. The aim of this project is to identify herbicides free of phytotoxic effects (including height and yield reduction) and otherwise suitable for use on a range of annual, seed-raised cut-flower species grown in the field. This is the first year of a three-year project, and in future years the project will be concerned with developing and testing herbicide programmes, testing reduced-rate herbicides, testing further species and herbicide combinations as required, and testing herbicide applications under protection (in Spanish tunnels).

Excluding bulbs, corms and tubers, the area of cut-flower and foliage production in the UK in 2003 included 161ha under protection (including glasshouses and polythene structures) and 475ha in the open, a total of 636ha (Defra, 2004a, b). The crops grown include large numbers of fashionable flowers, and traditional species such as chrysanthemums. In addition, 17.6 million lily bulbs were grown under protection, many of which will be housed in polythene structures. This production in the open, and a significant proportion of that under protection, say 500 to 600ha in all, will require herbicide treatment. While herbicide application costings specific to outdoor or tunnel-grown cut-flower crops are not readily available, extrapolations might be made from recent data on another ornamental field-grown crop treated with a range of herbicides, narcissus (Briggs, 2002). In that case, average costs of £60/ha and £9/ha are suggested for herbicide and application costs, respectively, though the latter might be trebled for cut-flowers to account for relative cost-ineffectiveness of spraying small areas of crop. To make two herbicide applications *per annum*, on a cut-flower area of about 550ha, would therefore cost around £96k. With improved knowledge of the responses of cut-flower crops to a range of herbicides, the cost of ineffective treatments would be saved, while treatments that were effective would result in labour savings (reduced hand weeding) and a better quality crop.

Compared with arable or major field vegetable crops, very few herbicides carry specific recommendations for use on flowers. A literature survey of herbicides for ornamental crops was carried out in Australia in 1990 (Rogers & Barth, 1990), and an examination of this review and of other world scientific literature showed that little information exists that is relevant to outdoor or polytunnel cut-flower production in western Europe. The HDC previously funded herbicide trials on sweet William, chrysanthemum and larkspur (Projects BOF 29, 30 and 40, respectively; see Deen, 1999). A recent Defra-funded project (HH1528SPC) on tunnel-grown cut-flowers included testing a range of herbicide treatments on several species, considering mainly crop tolerance in the early stages of growth (Hanks *et al*., 2001; Meeks *et al*., 2001), and this provided useful guidance for the current project.

MATERIALS AND METHODS

Plant material and husbandry

The choice of species and growing systems was decided following discussions between consultants and HDC BOF Panel members. In 2003, seed of the following plants were either purchased (Hamer Flower Seeds Ltd, Swavesey, UK) or provided by courtesy of Park Lane Flowers:

- China aster (*Callistephus chinensis*; Compositae) cv. Matsumoto Purple-rose (D, T)
- Cornflower (*Centaurea cyanus*; Compositae) cv. Blue Ball (D)
- Zinnia (*Zinnia elegans*; Compositae) cv. Illumination (D)
- Larkspur (*Delphinium consolida*; Ranunculaceae) cv. Deep-blue (D)
- Bupleureum (*Bupleureum griffitti*; Umbelliferae) (D)
- Snapdragon (*Antirrhinum majus*; Scrophulariaceae) cv. Rocket F_1 Carmine (T)
- Stock (*Matthiola incana*; Cruciferae) cv. Lucinda Lilac-rose (T)
- Delphinium (*Delphinium* hybrids; Ranunculaceae) cv. Pacific Giant Blue Bird (T)
- Phlox (*Phlox drummondi*; Polemoniaceae) cv. Dolly Deep-rose (T)

The flowers marked (D) or (T) above were either direct-drilled in the field, or were raised in cellular trays and later transplanted to the field, respectively.

The trial site was on a medium silty marine alluvial soil at Warwick HRI, Kirton, Boston, Lincolnshire, and was typical of the South Lincolnshire agricultural area where outdoor cut-flower crops are widely grown. The site had previously supported flower crops grown with minimal herbicide use, and previous cultivation in two directions was expected to give a reasonably uniform weed population typical of the area. Prior to setting up the trial the site was deep-ploughed, ploughed, cultivated and treated with a contact herbicide (diquat + paraquat) when needed. Standard soil sampling (0-15cm depth) across the site gave the following analysis: pH 7.1, nitrate index 0, P index 4, K index 2-, Mg index 3 and conductivity index 0. According to MAFF fertiliser recommendations, 100kgN/ha and 150 kg$K_2$0/ha (as 290kg ammonium nitrate (34.5%N)/ha and 300kg sulphate of potash (50%$K_2$0)/ha) were applied and ploughed in.

The crops were grown in beds 1.2m-wide and at 1.8m centres. The drilled and transplanted crops were in separate but adjacent areas of the field. Before drilling or transplanting three beds were allocated randomly for each crop. The beds for China aster (both drilled and transplanted), snapdragon and stocks only received a top-dressing of fertiliser (2.0kg sulphate of potash and 0.7kg ammonium nitrate per 100m^2) which was then raked into the soil surface. Plots 4.0m long along the beds, with 1.0m unplanted (guard) areas between plots, were allocated and labelled. Drilled crops were sown by hand in four rows 30cm apart along the beds, aiming for a density of about one plant every 5cm along the rows.

The raising of transplanted crops was done in '308' cellular trays using a fine propagation compost (Scotts Levington F1), germinating and growing the trays in a Venlo glasshouse at ambient temperatures and ventilated at 8°C. Standard husbandry was applied. During plant raising, plants were treated with fosetyl-aluminium (as Aliette 80 WG) and tolclofos-methyl (as Basilex) to control damping-off and other fungal diseases. Plants were transplanted by hand into six rows 20cm apart along the bed and with a spacing of 20cm in each row. Sowing and transplanting dates were as shown in Table 1 and 2.

In the field the following preventative spray programme was applied:

- pirimicarb + deltamethrin at 10-14 day intervals against aphids and caterpillars
- iprodione and chlorothalonil alternated at 10-14 day intervals against *Botrytis*, powdery mildew, etc.

All fungicides and insecticides were used at standard rates and according to label or other recommendations.

Crops were irrigated using a standard irrigation boom. Water was applied as required to establish all crops, and thereafter 25mm irrigation was applied as required to maintain soil conditions appropriate for effective herbicide action. Irrigation dates (other than for establishment) are shown in Tables 1 and 2, and (with rainfall data) in Figure 2. Meteorological data were obtained from the Kirton weather station, sited *ca.* 50m from the trial site. Pertinent weather data for the year of the trial are given in Figure 1, along with 10-year (1993-2002) averages. Figure 1 shows that 2003 was warmer and sunnier than average; June and July were somewhat wetter than average, and August and September somewhat drier (see also Figure 2). With the exception of cornflower and bupleurum, which emerged quickly, the other drilled crops were slower to emerge than the high population of weeds (which were then too advanced to achieve good control with the low doses of Betanal & Goltix applied at the 2-true leaves stage). There was rainfall soon after most residual soil-acting herbicides were applied and the wetter than average June and July (and irrigation) also enhanced herbicidal activity but also increased the risk of crop damage.

<u>Herbicide treatments</u>

Herbicide treatments were agreed on a crop-by-crop basis, taking account of previous experiences and other relevant information, including the perceived future availability of active ingredients and formulations. There was no attempt to produce a design 'balanced' across crops and herbicides. The emphasis was on assessing simple individual herbicide treatments, not whole herbicide programmes, the interpretation of which might be complex to interpret in the first year of the project; more complex treatments will be used in the later years of the project. Also, in the first year all herbicides were tested at a standard rate.

Herbicide treatments covered pre-emergence and post-crop-emergence timings for direct-drilled crops, and pre-transplanting and post-transplanting (pre- and post-weed-emergence) timings for transplanted crops. The treatment combinations are shown in Table 3 (drilled crops) and Table 4 (transplanted crops). The treatments listed provided a total of 104 herbicide x crop combinations. Known weed susceptibilities of the herbicides used are given in Table 5. The current legal status of the materials are listed in Table 6; note that the Long-Term Arrangements for Extension of Use (LTAEU) for non-edible crops including flowers will be reviewed before the end of 2004. The LTAEU must eventually be replaced by approval for a specific use.

Herbicide treatments were allocated randomly within each bed, and crops were arranged in three replicate blocks in order to eliminate effects due to local variations across the field. Trial layouts were approved by a senior HRI biometrician. Following accepted practice, additional plots were left untreated with herbicides and either (a) hand-weeded or (b) entirely untreated; this allowed weed control and the effects of herbicides and of competition on crop vigour to be assessed.

After reaching the appropriate stage of weed and crop development, herbicides were applied as soon as weather conditions permitted. In practice, some post-emergence Goltix and Betanal Flow applications (see Tables 3-12) were given after the recommended stage for weed treatment. Herbicides were applied using an 'Oxford' precision sprayer along the beds, with a medium spray quality for pre-emergence applications and a fine spray quality for post-em (cotyledon) weeds. Herbicides were applied in 200 litres water per ha. Tables 1 and 2 give the dates of spraying, and the growth stages of crops and weeds and weather conditions on the days sprays were applied.

Table 1. Diary of operations and sprays for drilled crops.

Crop	*Operation*	*Date (2003)*		*Weather (temperatures are mean daily values)*	*Growth stage*[1]	
		Date	*Day no.*		*Crop*	*Weeds*
China aster	Sown	13 May	133	-	-	-
	Pre-emergence sprays	15 May	135	Heavy cloud, light shower later, 9ºC	-	-
	Mean emergence	27 May	147	-	-	-
	Irrigate	30 May	150	-	-	-
	Irrigate	02 June	153	-	-	-
	Post-emergence sprays	12 June	163	Cloudy, dry, 17ºC	2TL	Small plant
	Irrigate	20 June	171			
	Irrigate	18 July	199	-	-	-
	Main cropping date	19 Sep	262	-	-	-
Cornflower	Sown	13 May	133	-	-	-
	Pre-emergence sprays	15 May	135	Heavy cloud, light shower later, 9ºC	-	-
	Mean emergence	19 May	139	-	-	-
	Post-emergence sprays	26 May	146	Heavy cloud, dry, 12ºC	2-3TL	Cot.-2TL
	Irrigate	30 May	150	-	-	-
	Irrigate	02 June	153	-	-	-
	Irrigate	20 June	171			
	Main cropping date	16 July	197	-	-	-
Zinnia	Sown	13 May	133			
	Pre-emergence sprays	15 May	135	Heavy cloud, light shower later, 9ºC	-	-
	Mean emergence	27 May	147	-	-	-
	Irrigate	30 May	150	-	-	-
	Irrigate	02 June	153	-	-	-
	Post-emergence sprays	12 June	163	Cloudy, dry, 17ºC	2TL	Small plant
	Irrigate	20 June	171			
	Irrigate	18 July	199	-	-	-
	Main cropping date	04 Aug	216	-	-	-
Larkspur	Sown	13 May	133	-	-	-
	Pre-emergence sprays	15 May	135	Heavy cloud, light shower later, 9ºC	-	-
	Mean emergence	5 June	156	-	-	-
	Irrigate	30 May	150	-	-	-
	Irrigate	02 June	153	-	-	-
	Post-emergence sprays	12 June	163	Cloudy, dry, 17ºC	2TL	Small plant
	Irrigate	20 June	171			
	Irrigate	18 July	199	-	-	-
	Main cropping date	15 Aug	227	-	-	-
Bupleurum	Sown	13 May	133	-	-	-
	Pre-emergence sprays	15 May	135	Heavy cloud, light shower later, 9ºC	-	-
	Mean emergence	30 May	150	-	-	-
	Irrigate	30 May	150	-	-	-
	Irrigate	02 June	153	-	-	-
	Post-emergence sprays	03 June	154	Cloudy, dry, 15ºC	2TL	1-3TL
	Irrigate	20 June	171			
	Irrigate	18 July	199	-	-	-
	Main cropping date	18 Aug	230	-	-	-

[1]Cot, cotyledon stage; TL, true leaves.

