HDC Project BOF 51

Final Report (2005)

Outdoor flowers: an evaluation of herbicides

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Grower Summary

Headlines

The lack of effective herbicides and herbicide programmes for use on outdoor cut-flower crops is a major constraint to UK-grown cut-flower production. Effective and safe programmes have been found for most of the cut-flower species studied – drilled China aster, cornflower, zinnia, larkspur and bupleurum, and transplanted China aster, stock, snapdragon and delphinium. It is clear from three years' trials that weeds in these crops must be controlled with residual herbicides, since safe, low doses of post-weed-emergence herbicides control only limited weed spectra and must be applied early, with weeds at the cotyledon to1-true-leaf (1-TL) stage.

Background and expected deliverables

Discussions with flower growers frequently highlight a need for advice on herbicides. There are very few herbicide recommendations for outdoor flower crops, because agrochemical companies do not consider the economic return from minor crops sufficient to justify the cost of development and of the 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 was to identify herbicides and develop herbicide programmes suitable for use on a range of mostly annual, seed-raised cut-flower species grown in the field.

Summary of the project and main conclusions

Three years' field trials were conducted over 2003 to 2005 with drilled China aster, cornflower, zinnia, larkspur, nigella and bupleurum, and transplanted China aster, stock, snapdragon, delphinium and phlox, to identify crop-safe and effective herbicides and develop suitable herbicide treatments into herbicide programmes that would provide safe weed control throughout the life of the crops. Crops previously the subject of HDC-funded herbicide trials - sweet William, chrysanthemum and larkspur (see projects BOF 29, 30 and 40) – were excluded from the new trials. In the first year a wide range of herbicides, including some newer active ingredients, was tested using single applications of herbicides. In the second year, some of the promising herbicide treatments were combined to build simple herbicide programmes, and, in addition, some further, newer actives or products were tested. These trials enable many unsuitable herbicide/crop combinations to be eliminated from further testing, and also highlighted some particularly useful herbicides. In the third year's trial, simple herbicide programmes were developed further, and simple, safe and effective herbicide programmes were formulated for nine of the eleven crops tested: drilled China aster, cornflower, zinnia, larkspur and bupleurum, and transplanted China aster, stock, snapdragon and delphinium. Nigella and phlox proved to be highly sensitive to the herbicides used, and it was not possible to identify suitable herbicides for these two species.

It was clear from these trials that weeds in cut-flower crops must be controlled with residual herbicides, because the safe low doses of post-weed-emergence herbicides control only limited weed spectra and must be applied early, to weeds at the cotyledon to 1-TL stage. Early removal of weeds avoids crop competition, while later applications, closer to flower initiation and (or) maturation are likely to cause more damage.

The herbicide programmes developed are listed below. Tank-mixes are indicated by '+'.

- China aster (drilled)

For drilled China aster the best programmes were based on pre-crop/weed-emergence Stomp + Centium (3.3 + 0.25 L/ha), followed by Goltix + Betanal (1.0 kg/ha + 1.8 L/ha) or Betanal Expert (1.5 L/ha) applied early post-emergence to cotyledon weeds. Goltix (1.7 kg/ha) and Betanal (up to 2.5 L/ha) would be possible post-weed-emergence alternatives.

- Cornflower (drilled)

Cornflowers are quick to emerge and their vigorous growth quickly suppresses weeds. A single treatment with a residual pre-crop/weed-emergence herbicide may be sufficient to achieve good weed control. The best treatment was Stomp + Flexidor (3.3 + 1.0 L/ha), with, if needed, a follow-up early post-emergence with Goltix (1.7 L/ha) applied to cotyledon weeds.

- Zinnia (drilled)

Although zinnia plants are tall at flowering stage, they do not provide a dense leaf canopy so they are poor competitors with weeds, particularly at early growth stages. The best treatment was pre-crop/weed-emergence Stomp + Centium (3.3 + 0.25 L/ha) followed by Goltix + Betanal (1.0kg/ha + 1.0 L/ha) applied early post-weed-emergence. Stomp + Flexidor (3.3 + 1.0 L/ha) followed by Goltix + Betanal (1.0kg/ha + 1.0 L/ha) was safe, but weed control was inferior. Both programmes caused a slight delay in flowering, so there is still scope for an improved treatment.

- Larkspur (drilled)

The best treatment for drilled larkspur was pre-crop/weed-emergence Stomp + Centium (3.3 + 0.25 L/ha). A lower dose of Centium (0.2 L/ha) should be effective alternative where cleavers are not anticipated. A follow-up with early post-weed-emergence Betanal (1.8 L/ha) or Goltix (1.7 kg/ha) could be applied if weed problems are severe, but these are not entirely crop-safe.

- Bupleurum (drilled)

Bupleurum has vigorous growth and soon smothers weeds. The best treatment for drilled bupleurum was pre-crop/weed-emergence Stomp + Flexidor (3.3 +1.0 L/ha) followed by early post-weed-emergence Goltix + Betanal (1.7 kg/ha + 1.8 L/ha). The post-emergence application might be safer when the bupleurum is at a later growth stage, though it is less effective on larger weeds; alternatively, Goltix alone (1.7 kg/ha) may be sufficient. Pre-crop/weed-emergence Stomp + Flexidor (as above) (or Stomp + aclonifen (3.3 + 2.0 L/ha)) might be all that is required where groundsel is not a problem.

- China aster (transplanted)

The best treatment for China aster was pre-transplanting Ronstar Liquid (4.0 L/ha), followed by early post-weed-emergence Betanal Expert (1.5 L/ha) when weeds are small. This combination gave better weed control than the industry standard Ramrod + Dacthal or Decimate.

- Stock (transplanted)

The best treatment was Dacthal + Butisan (9 kg/ha + 1.5 kg/ha) post-transplanting. Ronstar Liquid (4.0 L/ha) pre-transplanting, followed by post-transplanting Butisan (1.5 L/ha) could also be considered but caused slight stunting.

- Snapdragon (transplanted)

The best treatments for snapdragon were Ronstar Liquid (4.0 L/ha) pre-transplanting or Venzar (4.0 L/ha) post-transplanting. Nortron (2.0 L/ha) early post-weed-emergence for weeds escaping control was safe.

- Delphinium (transplanted)

Delphiniums are slow to compete with weeds and sensitive to herbicides, and all herbicides tested, including Ronstar Liquid, caused some damage on the newly transplanted crop. For the perennial crop, however, effective weed control (rather than total crop safety) during establishment seems to be more important. The best first-year treatment, as assessed from second-year plants, was post-transplanting Stomp + Centium (3.3 + 0.25 L/ha) followed by early post-weed-emergence Betanal (1.8 L/ha) or Goltix (1.7 kg/ha).

In the case of nigella (drilled), no safe, effective herbicide treatment was found. Treatments safe on larkspur cannot be extrapolated to this crop. Nigella produces less leaf cover, is not as tall as larkspur, and is less competitive with weeds. Nigella was more sensitive than larkspur to all herbicides tested. In the case of phlox (transplanted), Ronstar Liquid was not reliably crop-safe, and all the herbicides applied post-transplanting or post-weed-emergence were damaging. Further research on these two crops is needed.

Financial benefits

Several of the herbicides and herbicide programmes tested gave excellent weed control. These treatments have the potential to ease weed problems in cut-flower crops, reducing the costs of hand-weeding. The costs of the best herbicide programmes with two applications in drilled crops ranged from £70/ha to £110/ha for herbicides, and in transplanted crops from £63/ha to as much as £505/ha. Spray application costs (including the additional cost for spraying small areas of crop) of £22/ha to £28/ha are suggested for two herbicide applications. However, where weed pressure is low, or crops are effective at suppressing weeds, one application may be enough.

Action points for growers

The indicated herbicide treatments and programmes could be tested, at the grower's risk, on small commercial areas of the following crops: drilled China aster, cornflower, zinnia, larkspur and bupleurum, and transplanted China aster, stock, snapdragon and delphinium. No suitable herbicide programmes have yet been formulated for nigella and phlox.

INTRODUCTION

The UK demand for cut-flowers is growing rapidly, and the production of flowers under low-cost polythene tunnels provides an 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, since there are very few herbicide recommendations for outdoor flower crops - agrochemical companies do not consider the relatively small economic value of such specialist 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 selections may be made on the basis of ad hoc trials or anecdotal information. The aim of this project was to identify herbicides free from phytotoxic effects (including height and yield reduction) and otherwise suitable for use on a range of annual, seed-raised cut-flower species grown from transplants or drilled in the field.

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, 2004). The crops grown include large numbers of fashionable flowers, along with traditional species such as chrysanthemums. There is a very wide range of costs for herbicides – from £70/ha to £315/ha - to which application costs of £22/ha to £28/ha for two herbicide applications per year (Nix *et al.*, 2005) must be added. 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 by reduction of 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. An examination of the 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; Deen, 1999). A recent Defra-funded project (HH1528SPC) on tunnel-grown cut-flowers included testing a range of herbicide treatments on a range of 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.

In the present project, three years' field trials were conducted over 2003 to 2005 with drilled China aster, cornflower, zinnia, larkspur, nigella and bupleurum, and transplanted China aster, stock, snapdragon, delphinium and phlox, to identify crop-safe and effective herbicides and develop suitable herbicide treatments into herbicide programmes that would provide safe weed control throughout the life of the crops. In the first year a wide range of herbicides, including some newer active ingredients, was tested using single applications of herbicides. In the second year, some of the promising herbicide treatments were combined to build simple herbicide programmes, and, in addition, some further, newer actives or products were tested. These trials enable many unsuitable herbicide/crop combinations to be eliminated from further testing, and also highlighted some particularly useful herbicides. In the third year's trial, simple herbicide programmes were developed further, and safe and effective herbicide programmes were formulated. The full results of the 2003 and 2004 trials are available from the HDC in two Annual Reports. The best programmes, and some further single treatments, were tested in 2005 and are reported here, along with summaries of the previous findings and the overall conclusions and recommendations from the project.

MATERIALS AND METHODS

Plant material and husbandry, 2005 trial

The choice of species and growing systems was decided following discussions between researchers, consultants and HDC BOF Panel members. Seed of the following were purchased from Florensis (Hamer Flower Seeds Ltd, Swavesey, UK):

- China aster (*Callistephus chinensis*; Compositae) cv. Matsumoto Purple-rose (D, T)
- Cornflower (*Centaurea cyanus*; Compositae) cv. Boy Blue (D)
- Zinnia (*Zinnia elegans*; Compositae) cv. California Giants (D)
- Larkspur (*Delphinium consolida*; Ranunculaceae) cv. Sydney Purple (D)
- Nigella (*Nigella damascena*; Ranunculaceae) cv. Miss Jekyll Dark Blue(D)
- Bupleurum (*Bupleurum griffitti*; Umbelliferae) (D)
- Snapdragon (*Antirrhinum majus*; Scrophulariaceae) cv. Tattoo F_1 Carmine (T)
- Stock (*Matthiola incana*; Cruciferae) cv. Lucinda Lilac-rose (T)
- Delphinium (*Delphinium* hybrids; Ranunculaceae) cv. Pacific Giant Blue Bird (T)

The species marked (D) were direct-drilled in the field, and those marked (T) were raised in cellular trays and transplanted to the field later. Transplanted phlox (*Phlox drummondii*) was not tested in 2005, since previous trials had shown it to be sensitive to all herbicides tested except Ronstar Liquid, and no suitable novel compounds were available.

As in previous years, the trial site was on a medium silty marine alluvial soil at Warwick HRI, Kirton, Boston, Lincolnshire, typical of the South Lincolnshire agricultural area where outdoor cut-flower crops are widely grown. Previously, the trial area was treated with glyphosate to control creeping thistle. The site was flat-lifted and ploughed, and soil samples taken at 0-15cm depth across the site. Standard agricultural soil analysis showed: pH 7.7, nitrate index 0, P index 4, K index 2- and Mg index 3. According to MAFF fertiliser recommendations, 100kgN/ha and 150 kgK_2O/ha (as 290kg ammonium nitrate (34.5%N/ha) and 300kg sulphate of potash (50%K_2O/ha)) were applied across the trial area and cultivated in. The crops were grown in beds 1.2m-wide spaced at 1.8m centre-to-centre. The drilled and transplanted crops were placed in separate, but adjacent, areas of the field. Before drilling or transplanting, three beds were allocated randomly for each crop. Extra fertiliser was applied to the plots to be used for drilled China aster (2.4kg sulphate of potash and 0.85kg ammonium nitrate per 100m^2) and was raked into the soil surface. Plots 4.0m long along the beds, with 1.0m unplanted (guard) areas between plots, were marked in 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. Sowing dates were as shown in Table 1.

Seed for transplanted crops was sown in ‘308’ cellular trays using a fine, propagation compost (Humax), germinating and growing the trays in a Venlo glasshouse at ambient temperatures and ventilated at 8°C. Standard husbandry for raising young plants was applied. During plant raising, the young plants were treated with propamocarb hydrochloride (as Proplant) to control damping-off and other fungal diseases. Once grown to an appropriate size, they were transplanted by hand into six rows 20cm apart along the bed, with a spacing of 20cm in each row. Transplanting dates were as shown in Table 2.

Crops were irrigated using a standard irrigation boom. Water was initially applied as required to establish the crops, and thereafter 25mm irrigation was applied only as required to maintain soil conditions judged appropriate for effective herbicide action. Irrigation dates were as shown in Tables 1 and 2 (and with the rainfall data in Figure 2). In the field a preventative spray programme was applied against aphids and caterpillars, applying pirimicarb + deltamethrin at 10-14 day intervals at a standard rate and according to recommendations.

Meteorological data were obtained from the Kirton weather station, sited *ca.* 50m from the trial site. Weather data for the three years of the trials are summarised in Figure 1, along with 10-year averages. These show that the 2003 trial period was warmer and sunnier than average, and wetter during June and July. In 2004 temperatures were higher than average in June and August, but July was cooler, and the weather was less sunny, and wetter, than average. In 2005 there was less sun and less rainfall than average, and temperatures were higher than average in June but lower in August.

Herbicide treatments, 2005 trial

In the first year a wide range of herbicides, including some newer active ingredients, was tested using single applications of herbicides. In the second year, some of the promising herbicide treatments were combined to build simple herbicide programmes, and, in addition, some further, newer actives or products were tested. In the third year, 2005, simple herbicide programmes were developed further in order to formulate safe, effective herbicide programmes for the industry to use.

Throughout the project, only selected herbicides were applied to each flower crop, following discussions with Panel members and a review of the available information. The herbicide treatments comprised pre-emergence and post-crop-emergence applications for direct-drilled crops (Table 3) and pre-transplanting and post-transplanting (pre- and post-weed-emergence) applications for transplanted crops (Table 4). Applications to emerged weeds were aimed at when they were at cotyledon to 1-TL stage.

Herbicide treatments were allocated randomly within each bed, with crops arranged in three replicate blocks in order to eliminate effects due to variations across the field – this is important, as weed distribution is often patchy across a single field. Following accepted practice additional plots were left untreated and hand-weeded or entirely untreated; this allowed weed control and the effects of herbicides and of competition on crop vigour to be assessed.

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-emergence (cotyledon) weeds. Herbicides were applied in 200L water per ha. Tables 1 and 2 give the dates of herbicide applications, the growth stages of crops and weeds, and weather conditions on the day sprays were applied. Table 5 shows their current approval status, and their weed susceptibilities are given in Appendix 2.

Delphiniums planted for the 2004 trial were left down for a second year. No further herbicides were applied, although dead plant material was removed over the winter period.

Records, 2005 trial

The following assessments were made:

- Crop and weed seedling growth stage (GS) at the time of herbicide applications

- Crop tolerance (phytotoxic symptoms and crop stand) assessed on three occasions using the scores below:

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

- Overall weed control, scored from 0 to 10 (0, no weed control; 7, acceptable control; 10, complete control). Untreated plots were therefore scored as 0 and hand-weeded plots as 10
- Weed species present recorded at intervals (for Latin names see Appendix 1)
- Except for plots overwhelmed by weeds or where flowers were damaged by treatment and unmarketable, three bunches of ten stems were cropped from each plot at a commercial stage. Bunch weights and length were recorded. Bunches were assessed visually for quality compared with hand-weeded controls. The presence of small, damaged or fewer flowers, weak stems or chlorotic foliage, etc., was recorded. Standard vase-life testing was carried out in plain water at 20°C and 65% relative humidity under 1000 lux from cold white tubular fluorescent lamps on for 12 hours each day.

Table 1. Diary of operations and sprays for drilled crops in 2005. All crops drilled on 9 June 2005.

Crop	*Operation*	*Date*	*Temp., RH*	*GS crop**	*GS weeds (on untreated plots)**
China aster	Irrigate	10 June	-	-	-
	Rainfall 7.5mm	12 June	-	-	-
	Pre-emergence sprays	14 June	18ºC; 55%	-	-
	Rainfall 2.5mm	15 June	-	-	-
	Mean emergence	19 June	-	-	-
	Post-emergence sprays	28 June	18ºC; 60%	Cotyledon-2TL	Main species**, 2TL; chickweed, 2-4 TL; groundsel, 1 TL
	Main cropping date	30 Sept	-	-	-
Cornflower	Irrigate	10 June	-	-	-
	Rainfall 7.5mm	12 June	-	-	-
	Pre-emergence sprays	14 June	18ºC; 55%	-	-
	Rainfall 2.5mm	15 June	-	-	-
	Mean emergence	17 June	-	-	-
	Post-emergence sprays	28 June	18ºC; 60%	2 - 3TL	Main species**, 2TL; chickweed, 2-4 TL; groundsel, 1 TL
	Main cropping date	11 Aug	-	-	-
Zinnia	Irrigate	10 June	-	-	-
	Rainfall 7.5mm	12 June	-	-	-
	Pre-emergence sprays	14 June	18ºC; 55%	-	-
	Rainfall 2.5mm	15 June	-	-	-
	Mean emergence	19 June	-	-	-
	Post-emergence sprays	28 June	18ºC; 60%	2TL	Main species**, 2TL; chickweed, 2-4 TL; groundsel, 1 TL
	Main cropping date	11 Aug	-	-	-
Larkspur	Irrigate	10 June	-	-	-
	Rainfall 7.5mm	12 June	-	-	-
	Pre-emergence sprays	14 June	18ºC; 55%	-	-
	Rainfall 2.5mm	15 June	-	-	-
	Mean emergence #	1 July	-	-	-
	Post-emergence sprays	28 June	18ºC; 60%	emerging	Main species**, 2TL; chickweed, 2-4 TL; groundsel, 1 TL
	Main cropping date	09 Sept	-	-	-
# Emergence of larkspur late and uneven, seedlings beginning to emerge at the time of post-emergence applications					
Nigella	Irrigate	10 June	-	-	-
	Rainfall 7.5mm	12 June	-	-	-
	Pre-emergence sprays	14 June	18ºC; 55%	-	-
	Rainfall 2.5mm	15 June	-	-	-
	Mean emergence ##	25 June	-	-	-
	Post-emergence sprays	28 June	18ºC; 60%	cotyledon	Main species**, 2TL; chickweed, 2-4 TL; groundsel, 1 TL
	Main cropping date	27 Aug	-	-	-
Bupleurum	Irrigate	10 June	-	-	-
	Pre-emergence sprays	14 June	18ºC; 55%	-	-
	Irrigate	21 June	-	-	-
	Mean emergence ##	25 June	-	-	-
	Post-emergence sprays	28 June	18ºC; 60%	cotyledon	Main species**, 2TL; chickweed, 2-4 TL; groundsel, 1 TL
	Main cropping date	11 Aug	-	-	-

Emergence of nigella and bupleurum slow, seedlings at only cotyledon stage at time of post-emergence applications

*GS, growth stage of crop or weeds; TL, true leaves ** Shepherd's purse, small nettle, pale persicaria

Table 2. Diary of operations and sprays for transplanted crops in 2005.

Crop	*Operation*	*Date*	*Temp., RH*	*GS crop**	*GS weeds (on untreated plots)**
China aster	Pre-planting sprays	16 June	14ºC; 70%	-	-
	Transplanted	17 June	-	-	-
	Pre-weed-em sprays	20 June	21ºC; 66%	-	-
	Irrigate	21 June	-	-	-
	Post-emergence sprays	08 July	-	established	Main species**, 2-4TL; chickweed, 2-4 TL; black nightshade, 4TL
	Main cropping date	30 Aug	-	-	-
Snapdragon	Pre-planting sprays	20 June	21ºC; 66%	-	-
	Transplanted	21 June	-	-	-
	Irrigate	21 June	-	--	-
	Pre-weed-em sprays	23 June	19ºC; 67%	-	-
	Post-emergence sprays	08 July	-	established	Main species**, 2-4TL; chickweed, 2-4 TL; black nightshade, 4TL
	Main cropping date	16 Aug	-	-	-
Stock	Pre-planting sprays	17 June	18ºC; 72%	-	-
	Transplanted	17 June	-	-	-
	Pre-weed-em sprays	20 June	21ºC; 66%	-	-
	Irrigate	21 June	-	-	-
	Post-emergence sprays	08 July	-	established	Main species**, 2-4TL; chickweed, 2-4 TL; black nightshade, 4TL
	Main cropping date	18 Aug	-	-	-
Delphinium	Transplanted	21 June	-	-	-
	Irrigate	21 June	-	-	-
	Pre-weed-em sprays	23 June	19ºC; 67%	-	-
	Post-emergence sprays	08 July.	-	established	Main species**, 2-4TL; chickweed, 2-4 TL; black nightshade, 4TL

*GS, growth stage of crop or weeds; TL, true leaves ** Shepherd's purse, small nettle, pale persicaria

Table 3. Herbicide treatments and dates applied to direct-drilled crops in 2005. Dose rates in L/ha unless stated otherwise.

Species	*No.*	*Pre-weed-emergence (14 June)*	*Early post-weed-em (cotyledons – 1TL) (28 June)*
China aster	1	Control (untreated)	-
	2	Control (hand-weeded)	-
	14	Stomp+Centium (3.3 + 0.25)	-
	25	Stomp+Centium (3.3 + 0.2)	Betanal Expert (1.5)
	26	Stomp+Centium (3.3 + 0.2)	Goltix+Betanal (1.0kg + 1.8)
Cornflower	1	Control (untreated)	-
	2	Control (hand-weeded)	-
	4	Stomp+Flexidor (3.3 + 1.0)	-
	10	Aclonifen+Stomp (2.0 + 3.3)	Goltix (1.7kg)
	11	Aclonifen+Stomp (2.0 + 3.3)	Skirmish (1.0)
	12	Stomp+Flexidor (3.3 + 1.0)	Goltix (1.7kg)
	13	Stomp+Flexidor (3.3 + 1.0)	Skirmish (1.0)
Zinnia	1	Control (untreated)	-
	2	Control (hand-weeded)	-
	4	Stomp+Flexidor (3.3 + 1.0)	-
	14	Stomp+Centium (3.3 + 0.25)	
	15	Stomp+Centium (3.3 + 0.25)	Betanal (1.8)
	13	Stomp+Flexidor (3.3 + 1.0)	Skirmish (1.0)
	16	Stomp+Flexidor (3.3 + 1.0)	Goltix+Betanal (1kg + 1.0)
	17	Stomp+Centium (3.3 + 0.25)	Skirmish (1.0)
	18	Stomp+Centium (3.3 + 0.25)	Goltix+Betanal (1kg + 1.0)
Larkspur	1	Control (untreated)	-
	2	Control (hand-weeded)	-
	14	Stomp+Centium (3.3 + 0.25)	-
	19	Stomp+Centium (3.3 + 0.25)	Goltix (1.7kg)
	15	Stomp+Centium (3.3 + 0.25)	Betanal (1.8)
	17	Stomp+Centium (3.3 + 0.25)	Skirmish (1.0)
Nigella	1	Control (untreated)	-
	2	Control (hand-weeded)	-
	20	Stomp (2.0)	-
	21	Stomp (2.0)	Decimate (20)
	22	Stomp (2.0)	Skirmish (1.0)
	23	Stomp (2.0)	Betanal (1.8)
	24	Stomp (2.0)	Asulam (2.5)
Bupleurum	1	Control (untreated)	
	2	Control (hand-weeded)	-
	4	Stomp+Flexidor (3.3 + 1.0)	-
	5	Aclonifen+Stomp (2 + 3.3)	-
	6	CIPC+Linuron (2.8 + 1.7)	-
	7	CIPC+Linuron (4.2 + 1.7)	-
	8	Stomp+Flexidor (3.3 + 1.0)	Goltix+Betanal (1.7kg + 1.8)
	9	Stomp+Aclonifen (3.3 + 2.0)	Goltix+Betanal (1.7kg+1.8)

Table 4. Herbicide treatments and dates of application of transplanted crops in 2005. Dose rates in L/ha unless stated otherwise.

Species	*No.*	*Pre-transplant*	*Pre-weed-em (2-3d after planting)*	*Early post-weed-em*
China aster		16 June	20 June	8 July
	34	Untreated	-	-
	35	Handweeded	-	-
	37	-	Decimate (20)	Betanal Expert (1.5)
	38	Ronstar Liquid (4.0)	-	Betanal Expert (1.5)
Stock		17 June	20 June	8 July
	34	Untreated	-	-
	35	Handweeded	-	-
	39	Ronstar Liquid (4.0)	Dacthal + Butisan (9kg + 1.5)	-
	40	-	Dacthal + Butisan (9kg + 1.5)	-
	41	-	Butisan (1.5)	Goltix (1.7kg)
	42	Ronstar Liquid (4.0)	Butisan (1.5)	-
Snapdragon		20 June	23 June	8 July
	34	Untreated	-	-
	35	Handweeded	-	-
	43	Ronstar Liquid (4.0)	-	Goltix (1.5kg)
	44	-	Venzar (4.0)	Goltix (1.5kg)
	45	Ronstar Liquid (4.0)	-	Nortron (2.0)
	46	-	Venzar (4.0)	Nortron (2.0)
Delphinium		20 June	23 June	8 July
	34	Untreated	-	-
	35	Handweeded	-	-
	47	-	CIPC (2.8)	-
	48	-	CIPC + Linuron (2.8 + 1.1)	-
	49	-	Decimate (10)	-
	50	-	Stomp+Ramrod (3.3 + 9.0)	-
	51	-	Stomp+Ramrod (3.3 + 9.0)	Goltix (1.7kg)
	52	-	Stomp+Centium (3.3 + 0.25)	Goltix (1.7kg)
	53	-	Stomp+Centium (3.3 + 0.25)	Betanal (1.8)

Table 5. Status of the herbicides used in this project (as at November 2005).

*Product name**	*a.i. & formulation*	*Marketing co.*	*EC Review a.i.*	*Approval status*
-	**aclonifen** 600 g/L SC	Bayer CropScience	supported	No UK approval yet Registered in other EU member states: onions, herbs, carrots
Asulox	asulam 400g/L	Bayer CropScience	supported	UK orchards, pasture
Betanal Expert	desmedipham/ ethofumesate/ phenmedipham 25/151/75 g/L EC	Bayer CropScience	All on Annex 1	UK sugarbeet etc. LTAEU**
Betanal Flow	phenmedipham 160g/L SE	Bayer CropScience and others	Annex 1	UK sugarbeet etc. LTAEU
Boxer	florasulam 50g/L	Dow	Annex 1	UK cereals LTAEU
Butisan S	metazachlor 500g/L SC	BASF and others	supported	UK some vegetables LTAEU

Centium 360 CS	clomazone 360g/L encapsulated	Belchim	supported	UK some vegetables LTAEU
CIPC 40	chlorpropham 400g/L SC	Nufarm Whyte and others	Annex 1	UK some vegetables LTAEU
Crystal	flufenacet/pendimethalin 60/300g/L SC	BASF	Both on Annex 1	UK winter wheat LTAEU
Dacthal W 75	chlorthal-dimethyl 75% w/w WP	Certis and others	supported	UK ornamentals, brassicas etc. LTAEU
Decimate	chlorthal-dimethyl/ propachlor 225/216g/L	Certis	supported	UK some vegetables LTAEU
Defy	prosulfocarb 880g/L SC	Syngenta	supported	New Provisional Approval UK wheat LTAEU
Flexidor 125	isoxaben 125g/L SC	Landseer and others	supported	UK some vegetables LTAEU
Gesatop	simazine 500g/L	Syngenta and others	Failed Annex 1	UK ornamentals 'Essential Use' certain products until 2007
Goltix WG	metamitron 70%w/w WDG	Makhteshim and others	supported	UK sugarbeet etc. LTAEU
Kerb Flo	propyzamide 400g/L	Dow	Annex 1	UK ornamental plants
Linuron (various)	linuron 500 g/L SC	Makhteshim and others	Annex 1	UK some vegetables LTAEU
Nortron Flo	ethofumesate 500g/L SC	Bayer CropScience, and others	Annex 1	UK sugarbeet etc. LTAEU
-	**oxadiargyl** 400g/L SC	Bayer CropScience	Annex 1	No UK approval yet. Registered in other EU member states.
Ramrod Flowable	propachlor 480 g/L SC	Monsanto and others	supported	UK brassicas and other horticultural crops, LTAEU
Ronstar Liquid	oxadiazon 250g/L EC	Certis	supported	UK ornamentals LTAEU
Sencorex WG	metribuzin 70% w/w	Bayer CropScience	supported	UK some vegetables LTAEU
Skirmish	terbuthylazine/isoxaben 420/75g/L SC	Syngenta	supported	UK peas
Stomp 400 SC	pendimethalin 400g/L SC	BASF and others	Annex 1	UK some vegetables LTAEU
Venzar Flowable	lenacil 440g/L SC	Dupont and others	supported	UK ornamentals LTAEU

* In the text the brief product names, indicated here by bold type, are used.
** The Long-Term Arrangements for Extension of Use (LTAEU) have now been reviewed and, for non-edible crops, they will continue, possibly until 2008, though they must eventually be replaced by specific approvals (SOLAs).

Figure 1. Monthly weather for 2003, 2004 and 2005 and 10-year averages (1993-2002)

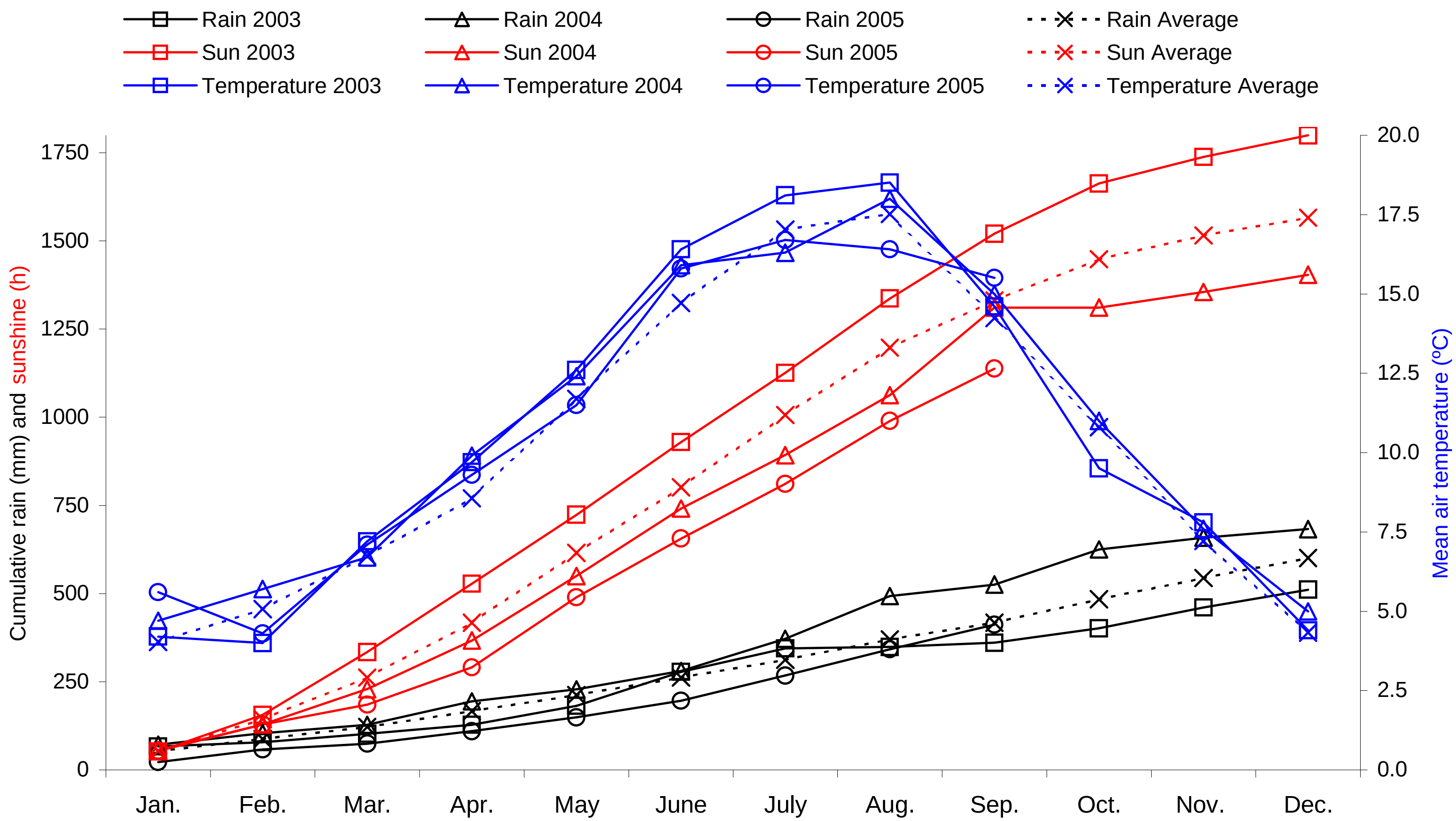
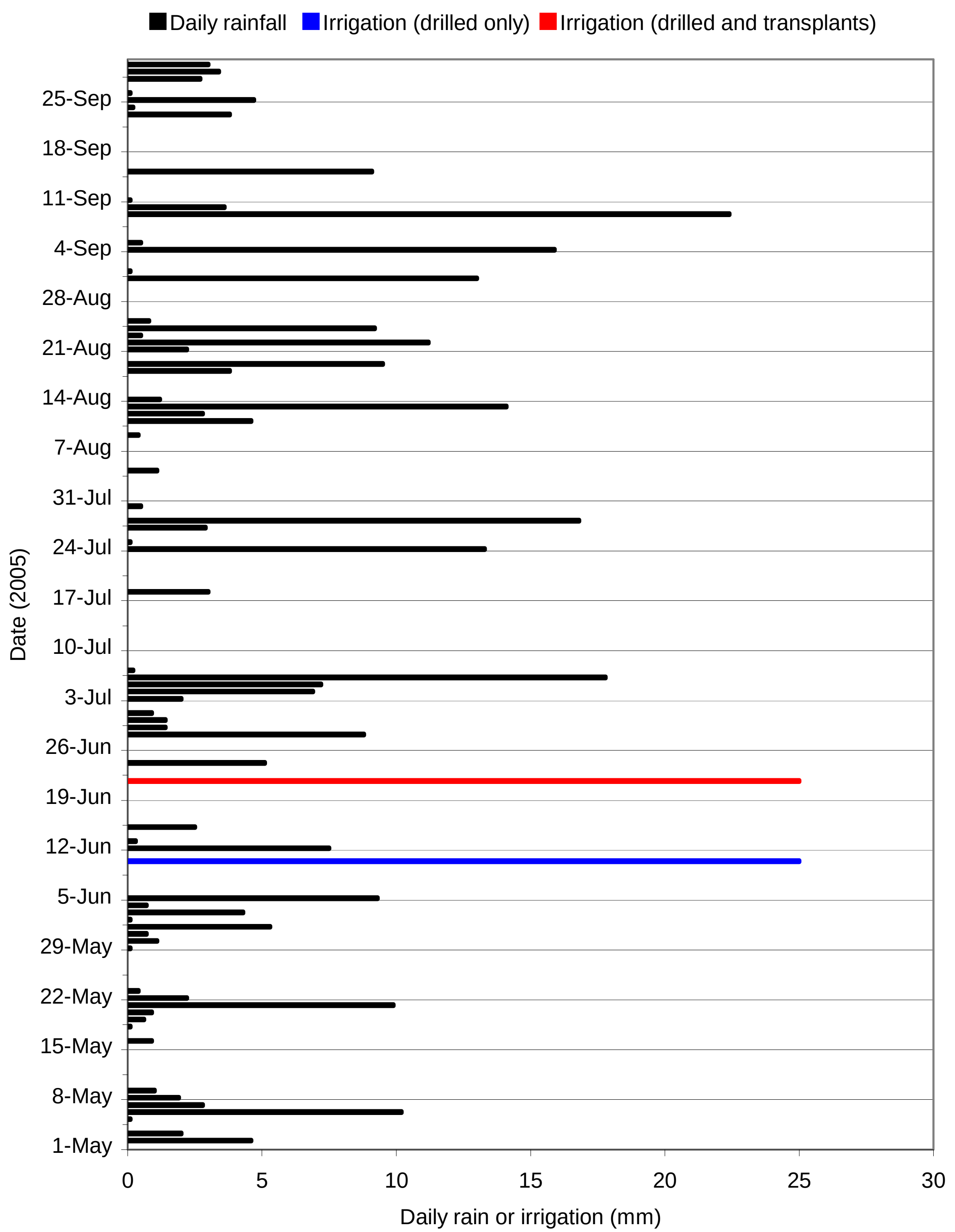


Figure 2. Rainfall and irrigation data for 2005 trial



RESULTS AND DISCUSSION

In the three years of the project, adequate rainfall and irrigation ensured good activity of residual herbicides and a realistic test of crop safety. The high population of weeds in all years - typically over 200/m^2 – provided a vigorous challenge for the herbicides tested.