Table 2. Diary of operations and sprays for transplanted crops.

Crop	*Operation*	*Date (2003)*		*Weather (temperatures are mean daily values)*	*Growth Stage*[1]	
		Date	*Day no.*		*Crop*	*Weeds*
China aster	Sown	05 June	156	-	-	-
	Pre-planting sprays	09 July	190	Cloudy, dry, 20ºC	-	none
	Transplanted	10 July	191	-	-	-
	Irrigate	19 July	200	-	-	-
	Post-emergence sprays	28 July	209	Light cloud, shower later, 17ºC	established	Cot – 1TL
	Irrigate	07 Aug	219	-	-	-
	Main cropping date	22 Sep	265	-	-	-
Snapdragon	Sown	05 June	156	-	-	-
	Pre-planting sprays	15 July	196	Light cloud, dry, 21ºC	-	none
	Transplanted	16 July	197	-	-	-
	Post-planting sprays	22 July	203	Cloudy, dry, 18ºC	-	none
	Irrigate	19 July	200	-	-	-
	Post-emergence sprays	28 July	209	Light cloud, shower later, 17ºC	established	Cot – 1TL
	Irrigate	07 Aug	219	-	-	-
	Main cropping date	05 Sep	248	-	-	-
Stock	Sown	20 May	140	-	-	-
	Pre-planting sprays	09 July	190	Cloudy, dry, 20ºC	-	none
	Transplanted	10 July	191	-	-	-
	Irrigate	19 July	200	-	-	-
	Post-planting sprays	22 July	203	Cloudy, dry, 18ºC	-	none
	Post-emergence sprays	28 July	209	Light cloud, shower later, 17ºC	established	Cot – 1TL
	Irrigate	07 Aug	219	-	-	-
	Main cropping date	04 Sept	247	-	-	-
Delphinium	Sown	20 May	140	-	-	-
	Irrigate	19 July	200	-	-	-
	Pre-planting sprays	22 July	203	Cloudy, dry, 18ºC	-	None
	Transplanted	23 July	204	-	-	-
	Post-planting sprays	28 July	209	Light cloud, shower later, 17ºC	-	Cot – 1TL
	Post-emergence sprays	05 Aug.	217	Cloudy, dry, 21ºC	5TL	3TL
	Irrigate	07 Aug	219	-	-	-
	Main cropping date	-	-	-	-	-
Phlox	Sown	05 June	156	-	-	-
	Irrigate	19 July	200	-	-	-
	Pre-planting sprays	28 July	203	Light cloud, shower later, 17ºC	-	Cot – 1TL
	Transplanted	29 July	210	-	-	-
	Post-planting sprays	05 Aug.	217	Cloudy, dry, 21ºC	-	2-3TL
	Irrigate	07 Aug	219	-	-	-
	Post-emergence sprays	08 Aug.	220	Heavy cloud, dry, 22ºC	established	Small plant

[1]Cot, cotyledon stage; TL, true leaves.

Records

As well as frequent *ad hoc* examinations, the following formal assessments were made:

- Crop and weed seedling stage of development at the time of treatments
- Crop tolerance (i.e. phytotoxic symptoms and crop stand) was assessed on two occasions using the scores given in the table below

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 a material reduction in yield or quality at cropping)
8	10 – 20% damage
9	5 – 10% damage
10	No damage (as untreated controls)

- Percentage weed control: an estimate was made of the percentage of the soil area between crop plants covered by weeds. Weed control was then expressed as this figure subtracted from 100.
- Weed species present were recorded at monthly intervals
- Except for treatments where the flowers were overwhelmed by weeds, or the flowers were damaged to a point of unmarketability by the treatment, three bunches of ten stems were cropped from each plot at a commercial cropping stage. Bunch weights and overall bunch length were recorded. Bunches from all cropped treatments were lined up and assessed visually for quality, compared with the hand-weeded controls. The presence of any adverse effects, such as small, damaged or fewer flowers, weak stems or chlorotic foliage, was recorded.

Table 3. Herbicide treatments applied to the five direct-drilled crops in 2003. Treatments represented as grey boxes were not used.

Ref.	*Product name and (a.i. and %)*	*Rate*	*Stage*	*Aster*	*Cornflower*	*Zinnia*	*Larkspur*	*Bupleurum*	*Notes*
1	Control – no treatment	-	-	1	1	1	1	1	-
2	Control – hand-weeded	-	-	2	2	2	2	2	-
3	Dacthal W-75 (chlorthal-dimethyl 75%w/w)	9.0 kg/ha	Pre-em weed/crop		3	3	3		-
4	Kerb Flo (propyzamide 400g/l)	2.1 l/ha	Pre-em weed/crop		4	4			-
5	Centium 360 CS + Stomp 400 SC (clomazone 360g/l + pendimethalin 400g/l)	0.25 l/ha +3.3 l/ha	Pre-em weed/crop	5	5	5	5	5	Apply Stomp soon after drilling
6	Stomp 400 SC (pendimethalin 400g/l)	5.0 l/ha	Pre-em weed/crop					6	Apply Stomp soon after drilling
7	Stomp 400 SC + Sencorex WG (pendimethalin 400g/l + metribuzin 70%w/w)	3.3 l/ha +0.5 kg/ha	Pre-em weed/crop					7	Apply Stomp soon after drilling
8	Flexidor 125 (isoxaben 125g/l)	1.0 l/ha	Pre-em weed/crop		8	8		8	-
9	CIPC 40 + Ashlade Linuron FL (chlorpropham 400g/l + linuron 480g/l)	4.2 l/ha +1.7 l/ha	Pre-em weed/crop					9	-
10	Prosulfocarb product (prosulfocarb 800g/l)	5.0 l/ha	Post-em crop	10	10	10	10	10	Product name not yet known
11	Boxer (florasulam 50g/l)	50 or 100 ml/ha	Post-em crop	11 50ml	11 50ml	11 50ml	11 100ml	11 100ml	-
12	Sencorex WG (metribuzin 70%w/w)	0.75 kg/ha	Post-em crop				12	12	Apply before weed 1 true leaf
13	Goltix WG (metamitron 70%w/w)	1.7 kg/ha	Post-em crop	13	13	13		13	For cotyledon weeds
14	Betanal Flow (phenmedipham 160g/l)	1.8 l/ha	Post-em crop	14	14	14	14	14	For cotyledon weeds
15	Ashlade Linuron FL (linuron 480g/l)	1.0 l/ha	Post-em crop	15	15	15	15	15	-

Table 4. Herbicide treatments applied to the five transplanted crops in 2003. Treatments represented as grey boxes were not used.

Ref.	*Product name and (a.i. and %)*	*Rate*	*Stage*	*Aster*	*Snapdragon*	*Stocks*	*Delphinium*	*Phlox*	*Notes*
16	Control – no treatment	-	-	16	16	16	16	16	-
17	Control – hand-weeded	-	-	17	17	17	17	17	-
18	Ronstar Liquid (oxadiazon 250g/l)	4.0 l/ha	Pre-plant	18	18	18	18	18	-
19	Raft 400 SC (oxadiargyl 400g/l)	1.0 l/ha	Pre-plant	19	19	19			-
20	Simazine or Gesatop (various products) (simazine 500g/l)	1.5 l/ha	Post-plant & Pre-weed-em		20	20	20	20	-
21	Decimate (chlorthal-dimethyl + propachlor 225:216g/l)	10.0 l/ha	Post-plant & Pre-weed-em			21	21		-
22	Dacthal W-75 + Butisan S (chlorthal-dimethyl 75%w/w + metazachlor 500g/l)	9.0 kg/ha + 1.5 l/ha	Post-plant & Pre-weed-em		22	22	22		-
23	Stomp 400 SC (pendimethalin 400g/l)	3.3 l/ha	Post-plant & Pre-weed-em			23	23	23	-
24	Stomp 400 SC + Centium 360 CS (pendimethalin 400g/l + clomazone 360g/l)	3.3 l/ha + 0.25 l/ha	Post-plant & Pre-weed-em			24	24	24	-
25	CIPC 40 + Linuron 50 (chlorpropham 400g/l + linuron 500g/l)	4.2 l/ha + 1.7 l/ha	Post-plant & Pre-weed-em		25		25	25	-
26	Venzar Flowable (lenacil 440g/l)	4.0 l/ha	Post-plant & Pre-weed-em		26			26	-
27	Prosulfocarb product (prosulfocarb 800g/l)	5.0 l/ha	Post-weed em	27					Product name not yet known
28	Boxer (florasulam 50g/l)	25 or 50 ml/ha	Post-weed em	28 50ml			28 25ml		-
29	Goltix WG (metamitron 70% w/w)	1.7 kg/ha	Post-weed em	29	29	29	29	29	For cotyledon weeds
30	Betanal Flow (phenmedipham 160g/l)	1.8 l/ha	Post-weed em	30	30	30	30	30	For cotyledon weeds
31	Sencorex WG (metribuzin 70%w/w)	0.75 kg/ha	Post-weed em				31		Before weed 1 true leaf

Figure 1. Monthly weather data for 2003 and 10-year averages (1993-2002)