Weed populations

In 2005, the weed population on untreated plots of the drilled crops was high (224 weeds/m^2) (Table 6): the predominant species were shepherd's purse, small nettle and chickweed, with some knotgrass and groundsel. In addition, there were lower numbers of pale persicaria, fat-hen and fig-leaved goosefoot, and a few field speedwell, wild radish, green nightshade and charlock were present on occasional plots.

Table 6. Assessment of weed species on 5 July 2005 on untreated, drilled plots. Figures are the number of weed species/m^2 (mean of counts in one 0.33 m^2 quadrat for seven plots in three replicates).

Shepherd's purse	Small nettle	Chickweed	Knotgrass	Groundsel	Pale persicaria	Fat-hen	Fig-leaved goosefoot	Mayweeds *	Red dead-nettle	Redshank	TOTAL
74	53	37	17	16	9	8	6	2	1	1	224

* pineappleweed, scented and scentless mayweeds

The weed population on untreated plots of the transplanted crops was also high - 260 weeds/m^2 (Table 7). The predominant species were shepherd's purse, small nettle, pale persicaria and mayweeds, with smaller numbers of black and green nightshade and chickweed.

Table 7. Assessment of weed species on untreated, transplanted plots on 18 July 2005. Figures are the number of weed species/m^{-2} (mean of counts in one 0.33 m^2 quadrat for four plots in three replicates).

Shepherd's purse	Small nettle	Pale persicaria	Mayweeds*	Black nightshade	Green nightshade	Chickweed	Knotgrass	Groundsel	Fat-hen	Smooth sowthistle	TOTAL
117	57	25	20	12	2	9	3	5	5	5	260

* pineappleweed, scented and scentless mayweeds

Full tables of the weed species not controlled by the herbicide treatments are given in Appendix 3.

Herbicide evaluations - drilled crops

In the 2003 trial single applications of a range of herbicides were tested. The main positive results were:

- Centium + Stomp applied pre-emergence showed promise as a safe effective herbicide tank-mix for several species, but not cornflower or bupleurum.
- Pre-emergence Kerb was safe on the species tested, though weed control was poor and a tank-mix might be needed.
- Pre-emergence CIPC + Linuron was tolerated by bupleurum and was very effective.
- Post-emergence Goltix and Betanal were safe to some crops, but early application to weeds at the cotyledon to 1-TL growth stage was essential for efficacy.

As a result of this trial several herbicide treatments were eliminated from further testing because of their poor weed control or crop-toxicity:

- Simazine and Sencorex killed the crops on which they were tested.
- Dacthal showed poor weed control.
- Linuron, applied post-weed-emergence, killed China aster, zinnia, larkspur and bupleurum, and caused unacceptable damage and delayed flowering in cornflower.
- Boxer, post-weed-emergence, caused severe damage to all five species tested.
- Defy, post-weed-emergence, caused severe damage to zinnia, was damaging to China aster and larkspur, and weed control was poor.

In the 2004 trial herbicide programmes were evaluated and compared with single treatments, and some further pre-emergence residual herbicides were tested: Crystal, tank-mixes of Stomp + aclonifen and Stomp + Flexidor. Since post-emergence Goltix or Betanal are seldom used alone, tank-mixes and Betanal Expert were also tested. As a result, further herbicide treatments were subsequently eliminated because of poor weed control and (or) phytotoxicity:

- Crystal was safe to all species tested, although there was some stunting and delayed flowering in nigella, but its weed control was poor.
- Aclonifen in tank-mix with Stomp killed zinnia, larkspur and nigella, and was not well tolerated by China aster, though it was safe on bupleurum and cornflower.

In the 2005 trial the best herbicide programmes, and some further single treatments, were tested. Skirmish was included in the trial because its manufacture had been resumed. All applications to emerged weeds were made when they were at the cotyledon to 1-TL growth stage, but the emergence of larkspur, nigella and bupleurum was late this year so that these crops were more advanced than was preferred by the time post-emergence applications were made.

- Groundsel escaped control with many of the herbicides evaluated, but had senesced by the cropping stage of most flowers so did not interfere with picking, leading to higher-than-expected weed control scores for the last weed assessments. Early post-weed-emergence herbicides tested - Goltix, Betanal and Asulox - were effective on groundsel at the cotyledon to1-TL stage.
- Skirmish was applied early post-emergence but caused severe scorch, followed by plant death, for all flower species tested, and its control of groundsel was poor.

In the following crop-by-crop sections, the three years' results are summarised, the year being indicated for the main findings so that more detailed results can be consulted in the 2003 and 2004 Annual Reports or, for the 2005 trial, in Figures 3 – 8. Results for herbicides that were found to be generally harmful to the crops (see previous paragraphs) are not repeated in these summaries.

China aster (drilled) (see Figure 3 for 2005 results)

- Pre-emergence Centium + Stomp provided generally good weed control, though some groundsel escaped, without causing any crop damage (2003, 2004, 2005). From product information it was known that Stomp alone did not control groundsel.
- Crystal, another pre-emergence herbicide containing pendimethalin, was also crop-safe, but weed control was poor and groundsel escaped control (2004).
- Post-weed-emergence Goltix and Betanal were both crop-safe (2003).
- After Centium + Stomp, post-emergence follow-up with Goltix + Betanal or Betanal Expert (alone) caused slight scorch and stunting of the crop, though at an acceptable level, while follow-up with Betanal alone (tested up to 2.5L/ha) was safe but did not control remaining weeds (2004, 2005). These programmes gave excellent weed control, including groundsel.
- The results clearly suggested using a programme based on pre-crop/weed-emergence Centium + Stomp, followed by Betanal, Goltix, Betanal + Goltix, or Betanal Expert, all applied early post-weed-emergence on cotyledon stage weeds.

Cornflower (drilled) (see Figure 4 for 2005 results)

- Pre-emergence Flexidor gave good weed control with no significant damage to cornflower, and pre-emergence Centium + Stomp gave good weed control but caused some crop damage from which it partly recovered. Pre-emergence Kerb or Dacthal were both crop-safe but gave poor weed control (2003).
- Pre-emergence Stomp + Flexidor was effective in controlling most weeds, but not groundsel (2004, 2005), though in 2005 the groundsel senesced before the cornflower were ready for picking. Pre-emergence Kerb + Flexidor left groundsel, mayweeds and pale persicaria (2004). Both Stomp + Flexidor and Kerb + Flexidor were considered crop-safe (2004).
- Pre-emergence aclonifen + Stomp initially caused cornflower slight chlorosis and stunting, but the crop recovered, and weed control was good with the exception of groundsel (2004). In 2005 using Stomp + aclonifen caused more crop damage, with typical aclonifen effects (yellowing).
- Post-emergence Goltix and Defy were safe to the crop and Betanal was only slightly damaging (2003).
- Early post-emergence Betanal Expert or Goltix + Betanal were tested following pre-emergence Stomp + Flexidor: the programme gave excellent weed control, but the post-emergence treatment lacked crop safety (2004). Following Stomp + Flexidor by early post-emergence, low-dose Goltix was safer and gave excellent weed control (2005).
- Cornflowers emerged before the other flower species, and their vigorous growth can quickly suppress weeds. Provided good initial control of weeds is achieved through using a suitable residual pre-crop/weed-emergence tank-mix – Stomp + Flexidor – a further application may not be needed.

Zinnia (drilled) (see Figure 5 for 2005 results)

- Temperatures were high after drilling in 2004 and 2005, and zinnia seed was quick to germinate. Although the crop was tall, it did not provide a dense leaf canopy so is a poor competitor with weeds, particularly at the early growth stages.
- Pre-emergence Stomp + Flexidor and Flexidor were crop-safe and the tank-mix controlled nettle and most other weeds, though groundsel and some pale persicaria remained, so a

post-emergence application would be needed (2003, 2004, 2005). Pre-emergence Stomp + Centium was similar, though less effective on nettle (2004).
- Pre-emergence Kerb or Dacthal were crop-safe but controlled only a limited weed spectrum (2003).
- Several post-emergence herbicides failed to achieve good weed control and (or) caused crop damage (2003).
- Following Stomp + Centium, post-emergence Betanal controlled weeds including nettle, but scorched and stunted the crop though with some recovery that deemed the damage just acceptable, and flower cropping was delayed (2004, 2005). Following Stomp + Flexidor, post-emergence Betanal Expert killed the crop (2004).
- Low-dose tank-mix Goltix + Betanal was the safest post-emergence treatment, but it also delayed cropping (2005).
- The best programme was pre-crop/weed-emergence Stomp + Centium, followed by Goltix + Betanal applied early post-weed-emergence. Stomp + Flexidor followed by Goltix + Betanal was safe, but weed control was inferior. Both programmes caused a slight delay in flowering; pre-emergence herbicides alone did not.

<u>Larkspur (drilled) (see Figure 6 for 2005 results)</u>
- Emergence of larkspur in 2005 was slow, compared with the other species, but better than in 2004. In 2003 and 2004 trials it was sensitive to several herbicides.
- Pre-emergence Dacthal was safe, but its weed control was poor (2003).
- Pre-emergence Centium + Stomp gave good weed control and negligible crop damage (2003, 2004). In 2005 Centium + Stomp was confirmed as acceptably crop-safe, though there was some transient leaf bleaching and stunting and groundsel and some shepherd's purse escaped control.
- Post-emergence Betanal caused scorch initially, but the plants recovered. Other post-emergence herbicides, applied singly, were either ineffective and (or) caused some crop damage (2003).
- Early post-emergence applications of Betanal Expert or Goltix + Betanal, following Stomp + Centium pre-emergence, both caused unacceptable damage - severe stunting and some plant death, though weed control was excellent (2004).
- Programmes of Stomp + Centium followed by early post-emergence Goltix or Betanal were evaluated (2005). The initial damage from Goltix was unacceptable, with scorch followed by severe stunting. Betanal was slightly safer, causing scorch but less stunting. Both Goltix and Betanal delayed flowering, but there was some recovery and the damage was deemed just acceptable before cropping. Both Betanal and Goltix controlled groundsel, and weed control for these programmes was excellent.
- The best pre-crop/weed-emergence treatment was Stomp + Centium, and a lower dose of Centium (0.2 L/ha) should be effective where cleavers are not anticipated. A follow-up with early post-weed-emergence Betanal or Goltix could be applied, but only if weed problems are severe since they are not entirely crop-safe.

<u>Nigella (drilled) (see Figure 7 for 2005 results)</u>
- Nigella was included in the 2004 trial to assess whether herbicide programmes for larkspur could be extrapolated to this species (both are members of the Ranunculaceae). Nigella has less leaf cover and is less competitive than larkspur, needing a high population in order to compete with weeds; it was more sensitive than larkspur to all herbicides tested.

- None of the pre-emergence herbicides tested singly was both crop-safe and effective on weeds (2004).
- When Stomp was applied five days after sowing, crop emergence was delayed and plants became stunted with distorted growing points; the damage was still unacceptable at cropping (2005). Weed control was poor, with several weed species escaping control.
- A follow-up early post-emergence treatment with Goltix + Betanal or Betanal Expert killed the crop (2004). Other early post-emergence applications - Decimate, Skirmish, Betanal and Asulam – were tested when nigella was at the cotyledon stage and some weeds at the 2-TL stage (2005). None of the treatments was safe, all increased crop damage though there was some recovery by flowering, and all failed to give adequate weed control. Betanal and Asulam controlled groundsel.
- No safe, effective treatment was found for nigella. Treatments safe on larkspur cannot be extrapolated to this crop.

<u>Bupleurum (drilled) (see Figure 8 for 2005 results)</u>
- Pre-emergence CIPC + Linuron, Flexidor and Stomp gave good weed control without significant crop damage in 2003. CIPC + Linuron controlled most weeds, though a few groundsel emerged later, and the combination was investigated further since it is an economical material to use. In 2004 there was frequent, heavy rainfall, and CIPC + Linuron resulted in a delay in emergence and a few plants dying, though the rest recovered. In 2005, this mix caused more severe crop damage, with delayed crop emergence followed by death or stunting.
- Pre-emergence Centium + Stomp and Sencorex + Stomp caused crop damage (2003). Stomp + Flexidor tank-mix was safe, but weed control was only just acceptable; aclonifen + Stomp was both crop-safe and effective (2004).
- Pre-emergence tank-mixes of Stomp + Flexidor and Stomp + aclonifen were tested again in 2005, and the aclonifen component caused more crop effects than previously, initially yellowing and stunting, although the bupleurum quickly recovered. Weed control was reasonable but weak on groundsel, so a follow-up treatment would be needed.
- Post-weed-emergence Betanal, Goltix and Defi were safe, while Boxer, Sencorex and Linuron were not (2003).
- Pre-emergence Stomp + Flexidor or CIPC + Linuron were followed by early post-emergence Goltix + Betanal or Betanal Expert, applied when bupleurum was at the cotyledon stage (2004). Before recovery from the effects of CIPC + Linuron, Betanal Expert completely killed the crop and Goltix + Betanal caused severe damage. Post-emergence Betanal Expert, applied after Stomp + Flexidor, caused severe stunting but there was negligible damage from Goltix + Betanal and its weed control was excellent (2004).
- Programmes of Stomp + Flexidor or Stomp + aclonifen followed by early post-emergence Goltix + Betanal, applied when the bupleurum was at only the cotyledon stage, were tested. Goltix + Betanal increased damage where it followed Stomp + aclonifen, causing severe stunting and crop loss. There was also some stunting where it followed Stomp + Flexidor, but bupleurum recovered before cropping. Weed control was excellent for both programmes. (2005).
- Bupleurum has vigorous growth and soon smothers weeds, even in 2005 where its emergence was slow relative to weed emergence, so in some years a pre-emergence wide-spectrum residual herbicide may be all that is required. The best treatment was pre-emergence Stomp + Flexidor followed by early post-weed-emergence Goltix + Betanal. The post-emergence application might have been safer when the bupleurum was at a later growth stage (but it would have been less effective on larger weeds) and Goltix alone may

have been sufficient. Pre-emergence Stomp + Flexidor or Stomp + aclonifen may be all that is required, particularly where groundsel is not a problem.

Herbicide evaluations - transplanted crops

A range of herbicides was screened and applied at a single timing, either pre-transplanting, post-transplanting (pre-weed-emergence) or post-weed-emergence. The pre-transplanting treatments were of Ronstar Liquid and oxadiargyl, two closely related residual herbicides. Oxadiargyl is not yet available in the UK. Ronstar Liquid and oxadiargyl were useful pre-transplanting treatments and controlled all weed species on the trial area - except for chickweed. Both chemicals were safe to China aster, stock and snapdragon, though Ronstar Liquid was less safe to delphinium and phlox. For the later trials only Ronstar Liquid was tested.

Several post-transplanting and post-weed-emergence treatments were phytotoxic and their use was eliminated after the first or second year's trial. Applied post-transplanting:

- Simazine killed snapdragon and phlox and caused severe damage and some death to stock and delphinium.
- CIPC + Linuron killed snapdragon, delphinium and phlox.
- Dacthal + Butisan caused severe stunting to snapdragon and some damage to delphinium.
- Venzar killed phlox**.**
- Stomp + aclonifen killed delphinium and snapdragon and severely stunted stocks.