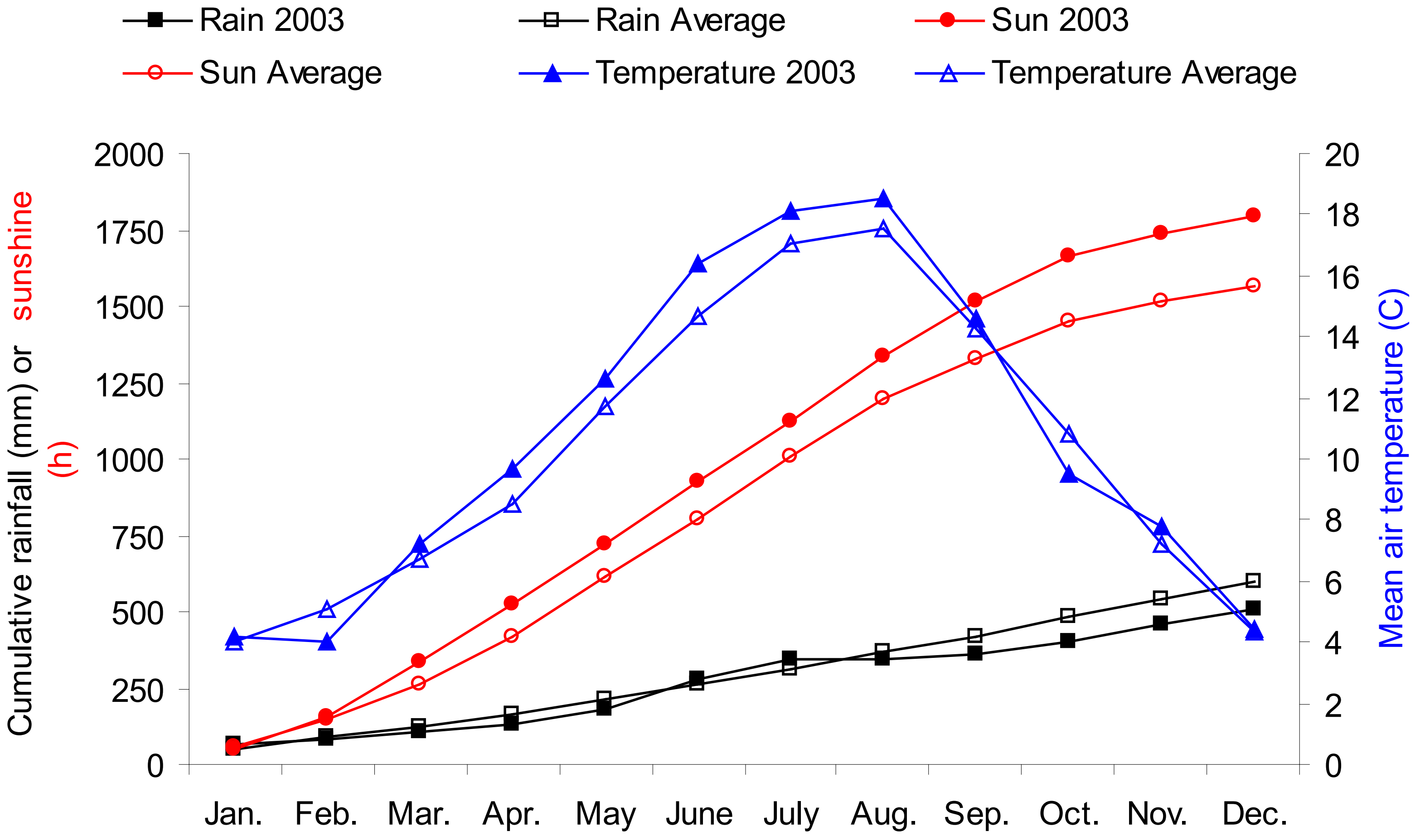


Figure 2. Rainfall and irrigation data for 2003 trials (see Tables 1 and 2 irrigation dates for drilled or transplanted)

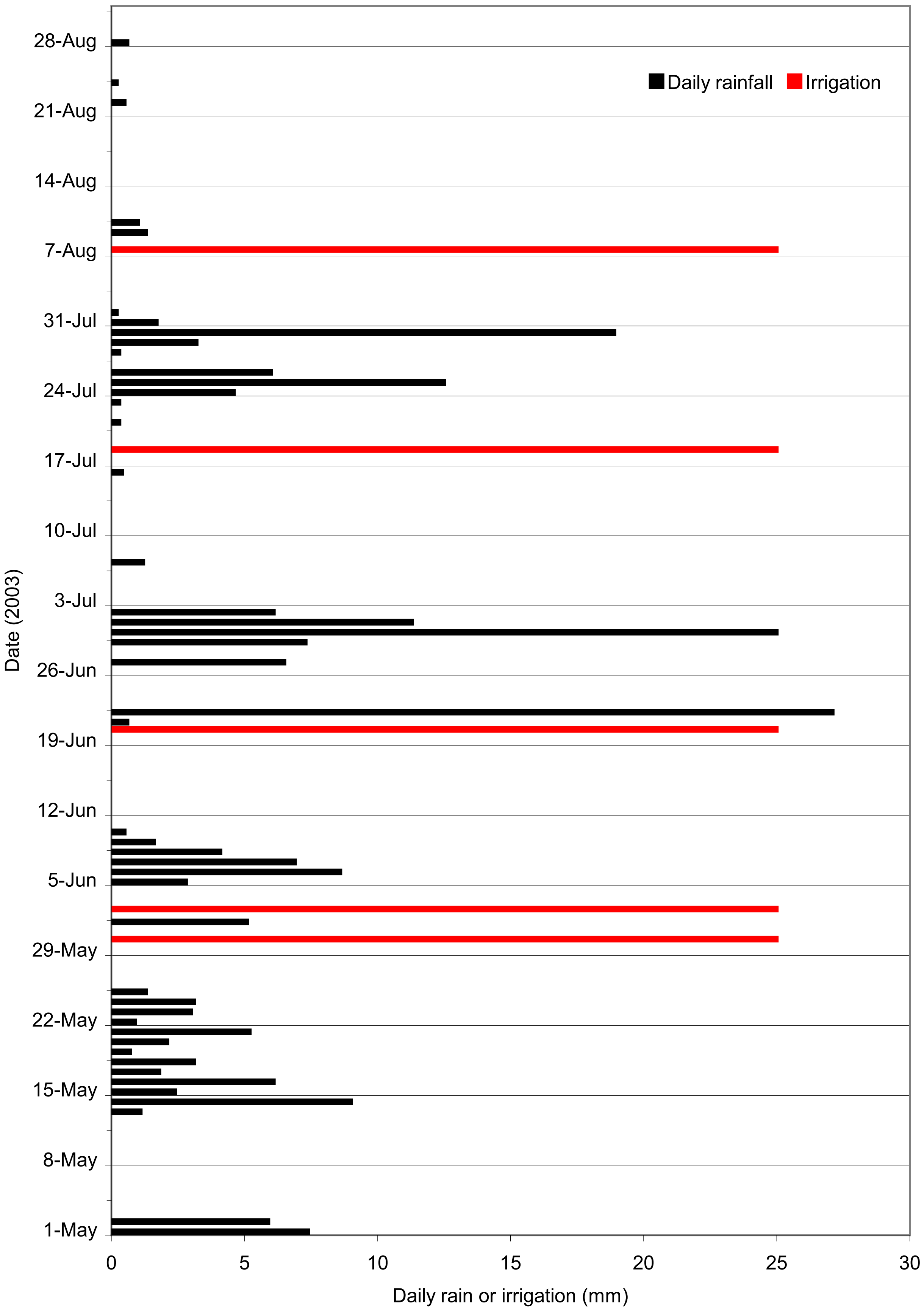


Table 5. Weed susceptibility to the herbicides used in the project, compiled from the registration holders' labels and other information. Raft is not listed, but has a similar weed spectrum to Ronstar. Only limited data are available for prosulfocarb. Herbicide rates shown are litre/ha unless otherwise stated. Key: S, susceptible; MS, moderately susceptible; R, resistant; MR, moderately resistant; blanks mean no data are available.

Common name	*Dacthal 9.0 kg*	*Kerb 2l/ha*	*Stomp+Centium 2.0 + 0.25*	*Stomp 5.0*	*Flexidor 2.0*	*CIPC + linuron 4.2+1.7*	*Venzar 4.0*	*Decimate 10.0*	*Butisan 1.5*	*Ronstar 4.0*	*Prosulfocarb 5.0*	*Boxer 0.1*	*Boxer 0.05*	*Sencorex 0.5kg*	*Goltix# 1.0 kg*	*Betanal# 1.5*	*Linuron 1.0*
Bindweed, black	MS	S	S	S			S	MS		S		S		S	MR	MS	S
Bugloss														S			MR
Charlock	MR	S	MS		S	S	S	MR		S		S	S	S	MS		S
Chickweed, common	S	S	S	S	S	S	S	S	S	R		S	S	S	S	S	S
Cleavers		MS	S	S	MR	S	S	S	MR			S	S	R	R	MR	R
Corn marigold	R			S	S	S	S	S				S		MS	S		R
Corn spurrey					S		S	S		S				S	S		S
Crane's-bill, cut-leaved									MR							R	
Deadnettle, henbit				S										S			
Dead-nettle, red	MS		S	S	S	S	MS	S	S	S				S	MS	S	MR
Dock(seedling), broad-lved															S		
Fat-hen	S	S	S/MS	S	S	S	MS	S		S		R	R	S	S	S	S
Fool's parsley			S												S		
Forget-me-not, field				S	S				S			S		S	S	MR	S
Fumitory, common	R	MS	MS	MS		S	S	R	R		S			S	MS	S	R
Gallant-soldier	R							S									S
Groundsel	R	R	S		MS	S	MS	S	S	S	R	S		S	S	S	MR
Hemp-nettle, common	S			S		S	R			R		S		S	S	S	S
Knot-grass	S	S	MS	S	S	S	S	S	R	S		R	R	MS	S	S	MR
Mayweed, scented	R	R	S/MS	MS	S	S	S	S	S	S	R	S	S	S	S		R
Mayweed, scentless	R	R	S/MS	MS	S	S	S	S	S	S	R	S	S	S	S	MS	R
Nettle, small	S	S			S	S	MS	S		S				S	S	S	S
Nightshade, black	MS	S	S	S		S	R	S				S		S	MR		MR
Orache, common	MS				S	S	S							S	S	S	S
Pansy, field	S		MS	S	S		R	S	R					MS	S	S	S
Parsley piert				S	S				S			S					
Pennycress, field	R						S	R	R					S	S	MS	S
Persicaria, pale			MS				S							S	MS	S	S
Pimpernel, scarlet	S			S	S	S	S			R				S	MR	S	S
Pineappleweed		R		MS	S	S				S	R	S			S		R
Poppy, common	S			S	S		S		MS						S	S	S
Redshank	MR	S		S	S	S	S	MS		S				S	MS	S	S
Shepherd's-purse	R		S	S	S	S	S	S	S	S				S	S	S	S
Sow-thistle, smooth			MS	S			S	MS		S				MS		R	S
Speedwell, common, field	S	S	MS	S		S	MS	S		S				S	S	S	S
Speedwell, ivy-leaved	R			S	S	S	R			S				S	MS	MS	
Sun spurge										S					S		
Thistle, creeping		R	R												R		R
Wild radish	R		MS		S		S	R		S				S	MR	S	S
Annual meadow-grass	MS	S	S	S		S		S	S			S		S	S	R	MR
Black-grass		S		S		S	R		S	R				MS			
Brome, barren		S															
Wild-oat		S				S											R
Volunteer oil-seed rape		R		MS	S							S	S	S			

Table 6. Status of the herbicides used in this project (as of July 2004).

Product name	*a.i. and formulation*	*Marketing company*	*EC Review of a.i.*	*Approval for outdoor flowers*
Dacthal W-75	chlorthal-dimethyl 75%w/w	Certis	supported	UK several flowers
Kerb Flo	propyzamide 400g/l	Dow Agrosciences etc.	Annex 1	UK ornamentals LTAEU
Centium 360 CS	clomazone 360g/l	Belchim	supported	UK some vegetables LTAEU
Stomp 400 SC	pendimethalin 400g/l	BASF etc.	Annex 1	UK some vegetables LTAEU
Sencorex WG	metribuzin 70%w/w	Bayer CropScience	supported	UK some vegetables LTAEU
Flexidor 125	isoxaben 125g/l	Landseer etc.	supported	UK some vegetables LTAEU
CIPC 40	chlorpropham 400g/l	Nufarm Whyte etc.	Annex 1	UK some vegetables LTAEU
Ashlade Linuron FL	linuron 480g/l	Several	Annex 1	UK some vegetables LTAEU
Ronstar Liquid	oxadiazon 250g/l	Certis	supported	UK ornamentals LTAEU
-	oxadiargyl 400g/l	Bayer CropScience	Annex 1	No UK registration yet
Gesatop	simazine 500g/l	Syngenta etc.	Failed Annex 1	UK ornamentals use until 2005
Decimate	chlorthal-dimethyl/ propachlor 225/216g/l	Certis	supported/ supported	UK some vegetables LTAEU
Butisan S	metazachlor 500g/l	BASF etc.	supported	UK some vegetables LTAEU
Venzar Flowable	lenacil 440g/l	Dupont etc.	supported	UK ornamentals LTAEU
-	prosulfocarb 800g/l	Syngenta	supported	To be registered for UK wheat
Boxer	florasulam 50g/l	Dow Agrosciences	Annex 1	UK cereals LTAEU
Goltix WG	metamitron 70%w/w	Makhteshim	supported	UK sugarbeet etc. LTAEU
Betanal Flow	phenmedipham 160g/l	Several	Annex 1	UK sugarbeet etc. LTAEU

RESULTS

There were no obvious differences in the visual quality of stems cropped from the hand-weeded controls and from the successful herbicide treatments, nor were there any statistically significant reductions in bunch weight due to herbicide treatments. There were statistically, but probably not commercially, significant reductions in bunch length of 2 – 3cm in stock when Raft (pre-planting), Simazine or Stomp (post-transplanting), or Goltix or Betanal Flow (post-emergence) had been used, and several of these materials were found to cause other crop damage (see below). In transplanted China aster the use of prosulfocarb resulted in bunches an average of 4cm shorter than in hand-weeded controls, but this material also would not be used because of other adverse effects (see below).

China aster (drilled) (see Figure 3)

- Pre-emergence Centium + Stomp gave good weed control without causing any crop damage.
- Post-weed-emergence Goltix and Betanal were safe for the crop, though in this instance weed control was poor – China aster was slow to emerge and weeds were beyond the cotyledon or one true-leaf stage by the time conditions allowed sprays to be applied.
- These results suggest that a programme needs to be developed, based on pre-emergence Centium + Stomp followed by a Betanal and (or) Goltix application on cotyledon-stage weeds, possibly using a higher rate of Betanal.

Cornflower (drilled) (see Figure 4)

- Pre-emergence Flexidor gave good weed control with no significant crop damage. Pre-emergence Centium + Stomp gave good weed control, initially causing crop damage from which the crop only partly recovered.
- Post-weed-emergence Goltix was very safe, prosulfocarb, Betanal and Linuron also gave reasonable or good weed control without serious crop damage.
- This suggests a programme based on pre-weed-emergence Flexidor, and possibly Stomp or Kerb mixtures, followed by Goltix. Cornflowers have rapid, vigorous growth and suppress weeds, thus a further herbicide application may not be necessary if good initial control is achieved.

Zinnia (drilled) (see Figure 5)

- Pre-emergence Centium + Stomp (tank mix) and Flexidor (alone) gave good weed control without crop damage. Kerb was also safe, but controlled only a limited weed spectrum.
- All post-weed-emergence treatments either failed to achieve good weed control or caused crop damage. In some cases this may have been due to a delay in applications owing to weather conditions.
- This suggests using pre-weed-emergence Centium + Stomp, or Flexidor/Kerb mixtures, but an alternative herbicide post-weed-emergence is still needed.

Larkspur (drilled) (see Figure 6)

- Pre-emergence Centium + Stomp gave good weed control with negligible crop damage.
- Post-weed-emergence Betanal Flow application gave very little crop damage, but there was poor weed control due to weather conditions and late application.
- A useful programme would consist of pre-weed-emergence Centium + Stomp, followed by post-weed-emergence Betanal (or perhaps Goltix, which was not evaluated in this trial).

Bupleurum (drilled) (see Figure 7)

- Except for Centium + Stomp and Sencorex + Stomp (both Centium and Sencorex caused some crop damage), the pre-weed-emergence treatments gave good weed control without significant crop damage. Stomp + other partners could be considered.
- The post-weed-emergence treatments either failed to achieve good weed control (in some cases because of late application) or caused crop damage.
- Several materials could be used for pre-weed-emergence treatments, though CIPC 40 + Linuron is cheap and effective. Bupleurum is a vigorous plant and may suppress weeds, thus a further herbicide application may not be necessary if good initial control is achieved

China aster (transplanted) (see Figure 8)

- Both Ronstar and Raft pre-transplanting applications were safe and effective.
- Goltix and Betanal, applied early post-weed-emergence to small weeds, were safe and effective.
- Ronstar followed by Betanal would be a useful programme.

Snapdragon (transplanted) (see Figure 9)

- Both Ronstar and Raft pre-transplanting applications were effective and safe, causing only slight spotting on lower leaves after rain-splash.
- Of the pre-weed-emergence treatments evaluated, only Venzar was both safe to the crop while giving good weed control.
- Post-weed-emergence Goltix and Betanal were both damaging.
- Ronstar followed by Venzar would be a useful programme.

Stock (transplanted) (see Figure 10)

- Both Ronstar and Raft pre-transplanting applications were safe and effective.
- Pre-weed-emergence Decimate and Dacthal + Butisan and others were safe and effective, but Simazine caused severe crop damage
- Applied post-weed-emergence, Betanal caused more damage than Goltix. Goltix damage was at an acceptable level.
- Ronstar pre-transplanting and Goltix post-weed-emergence would be a useful programme, with the addition of a pre-weed-emergence application - the safest were Decimate and Dacthal + Butisan.

Delphinium (transplanted) (see Figure 11)

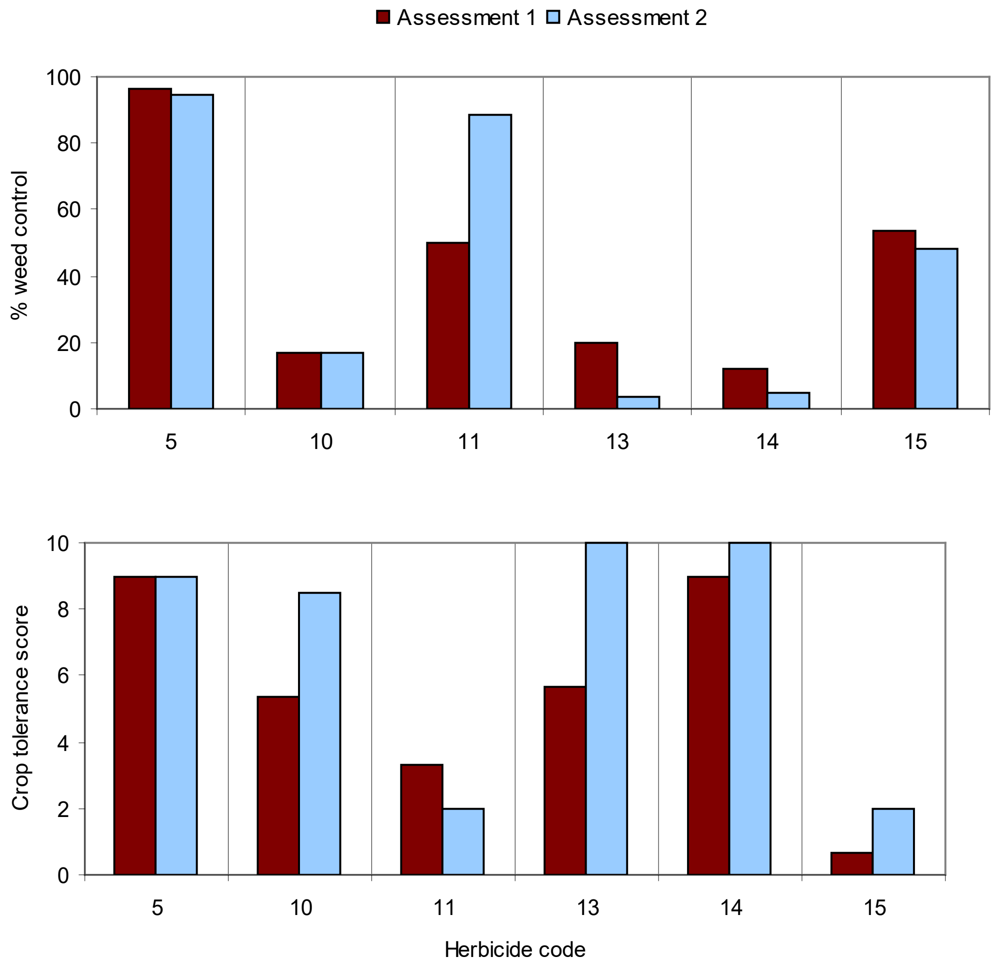
- Ronstar applied pre-transplanting was acceptably safe and effective.
- Decimate, Stomp and Stomp + Centium caused minor crop effects, but other materials were more damaging. All materials tested (except CIPC 40 + Linuron, and Simazine) showed a loss of weed control later in the season.
- Applied post-weed-emergence, Goltix or Betanal caused only slight crop damage and achieved good weed control, despite the relatively advanced stage of weed

development. Boxer achieved effective weed control despite the low rate used but was too damaging.
- A suitable programme would be Ronstar pre-transplanting, Stomp (with or without Centium) or Decimate pre-weed-emergence, and Goltix and (or) Betanal post-weed-emergence.

Phlox (transplanted) (see Figure 12)

- Weeds were present when phlox was transplanted, so weed control was poor
- Ronstar pre-transplanting caused minor crop damage and gave poor weed control.
- None of the materials applied pre- or post-weed-emergence was safe, and only CIPC 40 + Linuron produced effective weed control. Goltix and Betanal Flow were applied later than recommended.
- Phlox appears to be a difficult species to treat, and further investigations are needed.