Applied post-weed-emergence:

- Sencorex killed delphinium.
- Boxer caused severe damage to China aster and delphinium.
- Defy caused stunting in China aster, and weed control was poor.
- Betanal caused severe damage to snapdragon and lesser damage to stock.
- Goltix caused damage and delayed flowering of snapdragon

In the following crop-by-crop sections, the three years' results are summarised, the year being indicated for the main findings so that more detailed results can be consulted in the 2003 and 2004 Annual Reports or, for the 2005 trial, in Figures 9 – 13. Results for herbicides that were found to be generally harmful to the crops (see previous paragraphs) are not repeated in these summaries.

<u>China aster (transplanted) (see Figure 9 for 2005 results)</u>

- Ronstar Liquid and oxadiargyl were safe and effective applied pre-transplanting (2003).
- Goltix and Betanal, applied early post-weed-emergence to small weeds, were safe and effective; Defy and Boxer were not (2003).
- After Ronstar Liquid, pre-weed-emergence application of Butisan caused severe stunting (2004).
- After Ronstar Liquid, post-weed-emergence Goltix + Betanal caused slight crop effects initially, the crop recovering later, while Betanal Expert was safer and controlled weeds (including chickweed surviving the Ronstar Liquid treatment) but only scorching pale persicaria (2004, 2005).
- The best programme was a pre-transplanting application (Ronstar Liquid) followed by early post-weed-emergence Betanal Expert.

<u>Stock (transplanted) (see Figure 10 for 2005 results)</u>

- Ronstar Liquid and oxadiargyl were safe and effective applied pre-transplanting (2003).

- Post-transplanting Decimate and Dacthal + Butisan were safe and effective; Stomp and Stomp + Centium were also effective but less crop-safe (2003).
- Applied post-weed-emergence, Goltix damage was at an acceptable level, but Betanal was more damaging (2003).
- Following Ronstar Liquid, post-transplanting Dacthal + Butisan or Butisan resulted in slight chlorosis, an initial growth check or stunting, and some delay to flowering (compared with hand-weeded plots), though the crop recovered, so these effects were considered acceptable (2004, 2005). The programme completely controlled weeds.
- Following Dacthal + Butisan or Butisan post-transplanting, Goltix applied post-weed-emergence to small weeds (cotyledon to 1-TL stage) resulted in temporary chlorosis and stunting, the plants recovering but still having delayed flowering (2004, 2005). The programme completely controlled weeds. Butisan (alone) failed to control pale persicaria and knotgrass; with Dacthal + Butisan and Goltix the Goltix killed the pale persicaria, though a few knotgrass remained.
- The programme with Butisan followed by Goltix (1.7 L/ha) was effective, though the latter caused some temporary stunting and leaf chlorosis, but the plants recovered by flowering time (2005).
- The best programmes were post-transplanting Dacthal + Butisan, or pre-transplanting Ronstar Liquid followed by post-transplanting Butisan.

<u>Snapdragon (transplanted) (see Figure 11 for 2005 results)</u>

- Ronstar Liquid and oxadiargyl were safe and effective applied pre-transplanting (2003).
- Applied post-transplanting, only Venzar was crop-safe and gave effective weed control (2003).
- Goltix and Betanal, post-weed-emergence, was damaging to the crop (2003).
- Following pre-transplanting Ronstar Liquid, post-transplanting Goltix resulted in a stunted, thin crop (2004). Although the crop recovered later to some extent, the flowers were short and very late. Following Ronstar Liquid or post-transplanting Venzar, Goltix applied early post-weed-emergence and at a lower dose (1.5 kg/ha) caused less stunting and only a slight delay in flowering (2004). These programmes completely controlled weeds, but also caused some delay in flowering, compared with the hand-weeded plots.
- Programmes beginning with post-transplanting Venzar + Ramrod or Stomp and followed by early post-weed-emergence Goltix, there was severe stunting, along with some plant loss (due to Stomp) (2004). These programmes completely controlled weeds, but also caused some delay in flowering, compared with the hand-weeded plots.
- Stomp + aclonifen applied as a single treatment post-transplanting killed the crop (2004).
- Nortron applied as a single treatment post-weed-emergence caused very slight leaf distortion and there was no effect on flowering date, but weed control was poor (2004).
- All combinations in the 2005 trial gave good weed control. Ronstar Liquid gave the best start, controlling all weeds except chickweed. Goltix was not a good follow-up after Ronstar Liquid because it is ineffective on chickweed. Venzar post-transplanting was safe but several weed species remained – which could be controlled by Goltix or Nortron. However, Goltix, even at a low dose (1.5 L/ha) caused scorch and stunting and delayed flowering by about 14 days; Nortron caused slight thinning and vigour loss but was safer than Goltix.
- The best programme was pre-transplanting Ronstar Liquid or post-transplanting Venzar, followed by Nortron at early post-weed-emergence.

Delphinium (transplanted) (see Figure 12 for 2005 results)

- Ronstar Liquid had damaging effects on the crop and was considered to have a small margin of crop safety, consequently it was not tested further (2003).
- Post-transplanting Decimate, Stomp and Stomp + Centium caused only minor crop damage (2003). CIPC + Linuron caused severe crop damage; it was tested at a lower dose (2.8 + 1.1 L/ha) in 2005, but was still damaging.
- Applied post-weed-emergence, Betanal caused only slight crop damage and was safer than Goltix (2003).
- Applied post-transplanting, Stomp or Stomp + Centium or Stomp + Ramrod caused slight crop stunting but appeared to be acceptably safe, though some weed species escaped control (2004).
- Applied early post-weed-emergence to small weeds (cotyledon to 1-TL stage) after a post-transplanting treatment:
    - Betanal Expert (after Stomp, Stomp + Centium or Stomp + Ramrod) was very damaging initially and caused scorch and severe stunting.
    - Goltix + Betanal (also after Stomp, Stomp + Centium or Stomp + Ramrod) caused stunting but gave marginally better weed control.
    - Goltix (applied after Stomp + Centium) was safer.
    - Of these programmes, the best appeared to be Stomp + Centium followed by a low-dose (1.5 kg/ha) Goltix (2004).
- Flexidor + Goltix, applied as a single treatment post-transplanting, was just acceptable in terms of crop safety, but gave the best weed control (2004).
- In 2005 herbicide programmes were tested again, but none was completely safe. Post-transplanting Stomp + Ramrod left shepherd’s purse and groundsel and appeared less safe than Stomp + Centium (which left groundsel), and following by Goltix early post-weed-emergence increased damage.
- The best treatment was post-transplanting Stomp + Centium followed by early post-weed-emergence Goltix or, alternatively, Betanal.

Delphinium – second-year (see Figure 13)

Delphiniums planted for the 2004 trial were left down for a second year, no further herbicides being applied. The plants grew vigorously in spring 2005 and were assessed at intervals. They completely suppressed germinating weeds on those plots where weed control had been most effective in the previous year, not where the very safe but less effective treatments (such as Stomp) had been used, neither where the crop was severely damaged (by Betanal Expert) and less vigorous. The best plots were those previously treated with Stomp + Centium or Stomp + Ramrod and followed by Goltix with or without Betanal.

Phlox (transplanted)

Ronstar Liquid was not reliably crop-safe on phlox, and all the herbicides applied post-transplanting or post-weed-emergence were damaging.

Cut-flower quality

Except for treatments where the flowers were overwhelmed by weeds, or the flowers suffered herbicide damage and were unmarketable, three bunches of ten stems were cropped from each plot at a commercial cropping stage and their quality recorded.

In the 2003 trial 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 Simazine or Stomp (post-transplanting) or Goltix or Betanal (post-emergence) had been used, and several of these materials were found to cause other crop damage (see below). In transplanted China aster using Defy resulted in bunches an average of 4cm shorter than in hand-weeded controls, but stems from this treatment were unmarketable for other reasons. In most cases these results simply reflected crop tolerance scores, therefore the data are not presented.

In 2004 the bunch weights, stem lengths, appearance and vase-life were again a reflection of crop tolerance assessments. There were no obvious differences in the visual quality of stems cropped from the hand-weeded controls and from the successful herbicide treatments. In transplanted snapdragon, Goltix caused stunting and a delay in flowering.

In 2005 there were no differences in the visual quality or vase-life of stems cropped from the hand-weeded controls and from the successful herbicide treatments, nor were there any statistically significant reductions in bunch weight or stem length due to herbicide treatments. For delphiniums in their second year, the best quality and vase-life was for those treatments previously mentioned in the text (see Figure 13). In transplanted snapdragon, Goltix again caused stunting and a delay in flowering. In spite of the early effects of some herbicides in stocks, all gave similar weights, stem lengths and vase-life to those from the hand-weeded plots. In drilled nigella only the hand-weeded controls were marketable. Larkspur had recovered from herbicide damage by the time of cropping (except for those treated with Skirmish), and quality, bunch weight and stem length was similar to the hand-weeded plots. There was some delayed maturity for some zinnia treatments, but the stunting recorded was not reflected in the quality or weight of cropped stems. The bunch weights, stem lengths, appearance and vase-life were again a reflection of crop tolerance assessments.

CONCLUSIONS

It is clear from three years' trials that in cut-flower crops weeds must be controlled with residual herbicides. Early removal of weeds avoids weed/crop competition, while later applications, closer to flower initiation, are likely to cause more damage. In addition, suitable foliar-acting herbicides that are safe (preferably at low dose rates) and control narrow weed spectra, need to be applied early, to small weeds (cotyledon to 1-TL stage). In some cases a little hand-weeding may be a better solution. Small nettle deters flower-pickers - it was widespread on the trial area, though good control was achieved from several treatments (Flexidor, Dacthal, Kerb, Ronstar Liquid, Betanal and Goltix). Appendix 2 presents information on weed susceptibility and may help with the selection of appropriate herbicides.

Some flower species – e.g. drilled cornflower and bupleurum - emerge rapidly and their vigorous growth quickly suppresses weeds. Transplanted aster, stock and snapdragon are also quick to compete. In some seasons a pre-emergence wide-spectrum herbicide may be all that is required for such species. Other species are less competitive, e.g. delphinium transplants and drilled larkspur and nigella. Although zinnias are tall, they do not provide a dense leaf canopy, and are poor competitors, particularly at early growth stages. Nigella has less leaf cover and is less competitive than larkspur (both Ranunculaceae), and it was included in the project to assess whether herbicide programmes can be extrapolated from one species to another in the same family, a common assumption. In this case nigella was more sensitive than larkspur to all herbicides tested: no extrapolation was possible.

In the three years of the project, adequate rainfall and irrigation ensured good activity of residual herbicides and a realistic test of crop safety. Although water is needed after herbicide application for good residual activity, some residual herbicides are leached and are prone to cause damage if rainfall or irrigation are heavy. Pre-emergence tank-mix CIPC + Linuron (4.2 + 1.7 L/ha) appeared safe in 2003, but was less safe in 2004, and in 2005 even a lower dose (2.8 + 1.7 L/ha) caused severe damage: emergence was delayed and followed by death of some plants, and the remaining plants were stunted. This effect demonstrates the importance of evaluating herbicides for more than 1 year.

Most of the herbicides included in this study are currently available and, as far as could be anticipated, likely to remain so. Only in a few, promising cases were as yet unobtainable actives used. Thus oxadiargyl is a new active used pre-transplanting (at 1.0 L/ha) like Ronstar Liquid. Oxydiagyl is on Annex 1 and when it becomes available in the UK it could be used on transplants. Aclonifen is not yet available in the UK, and was damaging to most crops in this study, but in tank-mix with Stomp looked promising as a pre-emergence herbicide for bupleurum and cornflower.

Effective herbicides used on cut-flower crops need not only to be obviously non-phytotoxic, but must also be non-detrimental to crop quality at harvest and during vase-life. The quality of cropped stems was assessed by measuring stem length and bunch weight. Once clearly unsuitable herbicide treatments (those damaging crops to the point of unmarketability, or impractical to crop due to overgrowth by uncontrolled weeds) had been excluded, there were no significant differences in length or weight due to the ‘successful’ herbicide used. Quality was also assessed by comparing the visual appearance of stems from successful treatments against hand-weeded control plants, and no visual differences could be seen. Similar conclusions were drawn regarding length of vase-life, recorded under standard conditions; there were no adverse effects of successful herbicide treatments. In all instances, these quality measurements reflected the crop tolerance assessments made in the field.

Effective and safe herbicide programmes have been established for the drilled crops studied except nigella, and are summarised below.

- China aster (drilled)

For drilled China aster the best programmes were based on pre-crop/weed-emergence Stomp + Centium (3.3 + 0.25 L/ha), followed by Goltix + Betanal (1.0 kg/ha + 1.8 L/ha) or Betanal Expert (1.5 L/ha) applied early post-emergence to cotyledon weeds. Goltix (1.7 kg/ha) and Betanal (up to 2.5 L/ha) would be possible post-weed-emergence alternatives.

- Cornflower (drilled)

Cornflowers are quick to emerge and their vigorous growth quickly suppresses weeds. A single treatment with a residual pre-crop/weed-emergence herbicide may be sufficient to achieve good weed control. The best treatment was Stomp + Flexidor (3.3 + 1.0 L/ha), with, if needed, a follow-up early post-emergence with Goltix (1.7 L/ha) applied to cotyledon weeds.

- Zinnia (drilled)

Although zinnia plants are tall at flowering stage, they do not provide a dense leaf canopy, so are poor competitors with weeds, particularly at early growth stages. The best treatment was pre-crop/weed-emergence Stomp + Centium (3.3 + 0.25 L/ha) followed by Goltix + Betanal (1.0kg/ha + 1.0 L/ha) applied early post-weed-emergence. Stomp + Flexidor (3.3 + 1.0 L/ha) followed by Goltix + Betanal (1.0kg/ha + 1.0 L/ha) was safe, but weed control was inferior. Both programmes caused a slight delay in flowering, so there is still scope for an improved treatment.

- Larkspur (drilled)

The best treatment for drilled larkspur was pre-crop/weed-emergence Stomp + Centium (3.3 + 0.25 L/ha). A lower dose of Centium (0.2 L/ha) should be effective alternative, where cleavers are not anticipated. A follow-up with early post-weed-emergence Betanal (1.8 L/ha) or Goltix (1.7 kg/ha) could be applied if weed problems are severe, but these are not entirely crop-safe.

- Bupleurum (drilled)

Bupleurum has vigorous growth and soon smothers weeds. The best treatment for drilled bupleurum was pre-crop/weed-emergence Stomp + Flexidor (3.3 +1.0 L/ha) followed by early post-weed-emergence Goltix + Betanal (1.7 kg/ha + 1.8 L/ha). The post-emergence application might be safer when the bupleurum is at a later growth stage, though it is less effective on larger weeds; alternatively, Goltix alone (1.7 kg/ha) may be sufficient. Pre-crop/weed-emergence Stomp + Flexidor (as above) (or Stomp + aclonifen (3.3 + 2.0 L/ha)) might be all that is required where groundsel is not a problem.

- Nigella (drilled)

No safe, effective herbicide treatment was found for nigella. Treatments safe on larkspur cannot be extrapolated to this crop. Nigella produces less leaf cover, is not as tall as larkspur, and is less competitive with weeds. Nigella was more sensitive than larkspur to all herbicides tested. Further research is needed.

Effective and safe herbicide programmes have been established for the transplanted crops studied, except phlox, and are summarised below.

- China aster (transplanted)

The best treatment for China aster was pre-transplanting Ronstar Liquid (4.0 L/ha), followed by early post-weed-emergence Betanal Expert (1.5 L/ha) when weeds are small. This combination gave better weed control than the industry standard Ramrod + Dacthal or Decimate.

- Stock (transplanted)

The best treatment was Dacthal + Butisan (9 kg/ha + 1.5 kg/ha) post-transplanting. Ronstar Liquid (4.0 L/ha) pre-transplanting, followed by post-transplanting Butisan (1.5 L/ha) could also be considered but caused slight stunting.

- Snapdragon (transplanted)

The best treatments for snapdragon were Ronstar Liquid (4.0 L/ha) pre-transplanting or Venzar (4.0 L/ha) post-transplanting. Nortron (2.0 L/ha) early post-weed-emergence for weeds escaping control was safe.

- Delphinium (transplanted)

Delphiniums are slow to compete with weeds and sensitive to herbicides, and all herbicides tested, including Ronstar Liquid, caused some damage on the newly transplanted crop. For the perennial crop, however, effective weed control (rather than total crop safety) during establishment seems to be more important. The best first-year treatment, as assessed from second-year plants, was post-transplanting Stomp + Centium (3.3 + 0.25 L/ha) followed by early post-weed-emergence Betanal (1.8 L/ha) or Goltix (1.7 kg/ha).

- Phlox (transplanted)

Ronstar Liquid was not reliably crop-safe on phlox, and all the herbicides applied post-transplanting or post-weed-emergence were damaging. Further research is needed.

Several of the herbicide programmes tested gave excellent weed control, although several caused adverse crop effects. These programmes have the potential to ease weed problems in cut-flower crops, reducing the costs of hand-weeding. The costs of the best programmes with two applications in drilled crops ranged from £70/ha to £110/ha for herbicides, and in transplanted crops ranged from £63/ha to as much as £505/ha for herbicides. Spray application costs (including additional costs for spraying small areas) of £22/ha to £28/ha for two herbicide applications are suggested. However, where weed pressure is low, or the crops are effective at suppressing weeds, one application may be enough. Weed spectrum can differ considerably between fields, soil types, previous cropping, etc., and weed species are not easy to anticipate. Some of the better crop/herbicide combinations, given in the summary above, could be tested, at the grower's risk, on small areas of commercial flower crops. The names of active ingredients and formulations for the products tested are given in Table 5, and Appendix 2 indicates the weed susceptibility to the herbicides used and may be helpful in decision-making.