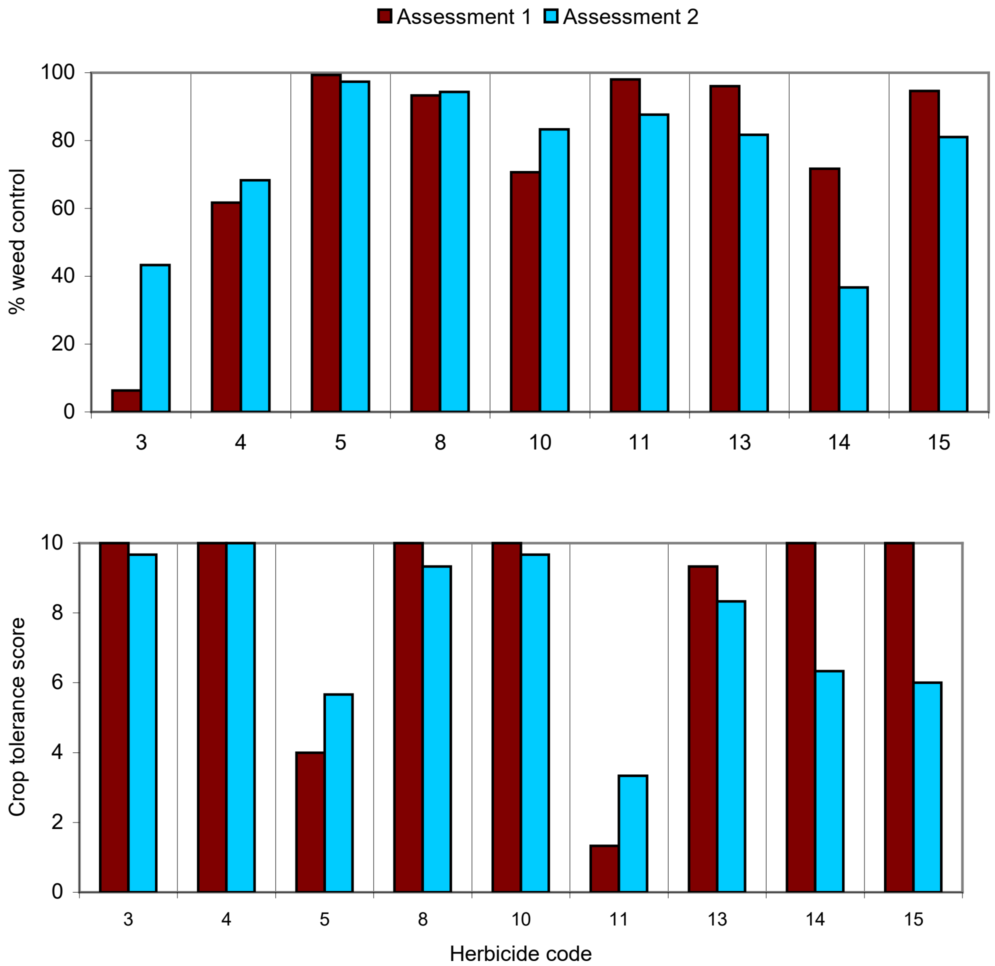
Figure 3. Crop and weed profile for drilled China aster (2003) on two assessment dates (weeks 25 and 27). Percentage weed control assessed from 0% (total weed cover) to 100% (total weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.**



Ref.	Herbicide timing	Herbicide	Crop damage	Weeds not controlled
5	Pre-weed-em.	Centium 360 CS + Stomp 400 SC	None	Annual meadow-grass, groundsel
10	Post-weed-em.	Prosulfocarb	Blackening, distortion, chlorosis and scorch initially.	Chickweed, groundsel, mayweed, nettle, shepherd's purse
11	Post-weed-em.	Boxer	Chlorosis, scorch and wilting. Crop death	Deadnettle, fumitory, annual meadow-grass, speedwell
13	Post-weed-em.	Goltix WG*	Chlorosis and scorch initially, crop recovered	Chickweed, groundsel, mayweed, nettle, shepherd's purse
14	Post-weed-em.	Betanal Flow*	None, except mild chlorosis initially	Chickweed, groundsel, annual meadow-grass, mayweed, nettle, shepherd's purse
15	Post-weed-em.	Ashlade Linuron FL	Scorch damage initially, proving lethal.	Groundsel, mayweed, nettle, shepherd's purse

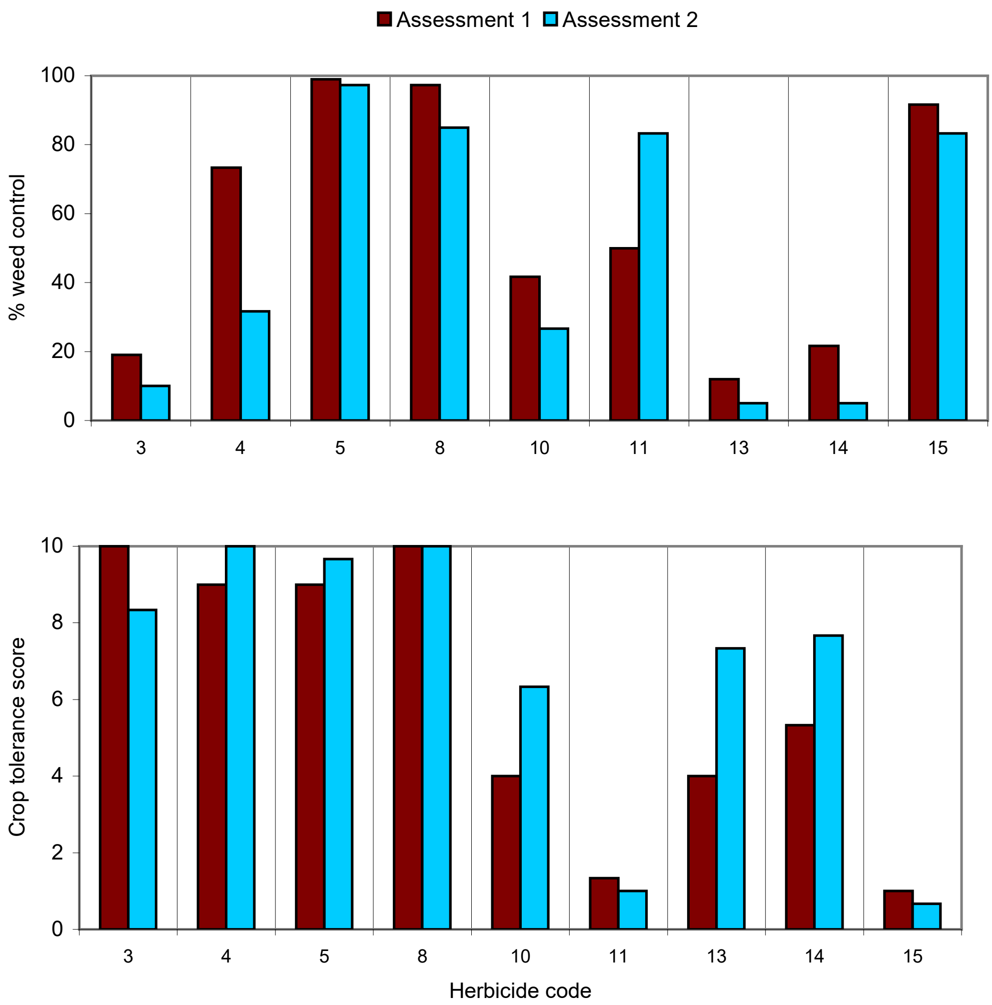
* Weeds beyond the recommended cotyledon – 1TL stage

Figure 4. Crop and weed profile for drilled cornflower (2003) on two assessment dates (weeks 25 and 27). Percentage weed control assessed from 0% (total weed cover) to 100% (total weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.**



Ref.	Herbicide timing	Herbicide	Crop damage	Weeds not controlled
3	Pre-weed-em	Dacthal W-75	None	Annual meadow-grass, groundsel, mayweeds, shepherd's purse
4	Pre-weed-em	Kerb Flo	None	Groundsel, mayweeds
5	Pre-weed-em.	Centium 360 CS + Stomp 400 SC	Initial bleaching of 50% leaf area. Plants recovered, but 10% height reduction, some delay in flowering, chlorosis	Annual meadow-grass, groundsel
8	Pre-weed-em.	Flexidor 125	Slight stunting and delay	Groundsel
10	Post-weed-em.	Prosulfocarb	Initial distortion and necrosis, crop recovered	Groundsel, mayweeds
11	Post-weed-em.	Boxer	Cotyledon chlorosis, first true leaf burnt off. Wilting, 30% height reduction	Groundsel
13	Post-weed-em.	Goltix WG	Slight chlorosis, stunting and delay	Chickweed, groundsel, knot-grass, mayweeds, redshank, shepherd's purse
14	Post-weed-em.	Betanal Flow	Slight chlorosis and stunting	Chickweed, annual meadow-grass, groundsel, mayweeds, nettle, shepherd's purse
15	Post-weed-em.	Ashlade Linuron FL	Slight chlorosis, stunting and delay	Annual meadow-grass, groundsel, knot-grass, mayweeds

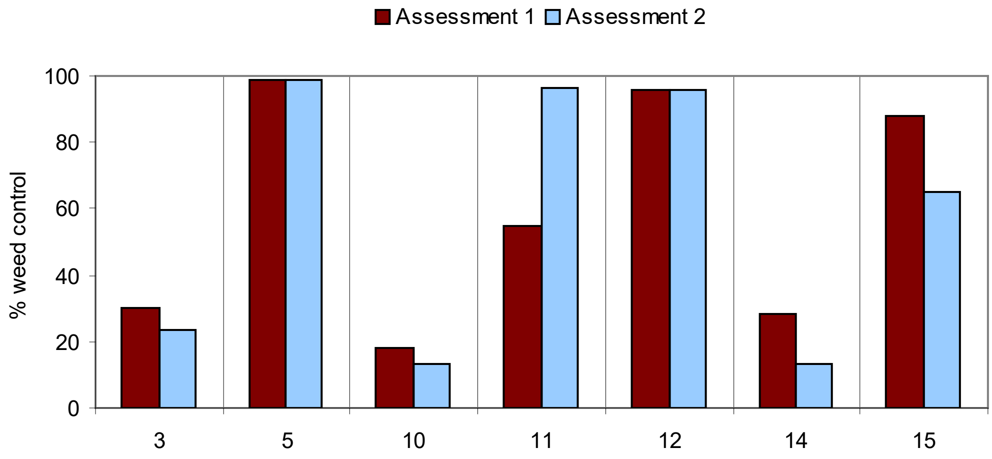
Figure 5. Crop and weed profile for drilled zinnia (2003) on two assessment dates (weeks 25 and 27). Percentage weed control assessed from 0% (total weed cover) to 100% (total weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.**

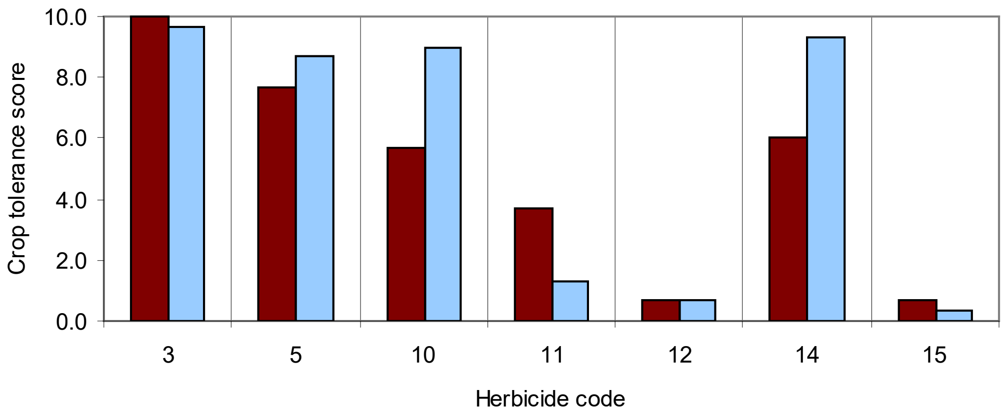


Ref.	Herbicide timing	Herbicide	Crop damage	Weeds not controlled
3	Pre-weed-em.	Dacthal W-75	Slight chlorosis	Grounsel, mayweed, shepherd's purse
4	Pre-weed-em.	Kerb Flo	None significant	Groundsel, mayweed
5	Pre-weed-em.	Centium 360 CS + Stomp 400 SC	None significant	Groundsel, sow-thistle
8	Pre-weed-em.	Flexidor 125	Initial slight chlorosis, recovering	Annual meadow-grass, groundsel, nettle
10	Post-weed-em.	Prosulfocarb	Necrosis and stunting	Chickweed, groundsel, mayweed, shepherd's purse
11	Post-weed-em.	Boxer	Severe chlorosis and wilting, death	Dead nettle, annual meadow grass, knotgrass, speedwell
13	Post-weed-em.	Goltix WG*	Chlorosis and necrosis	Chickweed, groundsel, mayweed, nettle, shepherd's purse
14	Post-weed-em.	Betanal Flow*	Chlorosis and necrosis	Chickweed, annual meadow-grass, groundsel, mayweed, nettle, shepherd's purse
15	Post-weed-em.	Ashlade Linuron FL	Much of crop killed	Groundsel, knotgrass, mayweed

* Weeds beyond the recommended cotyledon – 1TL stage

Figure 6. Crop and weed profile for drilled larkspur (2003) on two assessment dates (weeks 25 and 27). Percentage weed control assessed from 0% (total weed cover) to 100% (total weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.**

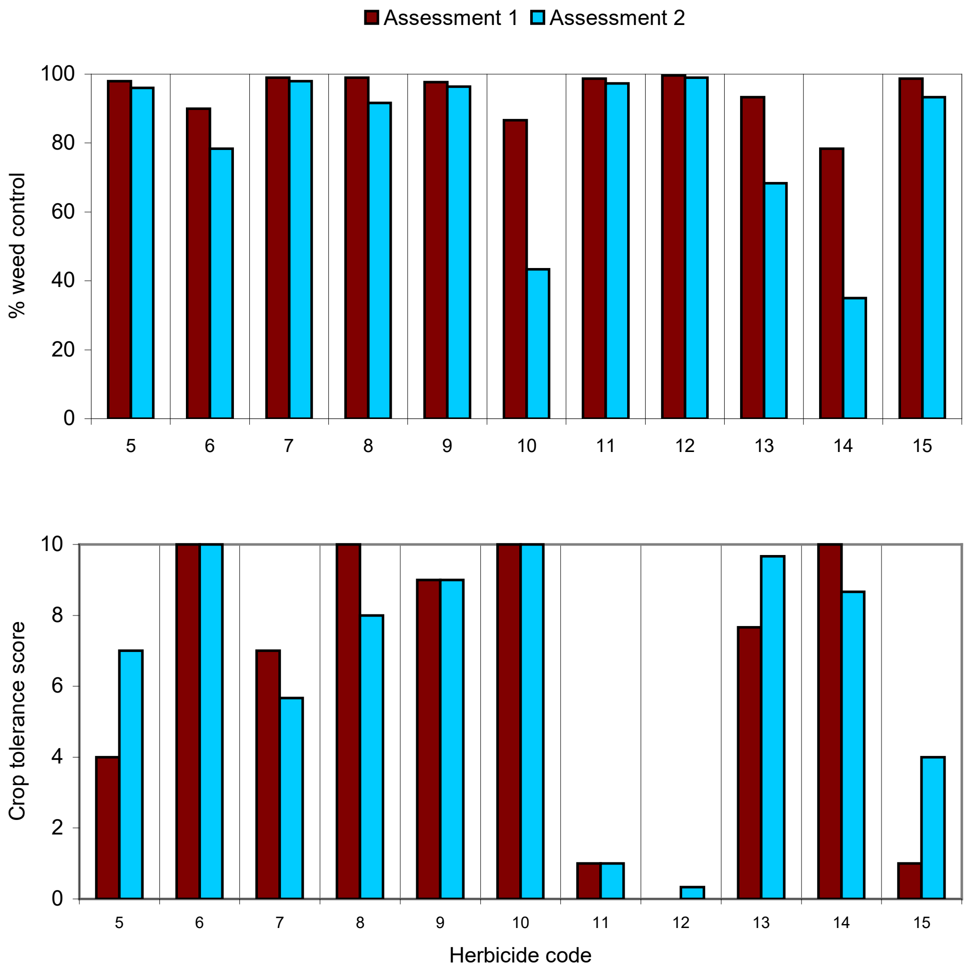




Ref.	Herbicide timing	Herbicide	Nature of crop damage	Weeds not controlled
3	Pre-weed-em	Dacthal W-75	Initially slight chlorosis	Grounsel, mayweed, shepherd's purse,
5	Pre-weed-em.	Centium 360 CS + Stomp 400 SC	Cotyledons scorched. Slight stunting and distortion from Stomp initially	Annual meadow-grass, groundsel
10	Post-weed-em.	Prosulfocarb	Initial slight scorch	Chickweed, grounsel, mayweed, poppy, shepherd's purse
11	Post-weed-em.	Boxer	Chlorosis, wilting, crop death	Annual meadow-grass, knotgrass, poppy speedwell
12	Post-weed-em.	Sencorex WG	Scorched, crop death	Charlock, groundsel, shepherd's purse
14	Post-weed-em.	Betanal Flow*	Initially slight scorch	Chickweed, groundsel, mayweed, nettle, shepherd's purse
15	Post-weed-em.	Ashlade Linuron FL	Crop death	Groundsel, mayweed

* Weeds beyond the recommended cotyledon – 1TL stage.

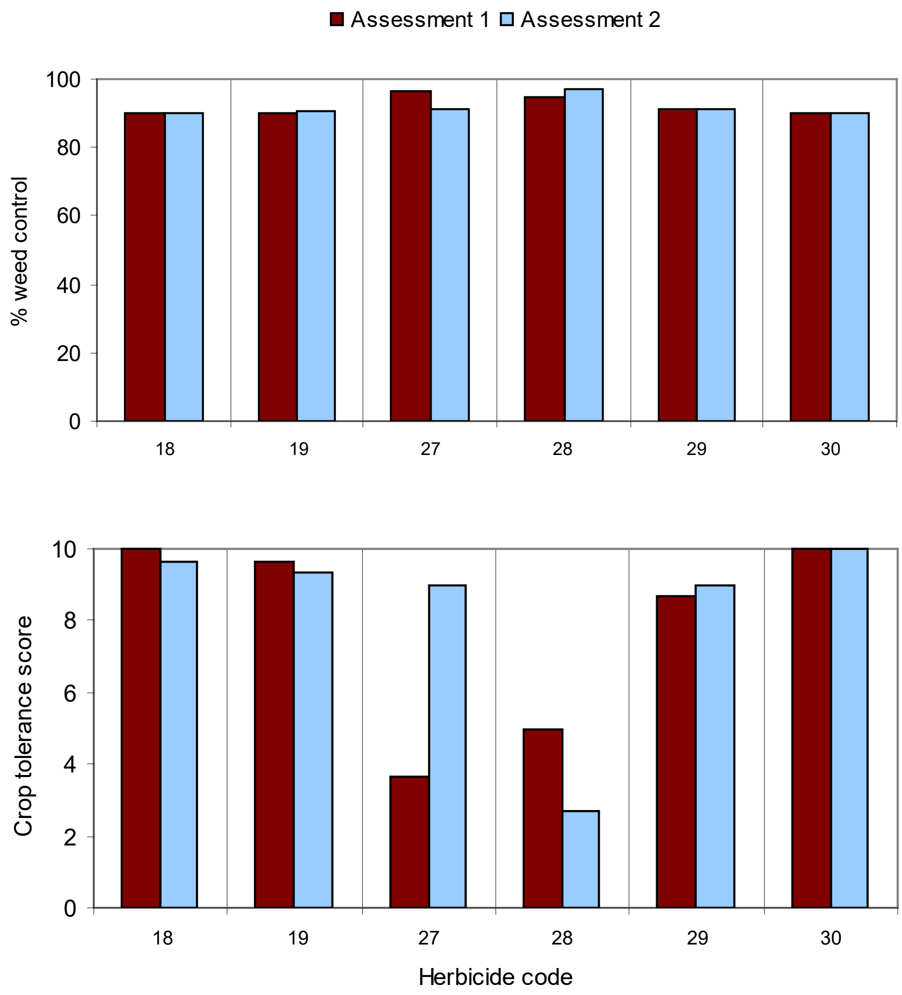
Figure 7. Crop and weed profile for drilled bupleurum (2003) on two assessment dates (weeks 25 and 27). Percentage weed control assessed from 0% (total weed cover) to 100% (total weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.**



Ref.	Herbicide timing	Herbicide	Crop damage	Weeds not controlled
5	Pre-weed-em.	Centium 360 CS + Stomp 400 SC	Leaf chlorosis and bleaching	Groundsel,
6	Pre-weed-em.	Stomp 400 SC	None but slight delay flowering	Groundsel
7	Pre-weed-em.	Stomp 400 SC + Sencorex WG	Some scorch, stunting and delay	-
8	Pre-weed-em.	Flexidor 125	None	Chickweed, annual meadow grass, groundsel, nettle
9	Pre-weed-em.	CIPC 40 + Ashlade Linuron FL	Some initial scorch, slight stunting and delay	-
10	Post-weed-em.	Prosulfocarb	None	Chickweed, groundsel, mayweed, nettle, pale persicaria
11	Post-weed-em.	Boxer	Chlorosis, wilting, death	Dead-nettle, annual meadow grass, knot-grass
12	Post-weed-em.	Sencorex WG	Crop death	-
13	Post-weed-em.	Goltix WG*	Some initial yellowing and scorch	Chickweed, groundsel, nettle, shepherd's purse, sow-thistle
14	Post-weed-em.	Betanal Flow*	Slight chlorosis	Chickweed, groundsel, mayweed, nettle, shepherd's purse, sow-thistle
15	Post-weed-em.	Ashlade Linuron FL	Crop stunted, death	Annual meadow grass, groundsel, knotgrass, mayweed

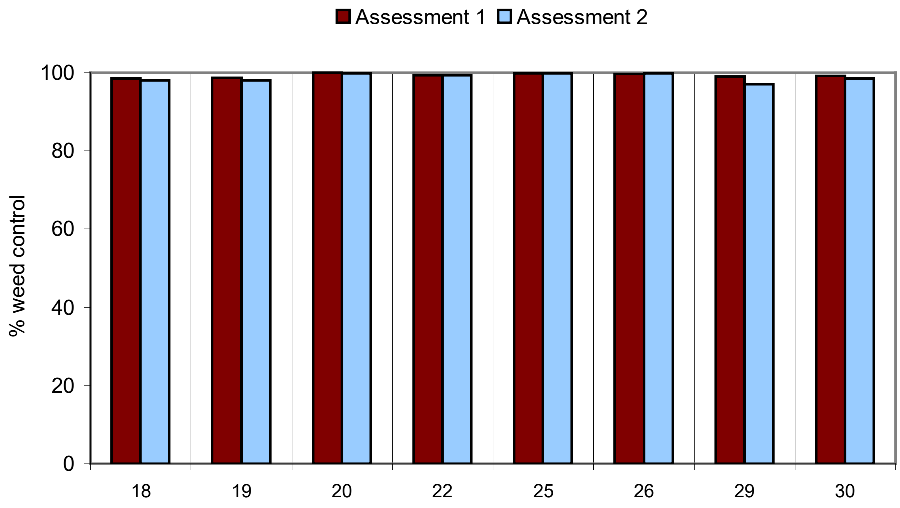
* Some weeds beyond the recommended cotyledon – 1TL stage.