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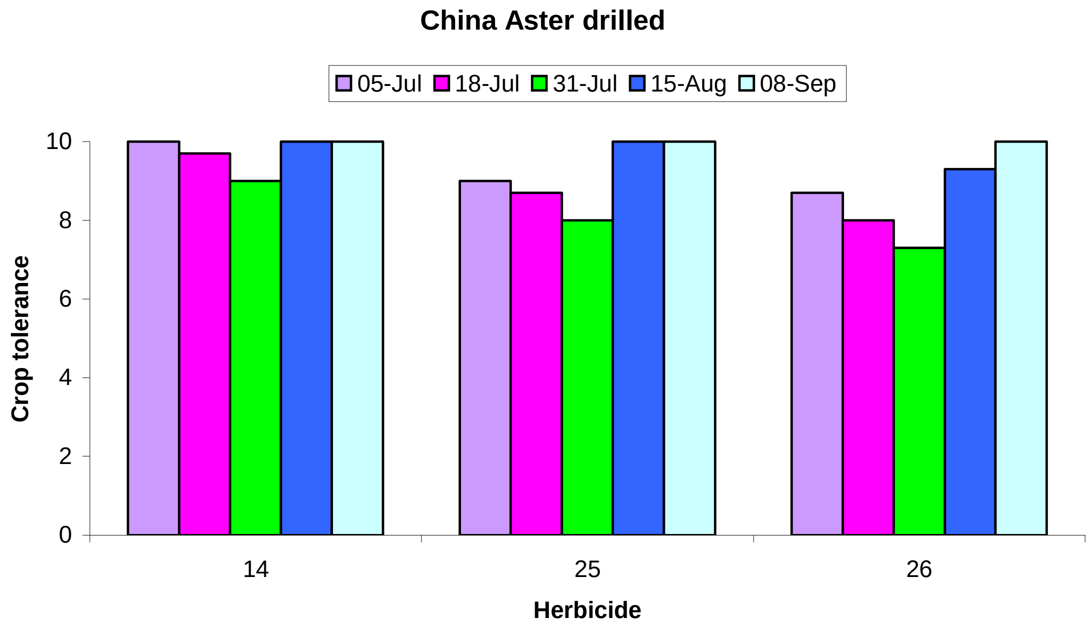
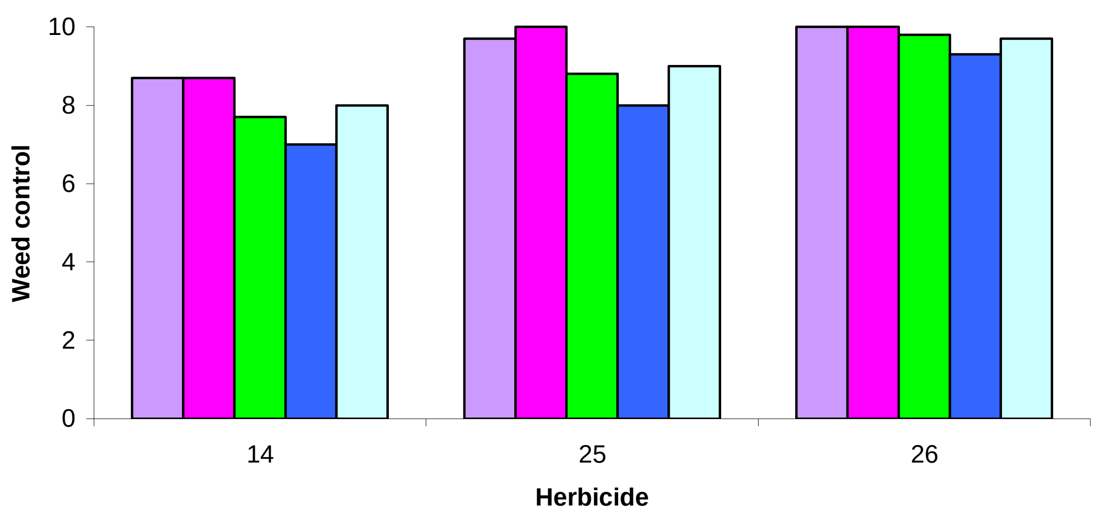
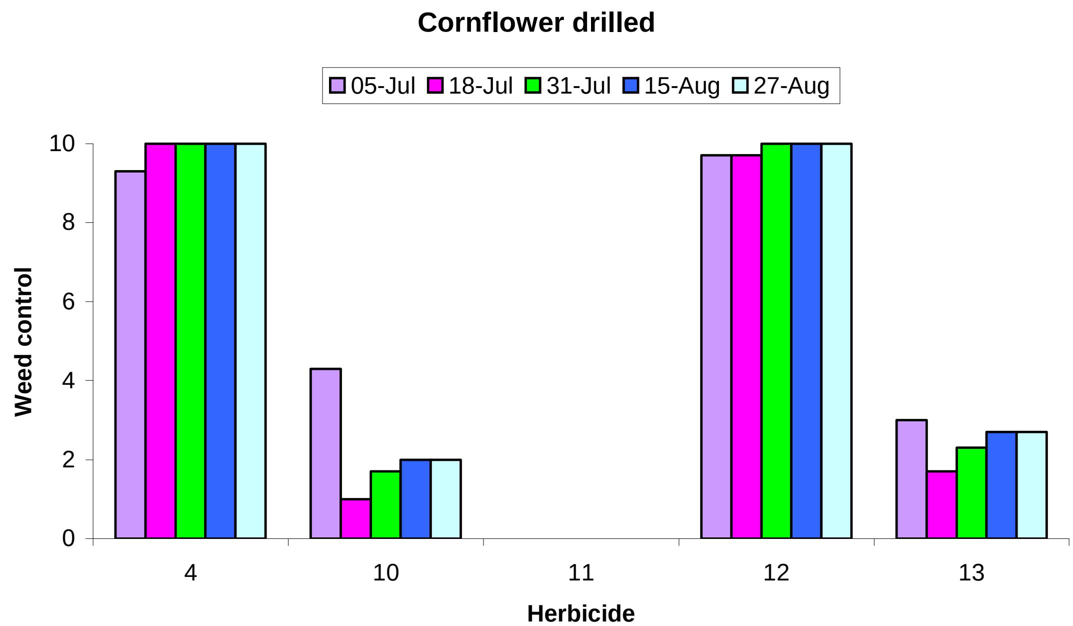
Figure 3. Crop and weed profile for **China aster drilled** on 9 June assessed on five dates (2005). Weed control assessed from 0 (no control) to 10 (complete weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.** Herbicides, crop damage and growth stages are shown in the table below.

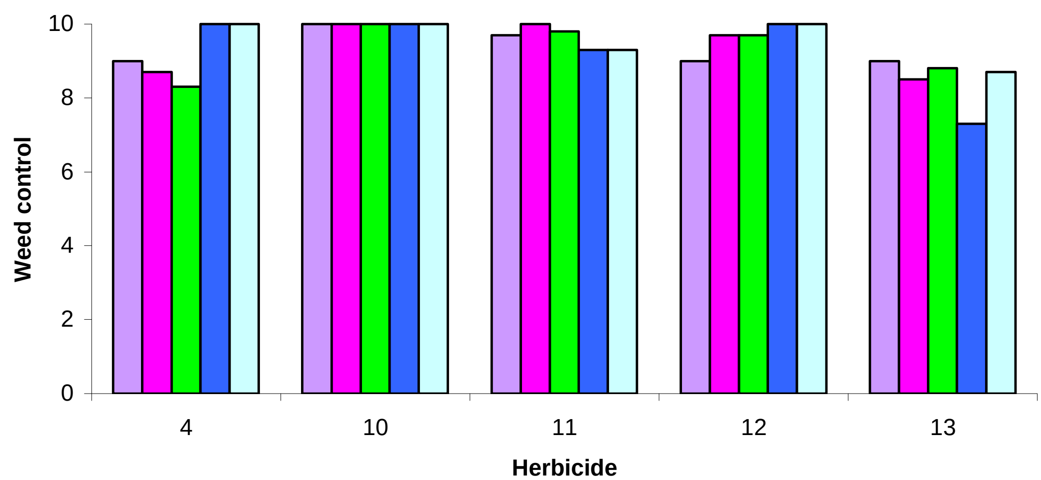




No.	*Pre-weed-emergence*	*Early post-weed-em*	*Crop damage*			
	14/6	*28/6 Cot-1/2-TL*	*5/7 3TL*	*18/7 6 TL*	*31/7 9 TL*	*15/8 60% cover*
14	Stomp+Centium 3.3 + 0.2		-	-	stunt delay	-
25	Stomp+Centium 3.3 + 0.2	Betanal Expert 1.5	slight stunt	stunt delay	stunt delay	-
26	Stomp+Centium 3.3 + 0.2	Goltix+Betanal 1.0+1.8	stunt	stunt	stunt delay	-

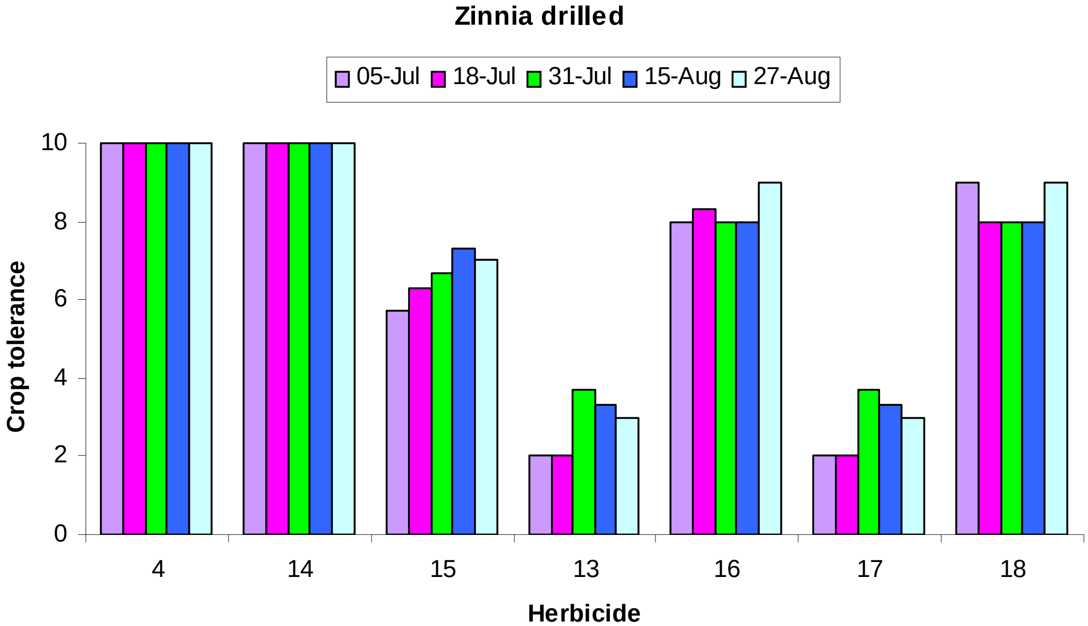
Figure 4. Crop and weed profile for **cornflower drilled** on 9 June assessed on five dates (2005). Weed control assessed from 0 (no control) to 10 (complete weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.** Herbicides, crop damage and growth stages are shown in the table below.

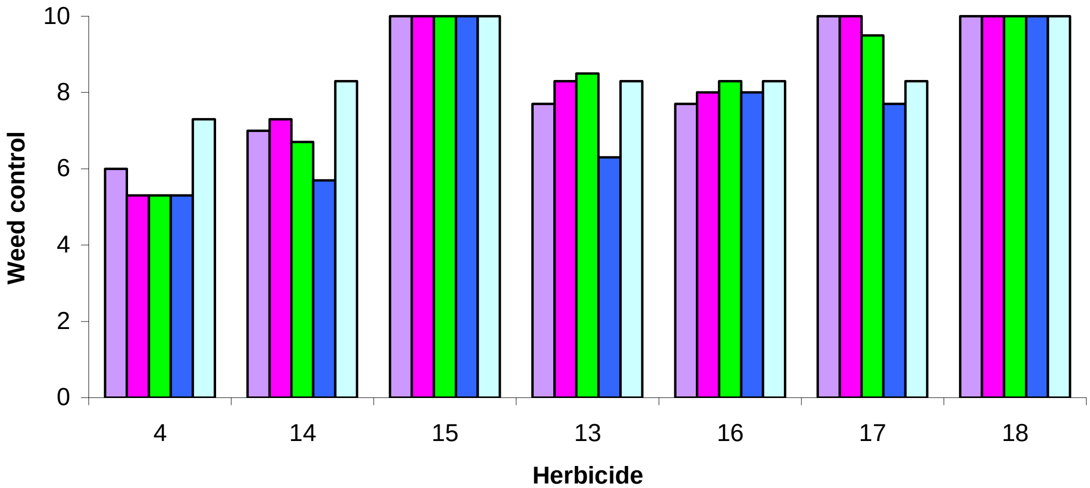




No.	*Pre-weed-emergence*	*Early post-weed-em*	*Crop damage*			
	14/6	*28/6 2-3TL*	*5/7 3TL*	*18/7 bud encl 80% cover*	*31/7 bud 100% cover*	*27/8 100% flower*
4	Stomp+Flexidor 3.3 + 1	-	-	-	-	-
10	Aclonifen+Stomp 2 + 3.3	Goltix 1.7	severe scorch	plant loss	-	-
11	Aclonifen+Stomp 2 + 3.3	Skirmish 1	complete kill	-	-	-
12	Stomp+Flexidor 3.3 + 1	Goltix 1.7	-	-	-	-
13	Stomp+Flexidor 3.3 + 1	Skirmish 1	plant loss	-	-	-

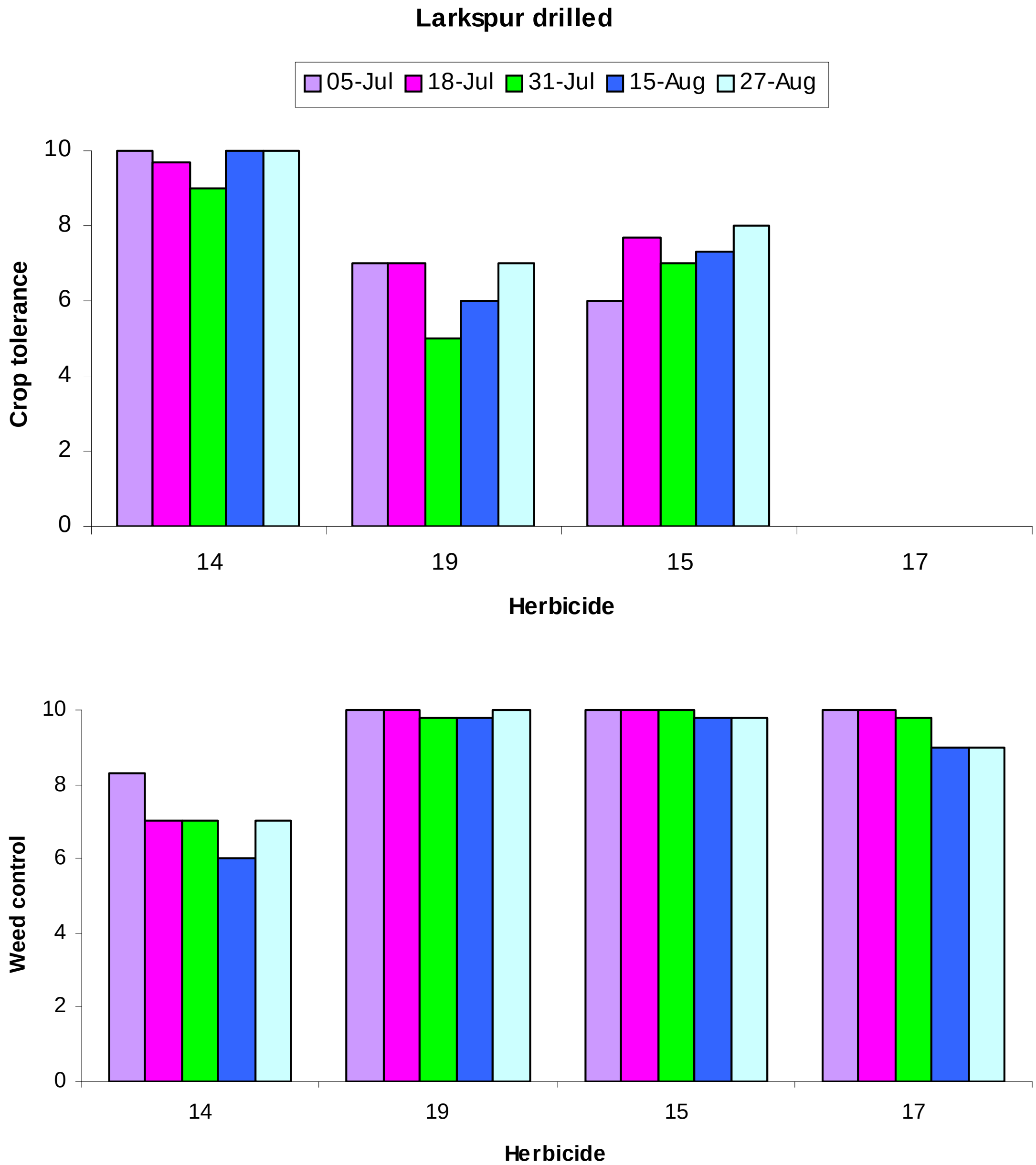
Figure 5. Crop and weed profile for **zinnia drilled** 9 June assessed on five dates (2004). Weed control assessed from 0 (no control) to 10 (complete weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.** Herbicides, crop damage and growth stages are shown in the table below.