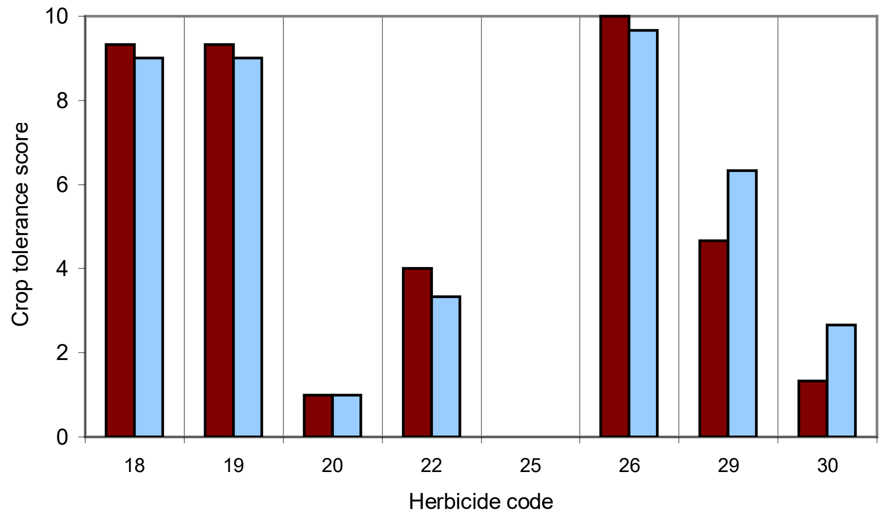
Figure 8. Crop and weed profile for transplanted China aster (2003) on two assessment dates (weeks 33 and 36). Percentage weed control assessed from 0% (total weed cover) to 100% (total weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.**



Ref.	Herbicide timing	Herbicide	Crop damage	Weeds not controlled
18	Pre-plant	Ronstar Liquid	None	Chickweed
19	Pre-plant	Raft 400 SC	None	Chickweed,
27	Post-weed-em.	Prosulfocarb	Stunting, slight blackening and distortion	Chickweed, groundsel
28	Post-weed-em.	Boxer	Severe stunting and wilting. Growing point damage, no flowers	Annual meadow-grass, chickweed, fat hen, groundsel, nettle, shepherd's purse, sow-thistle, speedwell
29	Post-weed-em.	Goltix WG	Slight stunting, thinning	Black nightshade, chickweed, , annual meadow-grass, nettle, shepherd's purse
30	Post-weed-em.	Betanal Flow	None	Chickweed, annual meadow-grass, groundsel, knotgrass, nettle, red shank, shepherd's purse

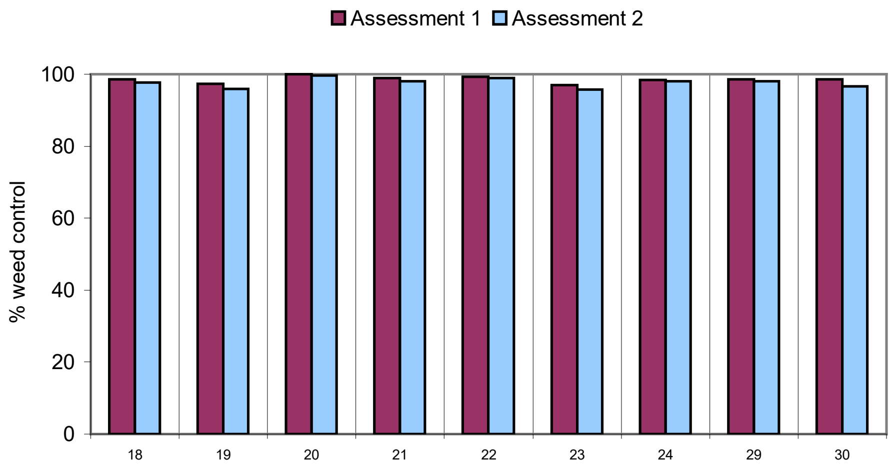
Figure 9. Crop and weed profile for transplanted snapdragon (2003) on two assessment dates (weeks 33 and 36). Percentage weed control assessed from 0% (total weed cover) to 100% (total weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.**

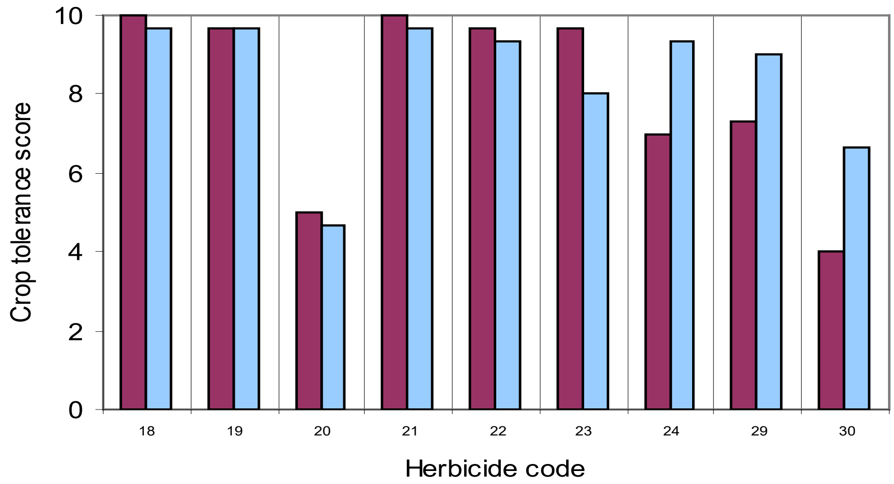




Ref.	Herbicide timing	Herbicide	Crop damage	Weeds not controlled
18	Pre-plant	Ronstar Liquid	Initial lower leaf spotting.	Chickweed
19	Pre-plant	Raft 400 SC	Initial lower leaf spotting.	Chickweed
20	Pre-weed-em.	Simazine	Scorch, death	
22	Pre-weed-em.	Dacthal W-75 + Butisan S	Severe stunting, leaves turned down, delayed flowering	
25	Pre-weed-em.	CIPC 40 + Linuron 50	Crop death	
26	Pre-weed-em.	Venzar Flowable	None	Groundsel
29	Post-weed-em.	Goltix WG	Lower leaves necrotic, stunting. Delayed flowering	Black nightshade, chickweed, annual meadow-grass, nettle, shepherd's purse
30	Post-weed-em.	Betanal Flow	Scorched and some dead plants. Some plants surviving but late and stunted. Delayed flowering	Chickweed, annual meadow-grass, groundsel, knotgrass, mayweed, nettle, shepherd's purse

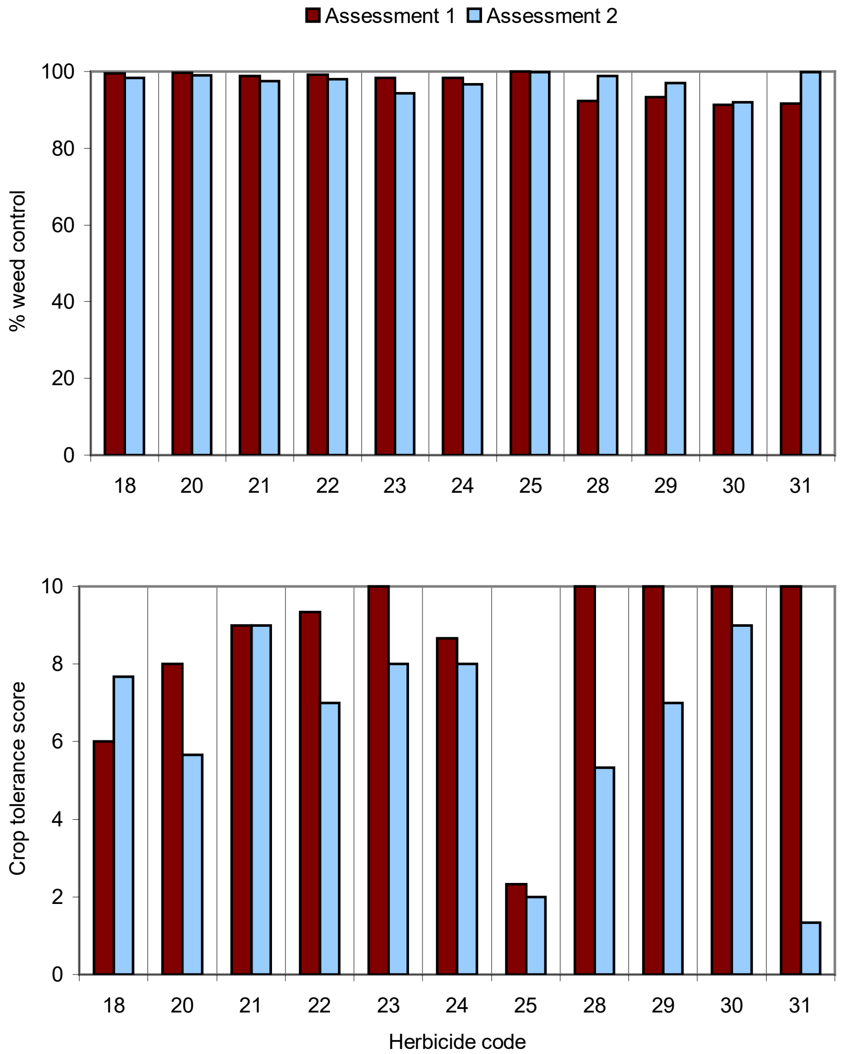
Figure 10. Crop and weed profile for transplanted stock (2003) on two assessment dates (weeks 33 and 36). Percentage weed control assessed from 0% (total weed cover) to 100% (total weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.**





Ref.	Herbicide timing	Herbicide	Crop damage	Weeds not controlled
18	Pre-plant	Ronstar Liquid	None	Chickweed
19	Pre-plant	Raft 400 SC	None	Chickweed
20	Pre-weed-em.	Simazine	Stunting and necrosis. No flowering	
21	Pre-weed-em.	Decimate	None	Chickweed, grass, groundsel, shepherd's purse
22	Pre-weed-em.	Dacthal W-75 + Butisan S	Slight stunting	Groundsel, knotgrass, redshank
23	Pre-weed-em.	Stomp 400 SC	Initial stunting, distortion and growing point damage	Groundsel
24	Pre-weed-em.	Stomp 400 SC + Centium 360 CS	Slight stunting, growing point distortion (Stomp), slight bleaching (Centium)	Groundsel
29	Post-weed-em.	Goltix WG	Leaf tip scorch, slight stunting and delay	Black nightshade, annual meadow-grass, groundsel, nettle, sow-thistle, speedwell
30	Post-weed-em.	Betanal Flow	Stunting, chlorosis. Necrotic lower leaves	Chickweed, annual meadow-grass, groundsel, mayweed, nettle, shepherd's purse, sow-thistle, speedwell