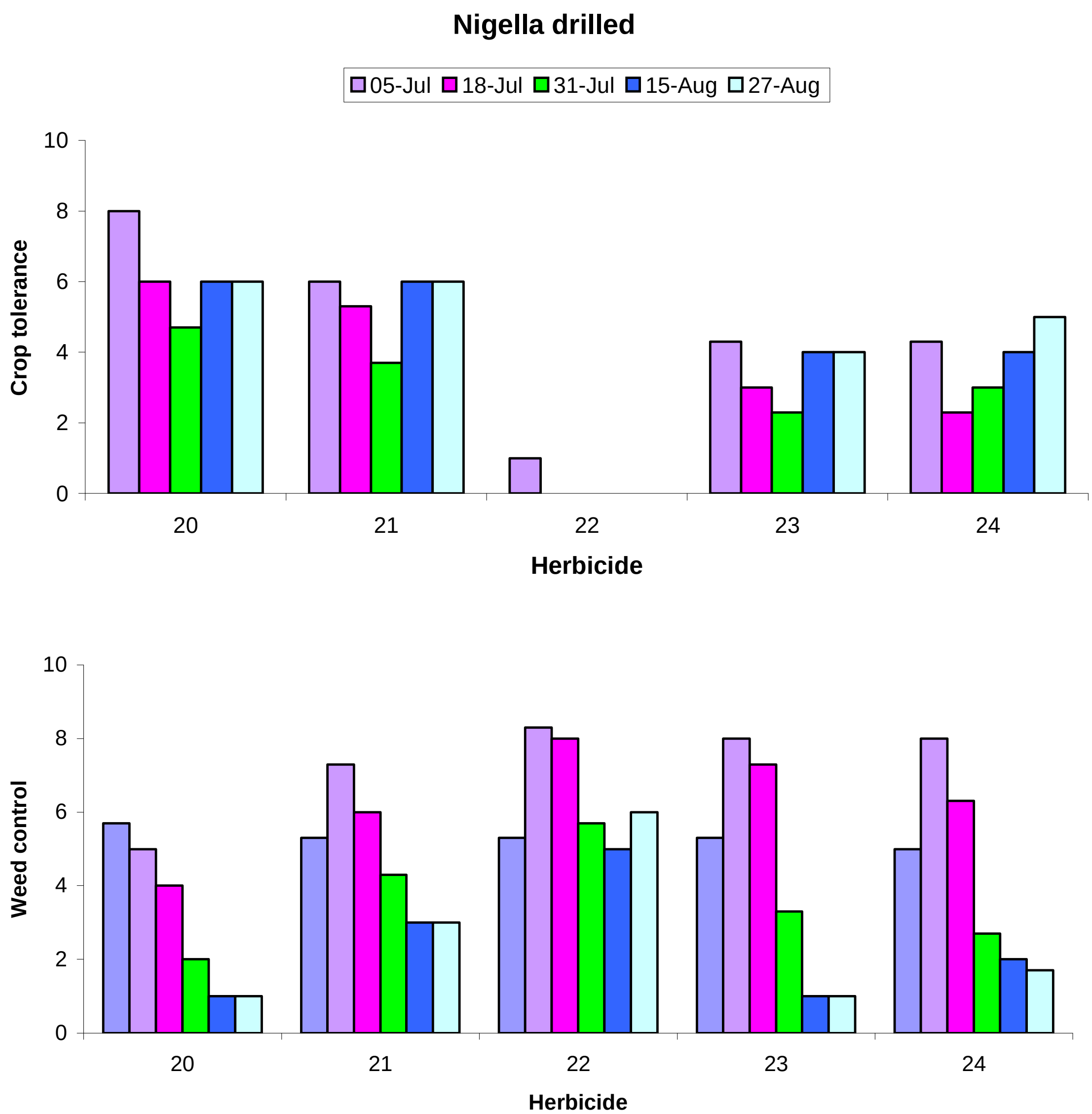
No.	*Pre-weed-emergence*	*Early post-weed-em*	*Crop damage*			
	14/6	*28/6*	*5/7 2 prsTL*	*18/7 bud encl*	*31/7 bud 80% cover*	*27/8 100% flowers*
4	Stomp+Flexidor 3.3+ 1	-	-	-	-	-
14	Stomp+Centium 3.3+ 0.25		-	-	-	-
15	Stomp+Centium 3.3+ 0.25	Betanal 1.8	scorch	stunt scorch	stunt delay	stunt loss
13	Stomp+Flexidor 3.3+ 1	Skirmish 1	severe scorch	stunt scorch	stunt loss	stunt loss
16	Stomp+Flexidor 3.3+ 1	Goltix+Betanal 1+1	scorch	stunt scorch	delay	slight delay
17	Stomp+Centium 3.3+ 0.25	Skirmish 1	severe scorch	stunt scorch	stunt loss	stunt loss
18	Stomp+Centium 3.3+ 0.25	Goltix+Betanal 1+1	scorch	stunt scorch	delay	slight delay

Figure 6. Crop and weed profile for **larkspur drilled** on 9 June assessed on five dates (2005). Weed control assessed from 0 (no control) to 10 (complete 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.** Herbicides, crop damage and growth stages are shown in the table below.



No.	*Pre-weed-emergence*	*Early post-weed-em*	*Crop damage*				
	14/6	*28/6 crop emerging*	*5/7 2-4TL*	*18/7 5 TL*	*31/7*	*15/8 buds*	*27/8 buds*
14	Stomp+Centium 3.3 + 0.25	-	-	bleach	-	-	-
19	Stomp+Centium 3.3 + 0.25	Goltix 1.7	scorch stunt	stunt	stunt loss	stunt loss	delay
15	Stomp+Centium 3.3 + 0.25	Betanal 1.8	scorch	stunt	stunt loss	stunt	stunt delay
17	Stomp+Centium 3.3 + 0.25	Skirmish 1	death	-	-	-	-

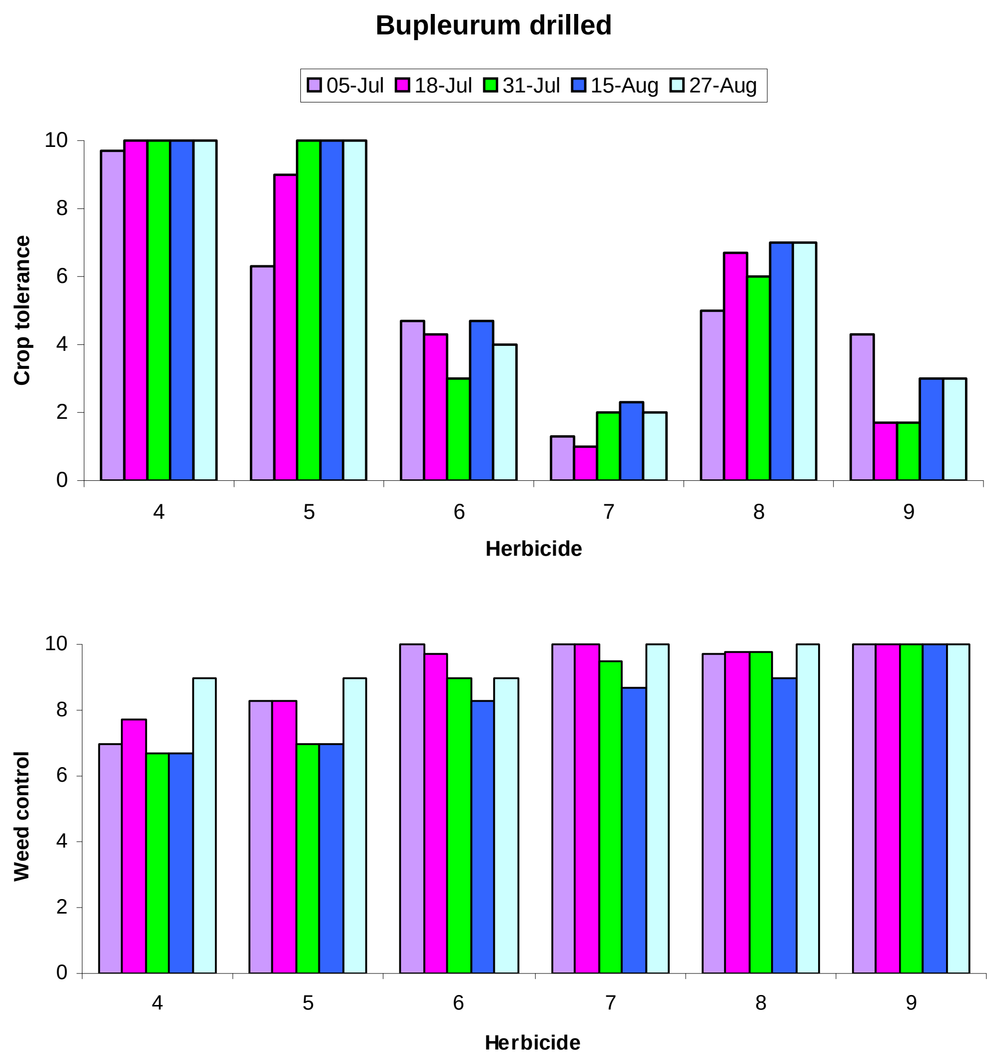
Figure 7. Crop and weed profile for **nigella drilled** on 9 June and assessed on five dates (2005). Weed control assessed from 0 (no control) to 10 (complete weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.** Herbicides, crop damage and growth stages are shown in the table below.



No.	*Pre-weed-em*	*Early post-weed-em*	*Crop damage#*				
	14/6	*28/6 cot*	*5/7 1-2TL*	*18/73 4 TL*	*31/7*	*15/8 bud*	*27/8 1 flower*
20	Stomp 2	-	delay	stunt	stunt	stunt	delay stunt
21	Stomp 2	Decimate 20	delay	stunt	stunt	stunt	delay stunt
22	Stomp 2	Skirmish 1	delay scorch	death	death	death	death
23	Stomp 2	Betanal 1.8	delay scorch	stunt scorch	stunt	stunt	delay stunt
24	Stomp 2	Asulam 2.5	delay scorch	stunt	stunt	stunt	delay stunt

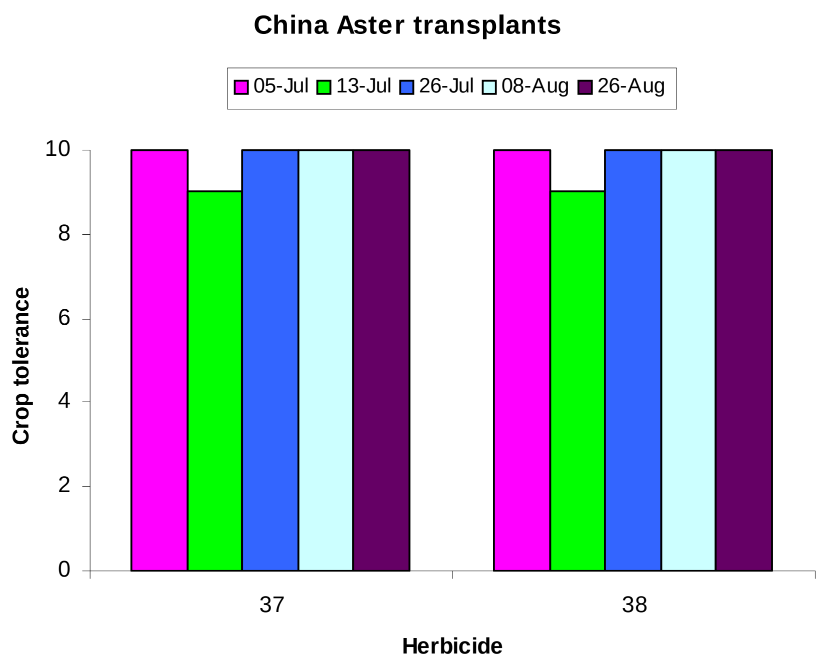
stunting and delay mainly from Stomp applied close to emergence

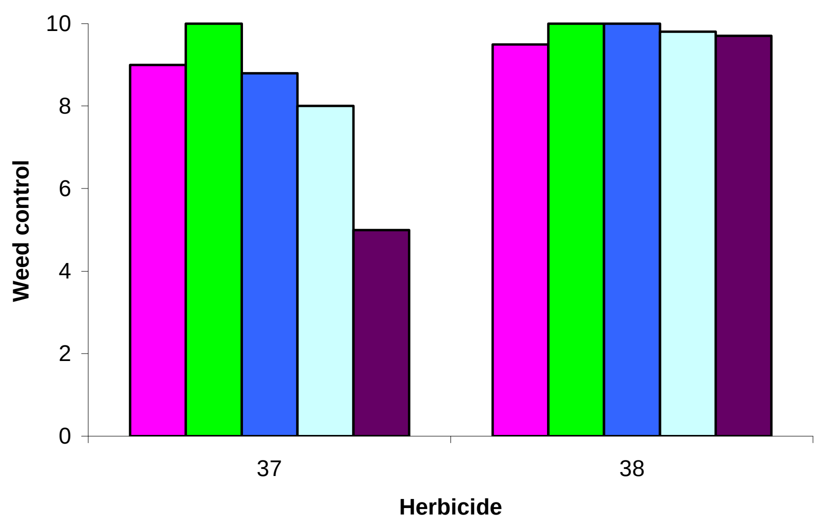
Figure 8. Crop and weed profile for **bupleurum drilled** on 9 June and assessed on five dates (2004). Weed control assessed from 0 (no control) to 10 (complete weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.** Herbicides, crop damage and growth stages are shown in the table below.



No.	*Pre-weed-emergence*	*Early post-weed-em*	*Crop damage*			
	14/6	*28/6 cot*	*5/7 2TL*	*18/7 4-5TL*	*31/7 7TL*	*15/8 buds*
4	Stomp+Flexidor (3.3 + 1)	-	-	-	-	-
5	aclonifen+Stomp (2 + 3.3)	-	stunt yellow	-	-	-
6	CIPC+Linuron (2.8 + 1.7)	-	loss	loss	loss	loss
7	CIPC+Linuron (4.2 + 1.7)	-	severe loss	severe loss	stunt loss	severe loss stunt
8	Stomp+Flexidor (3.3 + 1)	Goltix+Betanal (1.7+1.8)	stunt scorch	scorch	stunt loss	stunt loss
9	Stomp+Aclonifen (3.3+2)	Goltix+Betanal (1.7+1.8)	severe scorch	scorch	severe stunt loss	severe stunt loss

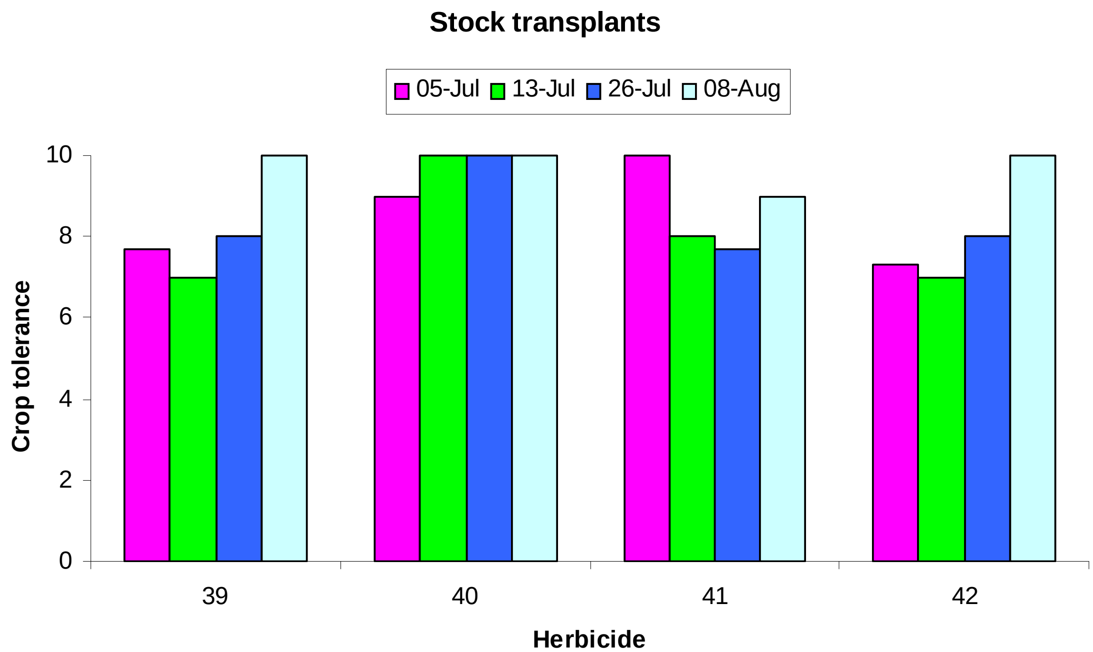
Figure 9. Crop and weed profile for **China aster transplanted** on 16-17 June and assessed on five dates (2005). Weed control assessed from 0 (no control) to 10 (complete weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.** Herbicides, crop damage and growth stages are shown in the table below.

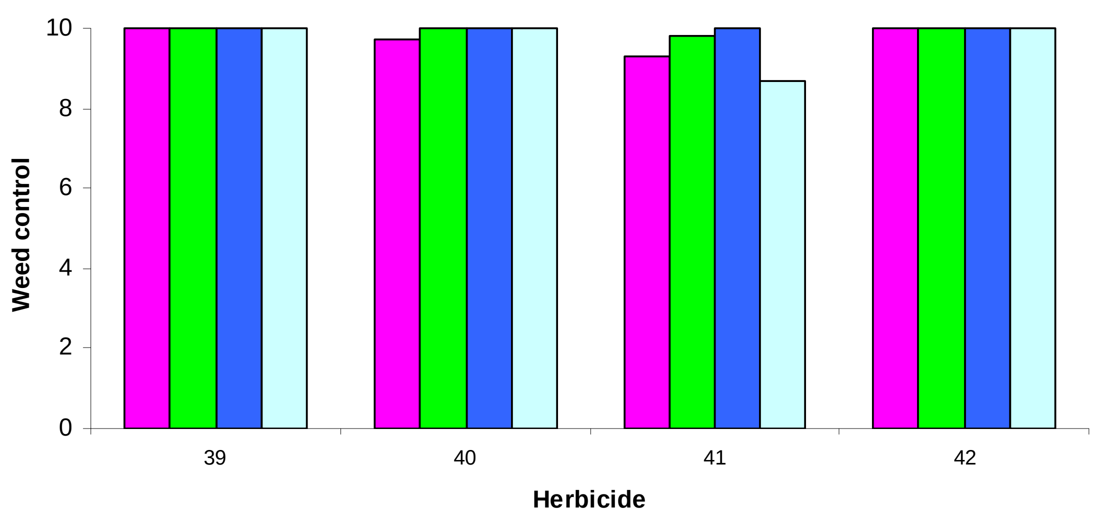




No.	*Pre-transplant*	*Pre-weed-em*	*Early post-weed-em*	*Crop damage*				
	16/6	*20/6*	*8/7*	*27/6*	*5/7*	*13/7*	*26/7*	*26 /8*
37		Decimate 20	Betanal Expert 1.5	-	-	slight stunt	-	-
38*	Ronstar Liquid 4		Betanal Expert 1.5	-	-	slight stunt	-	-

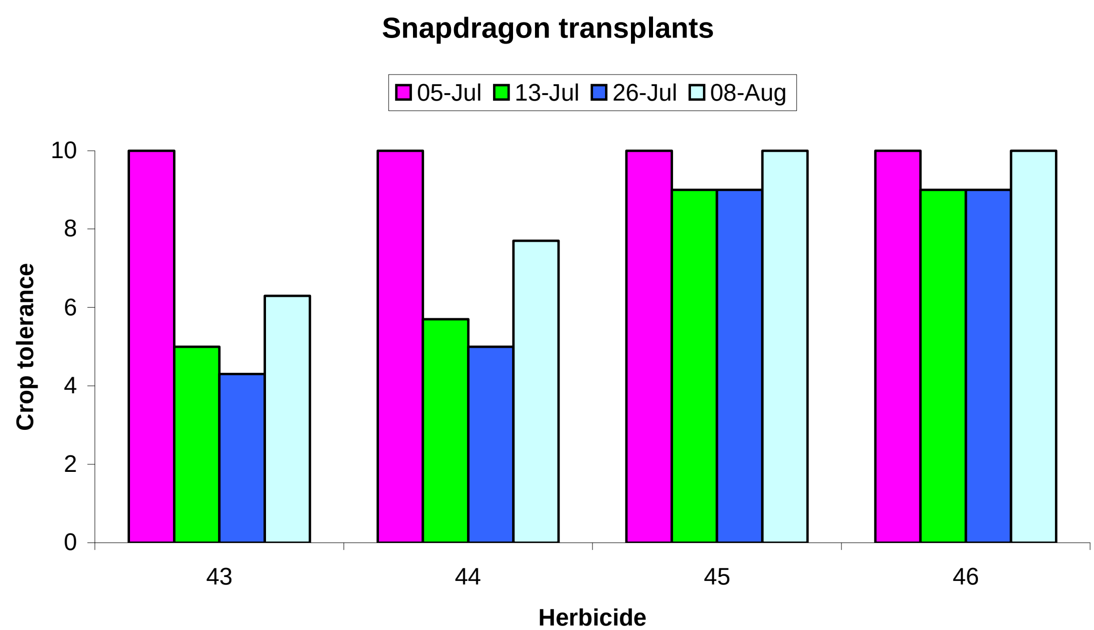
Figure 10. Crop and weed profile for **stocks transplanted** 17 –20 June assessed on four dates (2005). Weed control assessed from 0 (no control) to 10 (complete weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.** Herbicides, crop damage and growth stages are shown in the table below.

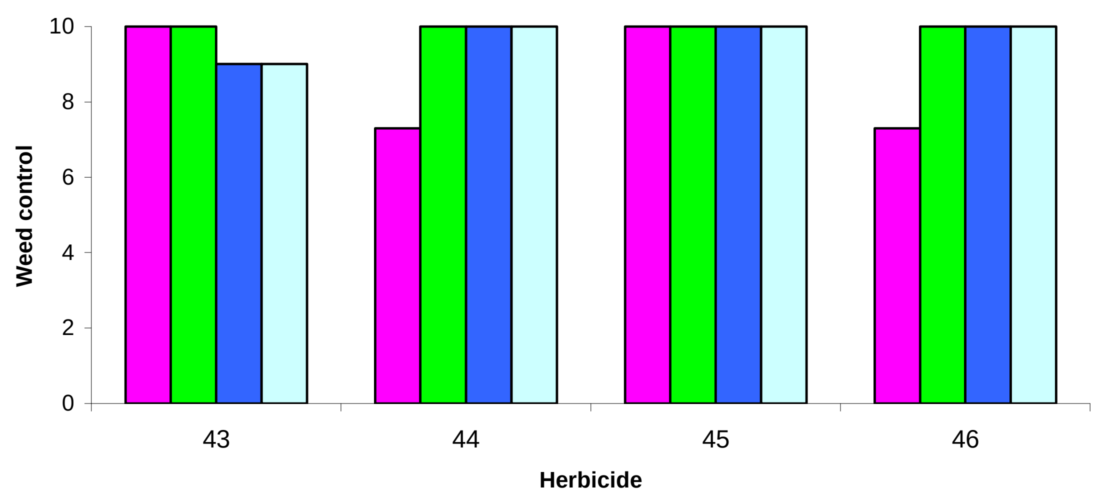




No.	*Pre-transplant*	*Pre-weed-em*	*Early post-weed-em*	*Crop damage*			
	17 /6	*20 /6*	*8/7*	*27/6*	*5/7*	*26/7*	*8/8*
39	Ronstar 4	Dacthal + Butisan 9kg+1.5	-	-	stunt	stunt	-
40*		Dacthal + Butisan 9kg+1.5		-	-	-	-
41		Butisan 1.5	Goltix 1.7	-		scorch chlorosis stunt	stunt
42	Ronstar 4	Butisan 1.5		-	stunt	stunt	-

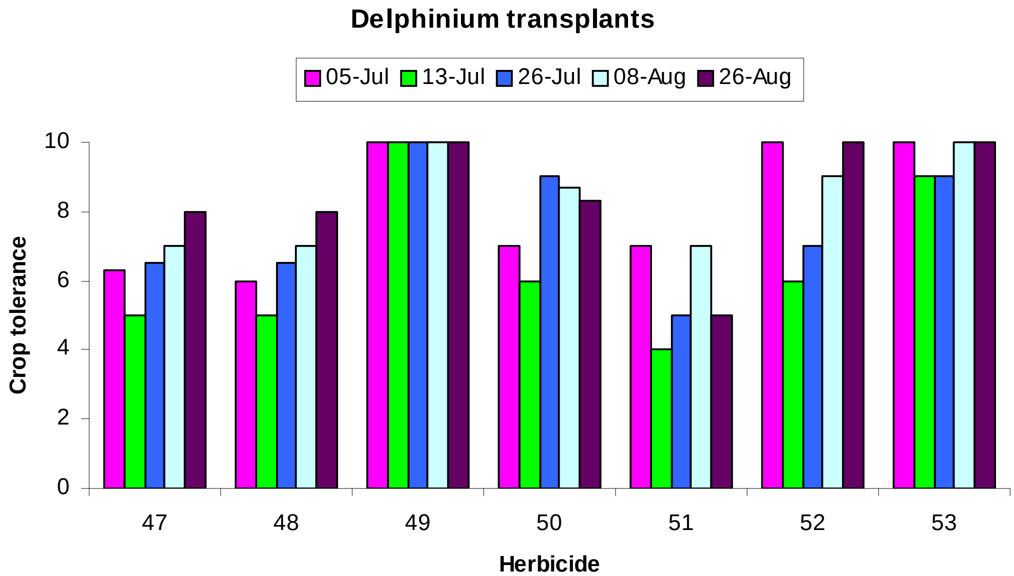
Figure 11. Crop and weed profile for **snapdragon transplanted** on 21 June and assessed on four dates (2005). Weed control assessed from 0 (no control) to 10 (complete weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.** Herbicides, crop damage and growth stages are shown in the table below.

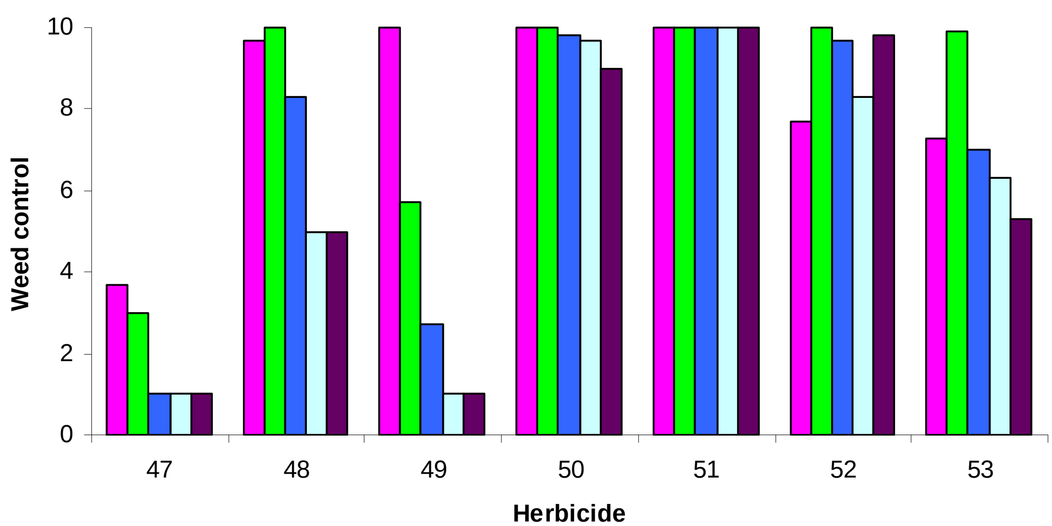




No.	*Pre-transplant*	*Pre-weed em*	*Early post-weed-em*	*Crop damage*			
	20/6	*23/6*	*8/7*	*5/7*	*13/7*	*26/7*	*6/8*
43	Ronstar 4		Goltix 1.5	-	stunt chlorosis	stunt scorch	stunt delay 60%flowering
44	-	Venzar 4	Goltix 1.5	-	stunt chlorosis	stunt scorch	stunt delay 60%flowering
45	Ronstar 4		Nortron 2	-	slight distortion	thinning	100% flowering
46		Venzar 4	Nortron 2	-	slight distortion	thinning	100% flowering

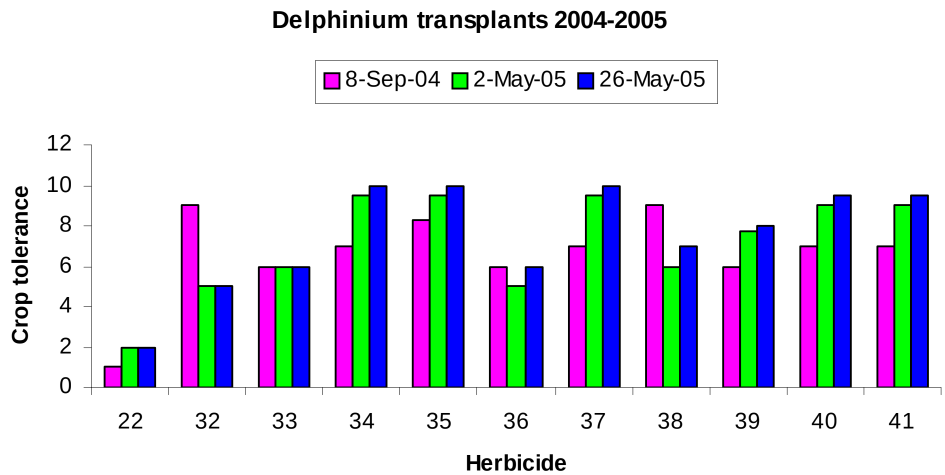
Figure 12. Crop and weed profile for **delphinium transplanted** 20 June 2005 assessed on five dates (2005). Weed control assessed from 0 (no control) to 10 (complete weed control), and crop tolerance scored from 0 (crop dead) to 10 (no damage); **the safest and most effective treatments therefore show as high values in both sets of histograms.** Herbicides, crop damage and growth stages are shown in the table below.

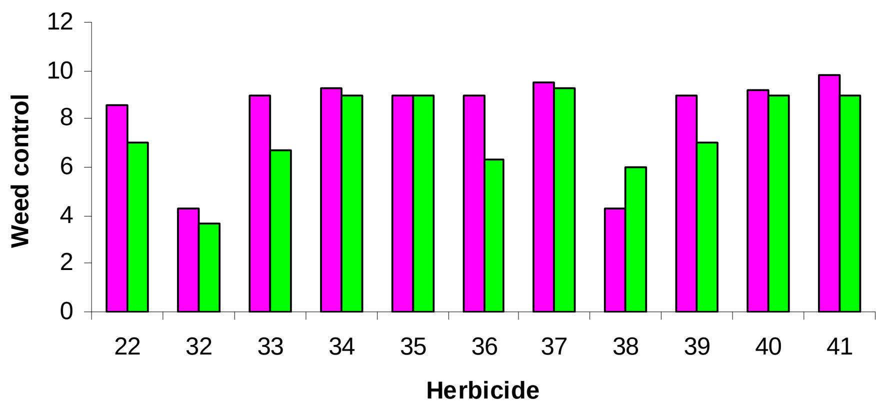




No.	*Pre-weed em*	*Early post-weed-em*	*Crop damage*		
	23/6	*8/7*	*5/7*	*13/7*	*8 /8*
47	CIPC 2.8	-	scorch stunt chlorosis	stunt	-
48	CIPC+Linuron 2.8+1.1	-	scorch stunt chlorosis	stunt	-
49	Decimate 10	-	-	-	-
50	Stomp+Ramrod 3.3+9	-	-	stunt	stunt loss
51	Stomp+Ramrod 3.3+9	Goltix 1.7	-	scorch	stunt loss
52	Stomp+Centium 3.3+0.25	Goltix 1.7	-	scorch	-
53	Stomp+Centium 3.3+0.25	Betanal 1.8	-	chlorosis leaf loss	-

Figure 13. Crop and weed profile for **delphinium transplanted 2004 and cropped 26 May 2005.** Weed control assessed from 0 (no control) to 10 (complete 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.** Herbicides, crop damage and weed control scores 2004-2005 are shown in the table below. No herbicides were applied in 2005 and the best treatments in the second year (shaded grey), were where the vigorous crop completely suppressed weeds; inferior treatments were where crop loss and/or weed burden in 2004, reduced suppression in the second year.





No.	*Pre-weed em*	*Early post-weed-em*	*Crop damage scores*			*Weed control scores*	
	22/7/04	*29/7/04*	*8/9/04*	*2/5/05*	*26/5/05*	*8/9/04*	*2/5/05*
22	Stomp+aclonifen 2+2	-	1	2m	2	8.6	7
32	Stomp 3.3	-	9	5	5	4.3	3.7 *
33	Stomp 3.3	Betanal Expert 1.5	6	6md	6	9	6.7*
34	Stomp 3.3	Goltix+Betanal 1.7 + 1.8	7	9.5	10#	9.3	9
35	Stomp+Centium 3.3 + 0.25	Goltix 1.7	8.3	9.5	10#	9	9
36	Stomp+Centium 3.3 + 0.25	Betanal Expert 1.5	6	5m	6	9	6.3*
37	Stomp+Centium 3.3 + 0.25	Goltix+Betanal 1.7 + 1.8	7	9.5	10#	9.5	9.3
38	Stomp+Ramrod3.3+9	-	9	6md	7	4.3	6*
39	Stomp+Ramrod3.3+9	Betanal Expert 1.5	6	7.7m	8	9	7*
40	Stomp+Ramrod3.3+9	Goltix+Betanal 1.7 + 1.8	7	9	9.5	9.2	9
41	Flexidor+Goltix 1+3	-	7	9	9.5	9.8	9

crop completely smothered weeds; m=missing plants; d=delayed flowering; *weeds chickweed, mayweed, shepherds' purse

APPENDIX 1

Weeds found on untreated areas and their Latin names

Latin name	Common name
Capsella bursa-pastoris	Shepherd's purse
Chenopodium album	Fat-hen
Chenopodium ficifolium	Fig-leaved goosefoot
Cirsium arvense	Creeping thistle
Fumaria officinalus	Common fumitory
Matricaria spp.	Mayweeds
Matricaria discoidea	Pineappleweed
Matricaria recutita	Scented mayweed
Lamium purpureum	Red dead-nettle
Persicaria maculosa	Redshank
Polygonum aviculare	Knotgrass
Polygonum convolvulus	Black-bindweed
Polygonum lapathifolium	Pale persicaria
Senecio vulgaris	Groundsel
Solanum nigrum	Black nightshade
Solanum physalifolium	Green nightshade
Sonchus oleraceus	Smooth sowthistle
Stellaria media	Common chickweed
Tripleurospermum inodorum	Scentless mayweed
Urtica urens	Small nettle
Veronica persica	Common field speedwell
Veronica hederifolia	Ivy-leaved speedwell