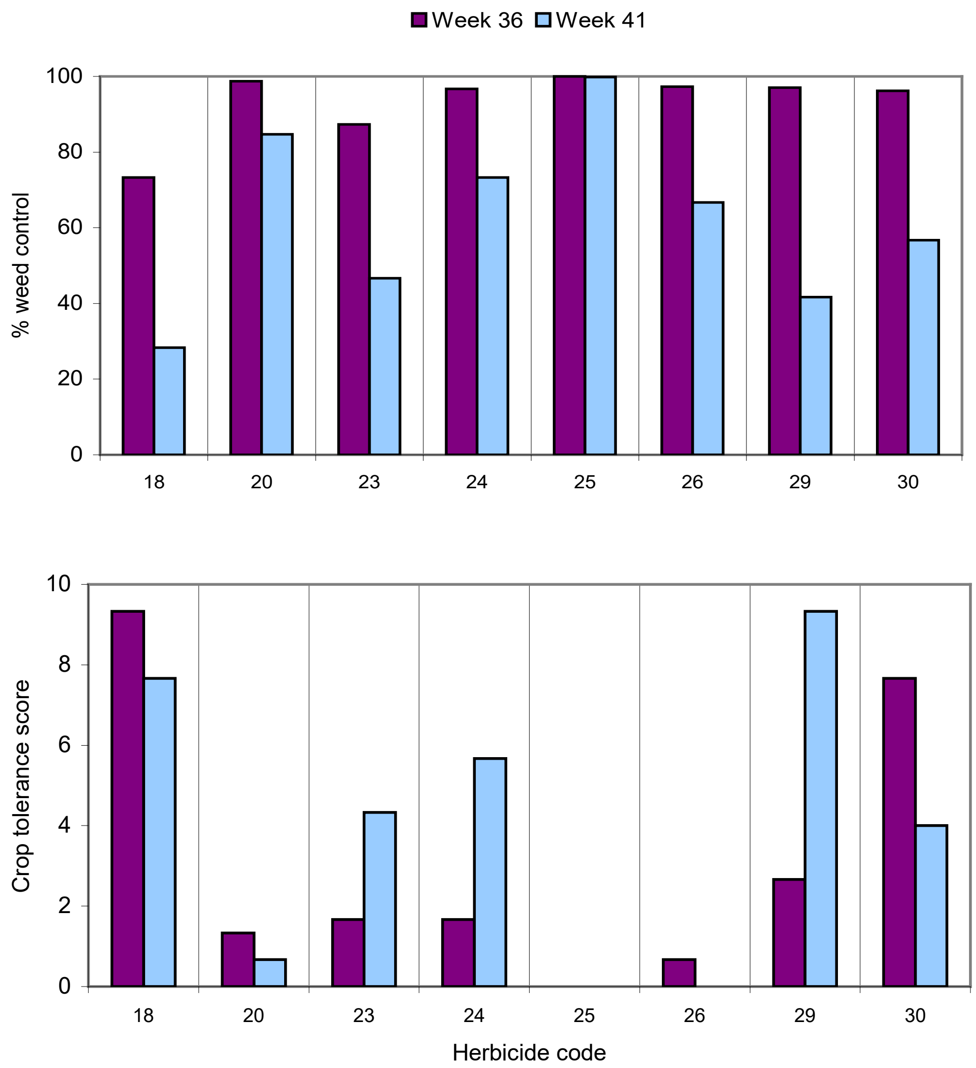
Figure 11. Crop and weed profile for transplanted delphinium (2003) on two assessment dates (weeks 33 and 36). Percentage weed control assessed from 0% (total weed cover) to 100% (total weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.**



Ref.	Timing	Herbicide	Crop damage	Weeds not controlled
18	Pre-plant	Ronstar Liquid	Occasional stunting and necrosis, recovering	Chickweed, groundsel
20	Pre-weed-em.	Simazine	Chlorosis and death	Annual meadow-grass, groundsel, nettle, shepherd's purse
21	Pre-weed-em.	Decimate	Slight necrosis	Chickweed, annual meadow-grass, groundsel, hedge mustard, nettle, shepherd's purse
22	Pre-weed-em.	Dacthal W-75 + Butisan S	Plants stunted, some distorted leaves	Annual meadow-grass, groundsel, mayweed, shepherd's purse
23	Pre-weed-em.	Stomp 400 SC	None	Groundsel, mayweed
24	Pre-weed-em.	Stomp 400 SC + Centium 360 CS	Slight bleaching (Centium)	Annual meadow-grass, groundsel, shepherds purse
25	Pre-weed-em.	CIPC 40 + Linuron 50	Plants stunted and leaves scorched, chlorosis. Delay in flowering. Lethal to many	-
28	Post-weed-em.	Boxer 25	Stunting and chlorosis	Chickweed, dead nettle, fat hen, grass, groundsel, mayweed, shepherd's purse, sow thistle, speedwell
29	Post-weed-em.	Goltix WG*	Slight necrosis initially	Chickweed, annual meadow-grass, groundsel, shepherd's purse
30	Post-weed-em.	Betanal Flow*	Slight necrosis initially	Chickweed, annual meadow-grass, groundsel, nettle, mayweed, shepherd's purse
31	Post-weed-em.	Sencorex WG	Crop death	Black-nightshade, annual meadow-grass, groundsel

* Weeds beyond the recommended cotyledon – 1TL stage.

Figure 12. Crop and weed profile for transplanted phlox (2003) on two assessment dates (weeks 36 and 41). Percentage weed control assessed from 0% (total weed cover) to 100% (total weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.**



Ref.	Herbicide timing	Herbicide	Crop damage	Weeds not controlled
18	Pre-plant	Ronstar Liquid	Slight scorch	Chickweed, deadnettle, annual meadow-grass, groundsel, nettle, shepherd's purse
20	Pre-weed-em.	Simazine	Crop death	Chickweed, deadnettle, annual meadow-grass, groundsel, nettle, shepherd's purse, speedwell
23	Pre-weed-em.	Stomp 400 SC	Stunting, no flowers	Chickweed, annual meadow-grass, groundsel, nettle, shepherd's purse
24	Pre-weed-em.	Stomp 400 SC + Centium 360 CS	Stunting, some bleaching, no flowers, sometimes lethal	annual meadow-grass, chickweed, groundsel, nettle, shepherd's purse
25	Pre-weed-em.	CIPC 40 + Linuron 50	Crop death	Groundsel
26	Pre-weed-em.	Venzar Flowable	Crop death	Chickweed, annual meadow-grass, groundsel, nettle, shepherd's purse
29	Post-weed-em.	Goltix WG*	Initial stunting, crop recovered	Chickweed, annual meadow-grass, groundsel, nettle, shepherd's purse
30	Post-weed-em.	Betanal Flow*	Some stunting, chlorosis and necrosis	Chickweed, annual meadow-grass, groundsel, nettle, shepherd's purse

* Weeds beyond the recommended cotyledon – 1TL stage

<u>Weed species</u>

Weed populations on untreated drilled flower plots were exceptionally high and no counts of weed numbers were made. The predominant weed species were mayweeds (mainly pineappleweed *Matricaria discoidea*, and some scentless mayweed *Tripleurospermum inodorum*), groundsel (*Senecio vulgaris*), shepherd's purse (*Capsella bursa-pastoris*), small nettle (*Urtica urens*) and chickweed (*Stellaria media*).

Fewer weeds emerged, later in the year, on the untreated transplanted plots. Weed numbers ranged from 100 to 288 weeds/m^2 on untreated plots. The predominant species were shepherd's purse, groundsel, small nettle and chickweed, with some mayweeds.

DISCUSSION

The main aim of the trial in 2003 was to test the tolerance of a range of cut-flowers to herbicides alone/in tank-mixes, when applied singly either pre- or post-emergence, so that herbicide programmes could be evaluated in 2004. Weed control was also assessed.

The herbicides selected were based on previous experience in other crops as well as cut-flowers. Herbicides may be safe if they do not control weedy relatives of the flower species. Only herbicides supported by Crop Protection Companies in the EC Pesticide Review were selected (though simazine subsequently failed to achieve Annex 1 status). A new herbicide, oxadiargyl, which has not yet been registered in the UK but is on Annex 1 and used in other parts of northern Europe, was also included.

All of the herbicides have weaknesses and do not control the whole spectrum of weeds commonly found in flower-growing areas (Table 5). For example, pre-emergence Stomp does not control groundsel and needs a partner such as Centium (which controls cleavers and groundsel, but has a rather limited weed spectrum). Sencorex controls a wide weed spectrum including mayweeds and groundsel, so does Butisan. Oxadiargyl controls a similar weed spectrum to Ronstar and neither of them control chickweed. Boxer is very effective on mayweeds, charlock and cleavers but was phytotoxic to the flower species tested. Post-emergence Betanal is seldom used alone in sugarbeet, and neither is Goltix.

An effective reliable residual pre-emergence herbicide, which controls a wide spectrum of broad-leaved weeds and causing no, or only transient, effects on the flower crop is the ideal. The 2003 trials were irrigated and soil conditions were optimum for good residual herbicide activity, and to assess crop tolerance.

The trial has enabled the identification of safe herbicides to several species of drilled and transplanted flowers, for use in weed control programmes, and of pre-emergence herbicides with a wide weed spectrum that could be used alone. However, it should be noted that these results are from only one year's trial.

The main conclusions of the study are summarised below.

Drilled flowers

Cornflower was the most competitive species and quickly grew above the weeds. Bupleurum also suppressed weeds. An effective residual herbicide for these flowers could avoid the need for a post-emergence herbicide.

Acceptable crop safety pre-emergence and good weed control was obtained as follows:
- China aster: Stomp + Centium
- Cornflower: Flexidor
- Larkspur: Stomp + Centium
- Zinnia: Stomp + Centium, Flexidor
- Bupleurum: CIPC + Linuron

Safe pre-emergence applications, but weed control was inferior:
- Cornflower: Kerb, Dacthal
- Larkspur: Dacthal
- Zinnia: Kerb, Dacthal
- Bupleurum: Stomp, Flexidor

Dacthal gave poor control of the weed spectrum on the trial area.

Safe post-emergence, but in some cases weeds were too large for good efficacy:
- China aster: Betanal Flow (safer than Goltix)
- Cornflower: Goltix
- Larkspur: Betanal Flow
- Zinnia: possibly Betanal Flow at lower dose
- Bupleurum: Goltix, Betanal Flow

Transplanted flowers

Stocks, snapdragon and China aster suppressed weeds, so, if a safe and effective residual herbicide were used, a post-emergence contact-acting herbicide would not needed, or at most a little hand-weeding.

Acceptable crop safety residual pre-transplanting pre-weed emergence and good weed control, except for chickweed:
- China aster: Ronstar, oxadiargyl
- Snapdragon: Ronstar, oxadiargyl
- Stocks: Ronstar, oxadiargyl
- Delphinium: Ronstar
- Phlox: Ronstar

Safe pre-weed emergence:
- Snapdragon: Venzar
- Stocks: Decimate, Dacthal + Butisan, possibly Stomp + Centium
- Delphinium: Decimate, Stomp, Stomp + Centium

Safe post-emergence:

- China aster: Goltix, Betanal Flow
- Stocks: Goltix
- Delphinium: Goltix, possibly Betanal Flow

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Gordon Hanks 15 August 2004