APPENDIX 2

<u>Weed susceptibility</u>

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

Common name	*Latin name*	***Dacthal 9.0 kg***	***Kerb 2***	***Stomp+Centium 2.0 + 0.25***	***Stomp + aclonifen 2.0 + 2.0***	***Stomp 5.0***	***Stomp 3.3***	***Crystal 2.0***	***Flexidor 2.0***	***CIPC + Linuron 4.2+1.7***	***Venzar 4.0***	***Decimate 10.0***	***Butisan 1.5***	***Ronstar Liquid 4.0***
Bindweed, black	*Fallopia convolvulus*	MS	S	S	S	S					S	MS		S
Bugloss	*Anchusa arvensis*													
Charlock	*Sinapis arvensis*	MR	S	MS	S				S	S	S	MR		S
Chickweed, common	*Stellaria media*	S	S	S	S	S	S	S	S	S	S	S	S	R
Cleavers	*Galium aparine*		MS	S	MS	S			MR	S	S	S	MR	
Corn marigold	*Chrysanthemum segetum*	R				S	S		S	S	S	S		
Corn spurrey	*Spergula arvensis*								S		S	S		S
Crane's-bill, cut-leaved	*Geranium dissectum*												MR	
Deadnettle, henbit	*Lamium amplexicaule*					S	S							
Dead-nettle, red	*Lamium purpureum*	MS		S	S	S	S	S	S	S	MS	S	S	S
Dock(seedling), broad-	*Rumex obtusifolius*													
Fat-hen	*Chenopodium album*	S	S	S/MS	S	S	S	S	S	S	MS	S		S
Fool's parsley	*Aethusa cynapium*			S	R?									
Forget-me-not, field	*Myosotis arvensis*					S	S		S				S	
Fumitory, common	*Fumaria officinalis*	R	MS	MS	MS	MS	MS			S	S	R	R	
Gallant-soldier	*Galinsoga parviflora*	R										S		
Groundsel	*Senecio vulgaris*	R	R	S	R		R		MS	S	MS	S	S	S
Hemp-nettle, common	*Galeopsis tetrahit*	S				S	S			S	R			R
Knotgrass	*Polygonum aviculare*	S	S	MS		S	S		S	S	S	S	R	S
Mayweed, scented	*Matricaria recutita*	R	R	S/MS	S	MS	MS		S	S	S	S	S	S
Mayweed, scentless	*Tripleurospermum inodorum*	R	R	S/MS	S	MS	MS		S	S	S	S	S	S
Nettle, small	*Urtica urens*	S	S				S		S	S	MS	S		S
Nightshade, black	*Solanum nigrum*	MS	S	S	MS	S				S	R	S		
Orache, common	*Atriplex patula*	MS					S		S	S	S			
Pansy, field	*Viola arvensis*	S		MS	MS	S	S	MS	S		R	S	R	
Parsley piert	*Aphanes arvensis*					S	S		S				S	
Pennycress, field	*Thlaspi arvense*	R									S	R	R	
Persicaria, pale	*Persicaria lapathifolia*			MS							S			
Pimpernel, scarlet	*Anagalis arvensis*	S				S	S		S	S	S			R
Pineappleweed	*Matricaria discoidea*		R		S	MS	MS		S	S				S
Poppy, common	*Papaver rhoeas*	S				S	S	S	S		S		MS	
Redshank	*Persicaria maculosa*	MR	S		S	S			S	S	S	MS		S
Shepherd's-purse	*Capsella bursa-pastoris*	R		S	S	S	MS	MS	S	S	S	S	S	S
Sow-thistle, smooth	*Sonchus oleraceus*			MS	MS	S	S				S	MS		S
Speedwell, common, field	*Veronica persica*	S	S	MS	S	S	S	S		S	MS	S		S
Speedwell, ivy-leaved	*Veronica hederifolia*	R				S	S	S	S	S	R			S
Sun spurge	*Euphorbia helioscopia*													S
Thistle, creeping	*Cirsium arvense*		R	R	R									
Wild radish	*Raphanus raphanistrum*	R		MS	S				S		S	R		S
Annual meadow-grass	*Poa annua*	MS	S	S	S	S	S			S		S	S	
Black-grass	*Alopecurus myosuroides*		S			S	S			S	R		S	R
Brome, barren	*Anisantha sterilis*		S											
Wild-oat	*Avena fatua*		S							S				
Volunteer oil-seed rape	*Brassica napus*		R			MS	MS		S					

Weed susceptibility to the herbicides used in the project at early post-emergence timing (weeds cotyledon to 1-TL stage), compiled from the registration holders' labels and other information. Herbicide rates shown are L/ha unless otherwise stated. Key: S, susceptible; MS, moderately susceptible; R, resistant; MR, moderately resistant; blanks, no data available; cot, cotyledon stage.

Common name	*Latin name*	***Goltix 1.0 kg***	***Betanal Flow 1.5***	***Betanal Expert 1.5***	***Nortron Flo 2.0***
Bindweed, black	*Fallopia convolvulus*	MR	MS	S	S
Bugloss	*Anchusa arvensis*			S cot	S
Charlock	*Sinapis arvensis*	MS		S cot	S
Chickweed, common	*Stellaria media*	S	S	S	S
Cleavers	*Galium aparine*	R	MR	S	S
Corn marigold	*Chrysanthemum segetum*	S		S	S
Corn spurrey	*Spergula arvensis*	S			S
Crane's-bill, cut-leaved	*Geranium dissectum*		R		
Deadnettle, henbit	*Lamium amplexicaule*			S	S
Dead-nettle, red	*Lamium purpureum*	MS	S	S	S
Dock(seedling), broad-lved	*Rumex obtusifolius*	S			
Fat-hen	*Chenopodium album*	S	S	S	S
Fool's parsley	*Aethusa cynapium*	S			
Forget-me-not, field	*Myosotis arvensis*	S	MR		
Fumitory, common	*Fumaria officinalis*	MS	S	S	S
Gallant-soldier	*Galinsoga parviflora*				
Groundsel	*Senecio vulgaris*	S	S	S	S
Hemp-nettle, common	*Galeopsis tetrahit*	S	S		S
Knotgrass	*Polygonum aviculare*	S	S	S	S
Mayweed, scented	*Matricaria recutita*	S		S	S
Mayweed, scentless	*Tripleurospermum inodorum*	S	MS	S	S
Nettle, small	*Urtica urens*	S	S	S	S
Nightshade, black	*Solanum nigrum*	MR		S	S cot
Orache, common	*Atriplex patula*	S	S	S	S
Pansy, field	*Viola arvensis*	S	S	S	S
Parsley piert	*Aphanes arvensis*				
Pennycress, field	*Thlaspi arvense*	S	MS	S	S
Persicaria, pale	*Persicaria lapathifolia*	MS	S	S	S
Pimpernel, scarlet	*Anagalis arvensis*	MR	S	S	S
Pineappleweed	*Matricaria discoidea*	S		S	S
Poppy, common	*Papaver rhoeas*	S	S		S
Redshank	*Persicaria maculosa*	MS	S	S	S
Shepherd's-purse	*Capsella bursa-pastoris*	S	S		S
Sow-thistle, smooth	*Sonchus oleraceus*		R		
Speedwell, common, field	*Veronica persica*	S	S	S	S
Speedwell, ivy-leaved	*Veronica hederifolia*	MS	MS	S	S
Sun spurge	*Euphorbia helioscopia*	S			
Thistle, creeping	*Cirsium arvense*	R			
Wild radish	*Raphanus raphanistrum*	MR	S	S	S
Annual meadow-grass	*Poa annua*	S	R	S	S
Black-grass	*Alopecurus myosuroides*				S
Brome, barren	*Anisantha sterilis*				
Wild-oat	*Avena fatua*				S
Volunteer oil-seed rape	*Brassica napus*				

APPENDIX 3

Weeds not controlled by herbicides in this project

Herbicides, dose rates (product in L/ha unless otherwise specified), dates of application and assessment, main weed species on untreated plots, and weed species not controlled are shown in the following tables. Weed species in bold text are those present in high numbers, those in parentheses present in low numbers.

China aster drilled 9 June 2005

	Pre-weed-em	*Early post-weed-em*	*Weeds not controlled*	*Weeds not controlled*	*Weeds not controlled*	*Weeds not controlled*
	14/6	*28/6*	*18/7*	*31/7*	*15/8*	*8/9*
1	untreated		**s. purse nettle chickweed** groundsel fat-hen p. persicaria	**s. purse nettle chickweed** groundsel fat-hen p. persicaria	**s. purse nettle chickweed** groundsel fat-hen p. persicaria	**s. purse nettle chickweed** groundsel dead fat-hen p. persicaria
14	Stomp+Centium 3.3+0.25	-	groundsel	groundsel	groundsel	groundsel dead s. purse
25	Stomp+Centium 3.3+0.25	Betanal Expert 1.5	-	p. persicaria (sowthistle)	p. persicaria (sowthistle)	p. persicaria s. purse (sowthistle)
26	Stomp+Centium 3.3+0.25	Goltix+Betanal 1.0+1.8	-	-	-	s. purse

Cornflower drilled 9 June 2005

	Pre-weed-em	*Early post-weed-em*	*Weeds not controlled*	*Weeds not controlled*	*Weeds not controlled*	*Weeds not controlled*	*Weeds not controlled*
	14/6	*28/6*	*27/6*	*18/7*	*31/7*	*15/8*	*27/8*
1	untreated			**s. purse nettle chickweed groundsel** fat-hen	**s. purse nettle chickweed groundsel** fat-hen	**s. purse nettle chickweed groundsel** fat-hen	**s. purse nettle chickweed groundsel** dead fat-hen
4	Stomp+Flexidor 3.3+1	-	groundsel	groundsel	groundsel	groundsel	groundsel dead
10	Aclonifen+Stomp 2+3.3	Goltix 1.7	groundsel	-	-	-	-
11	Aclonifen+Stomp 2+3.3	Skirmish 1	groundsel	-	-	groundsel	groundsel dead
12	Stomp+Flexidor 3.3+1	Goltix 1.7	groundsel	-	-	-	-
13	Stomp+Flexidor 3.3+1	Skirmish 1	groundsel	groundsel	groundsel	groundsel	groundsel dead

Zinnia drilled 9 June 2005

	Pre-weed-em	*Early post-weed-em*	*Weeds not controlled*	*Weeds not controlled*	*Weeds not controlled*	*Weeds not controlled*
	14/6	*28/6*	*18/7*	*31/7*	*15/8*	*27/8*
1	untreated		**s. purse nettle chickweed** groundsel fat-hen p. persicaria	**s. purse nettle chickweed** groundsel fat-hen p. persicaria	**s. purse nettle chickweed** groundsel fat-hen p. persicaria	**s. purse nettle chickweed** groundsel fat-hen p. persicaria
4	Stomp+Flexidor 3.3+1	-	groundsel p. persicaria	groundsel p. persicaria	groundsel p. persicaria	groundsel dead p. persicaria
14	Stomp+Centium 3.3+0.25		groundsel	groundsel	groundsel	groundsel dead
15	Stomp+Centium 3.3+0.25	Betanal 1.8	-	-	-	-
13	Stomp+Flexidor 3.3+1	Skirmish 1	groundsel p. persicaria	groundsel	groundsel	groundsel dead
16	Stomp+Flexidor 3.3+1	Goltix+Betanal 1+1	groundsel	groundsel	groundsel	groundsel dead
17	Stomp+Centium 3.3+0.25	Skirmish 1	-	-	groundsel	groundsel
18	Stomp+Centium 3.3+0.25	Goltix+Betanal 1+1	-	-	-	-

Larkspur drilled 9 June 2005

	Pre-weed-em	*Early post-weed-em*	*Weeds not controlled*	*Weeds not controlled*	*Weeds not controlled*	*Weeds not controlled*	*Weeds not controlled*
	14/6	*28/6*	*27/6*	*18/7*	*31/7*	*15/8*	*27/8*
1	untreated			**s. purse nettle chickweed** groundsel	**s. purse nettle chickweed** groundsel	**s. purse nettle chickweed** groundsel	**s. purse nettle chickweed** groundsel
14	Stomp+Centium 3.3+0.25	-	-	groundsel	groundsel	groundsel s. purse	groundsel dead s. purse
19	Stomp+Centium 3.3+0.25	Goltix 1.7	-	-	-	-	-
15	Stomp+Centium 3.3+0.25	Betanal 1.8	-	-	-	-	-
17	Stomp+Centium 3.3+0.25	Skirmish 1	-	-	groundsel	groundsel	groundsel dead

Nigella drilled 9 June 2005

	Pre-weed-em	*Early post-weed-em*	*Weeds not controlled*	*Weeds not controlled*	*Weeds not controlled*	*Weeds not controlled*
	14/6	*28/6*	*27/6*	*18/7*	*31/7*	*27/8*
1	untreated		**s. purse nettle** groundsel chickweed	**s. purse nettle** groundsel chickweed fat-hen pale persicaria	**s. purse nettle** groundsel chickweed fat-hen pale persicaria	**s. purse nettle** groundsel chickweed fat-hen pale persicaria
20	Stomp 2#	-	groundsel	all spp.	all spp.	all spp.
21	Stomp 2	Decimate 20	groundsel	s. purse groundsel	s. purse groundsel charlock	s. purse groundsel charlock
22	Stomp 2	Skirmish 1	groundsel	groundsel	groundsel	groundsel dead
23	Stomp 2	Betanal 1.8	groundsel	pale persicaria chickweed	pale persicaria chickweed groundsel	all spp.
24	Stomp 2	Asulam 2.5	groundsel	s. purse chickweed	s. purse chickweed	all spp.except groundsel

Stomp 2.0 L/ha too low for effective control

Bupleurum drilled 9 June 2005

	Pre-weed-emergence	*Early post-weed-em*	*Weeds not controlled*	*Weeds not controlled*	*Weeds not controlled*	*Weeds not controlled*
	14/6	*28/6*	*27/6*	*18/7*	*15/8*	*27/8*
1	untreated	-	**s. purse nettle** groundsel chickweed	**s. purse nettle** groundsel chickweed	**s. purse nettle** groundsel chickweed	**s. purse nettle** groundsel chickweed
4	Stomp+Flexidor 3.3 + 1	-	groundsel	groundsel	groundsel	groundsel dead
5	Aclonifen+Stomp 2 + 3.3	-	groundsel	groundsel	groundsel	groundsel dead
6	CIPC+Linuron 2.8 + 1.7		-	-	groundsel chickweed	groundsel dead chickweed
7	CIPC+Linuron 4.2 + 1.7		-	-	groundsel	groundsel dead
8	Stomp+Flexidor 3.3 + 1	Goltix+Betanal 1.7 + 1.8	groundsel	-	groundsel	-
9	Stomp+Aclonifen 3.3 + 2	Goltix+Betanal 1.7+1.8	groundsel	-	-	-

China Aster transplanted 16-17 June 2005

	Pre-transplant	*Pre-weed-em*	*Early post-weed-em*	*Weed species not controlled*	*Weed species not controlled*	*Weed species not controlled*
	16/6	*20/6*	*8/7*	*5/7*	*26/7*	*26 /8*
34	untreated			**s. purse nettle** pale persicaria mayweed fat-hen chickweed	**s. purse nettle** pale persicaria mayweed fat-hen chickweed	**s. purse nettle** pale persicaria mayweed fat-hen chickweed
37		Decimate 20	Betanal Expert 1.5	pale persicaria	pale persicaria	pale persicaria
38	Ronstar 4*		Betanal Expert 1.5	chickweed		

*chickweed not controlled by Ronstar Liquid

Stocks transplanted 17-19 June 2005

	Pre-transplant	*Pre-weed em*	*Early post-weed-em*	*Weed species not controlled*	*Weed species not controlled*	*Weed species not controlled*
	17/6	*20/6*	*8/7*	*5/7*	*13/7*	*26/7*
34	untreated			**s. purse nettle** pale persicaria mayweed chickweed		
39	Ronstar 4	Dacthal + Butisan 9kg+1.5	-	-	-	-
40		Dacthal + Butisan 9kg+1.5	-	-	-	-
41		Butisan 1.5	Goltix 1.7	pale persicaria knotgrass	knotgrass	-
42	Ronstar 4	Butisan 1.5	-	-	-	-

Snapdragon transplanted 21 June 2005

	Pre-transplant	*Pre-weed em*	*Early post-weed-em*	*Weed species not controlled*	*Weed species not controlled*	*Weed species not controlled*	*Weed species not controlled*
	20/6	*23/6*	*8/7*	*5/7*	*13/7*	*8/8*	*26/8*
34	untreated			**s. purse nettle** pale persicaria mayweed nightshade chickweed	**s. purse nettle** pale persicaria mayweed nightshade chickweed	**s. purse nettle** pale persicaria mayweed nightshade chickweed	**s. purse nettle** pale persicaria mayweed nightshade chickweed
43	Ronstar 4		Goltix 1.5	chickweed	-	chickweed	chickweed 100% cover
44	-	Venzar 4	Goltix 1.5	several spp.	-	-	-
45	Ronstar 4		Nortron 2	chickweed	-	-	-
46		Venzar 4	Nortron 2	several spp.	-	-	-

Delphinium transplanted 21 June 2005

	Pre-weed em	*Early post-weed-em*	*Weed species not controlled*	*Weed species not controlled*	*Weed species not controlled*
	23/6	*8/7*	*5/7*	*26/7*	*26 /8*
34	untreated	-	**s. purse pale persicaria nettle** mayweed fat-hen groundsel	**s. purse pale persicaria nettle** mayweed fat-hen groundsel	**s. purse pale persicaria nettle** mayweed fat-hen groundsel
47	CIPC 2.8	-	s. purse pale persicaria nettle mayweed	s. purse pale persicaria nettle mayweed fat-hen groundsel 100% cover	s. purse pale persicaria nettle mayweed fat-hen groundsel 100% cover
48	CIPC + Linuron 2.8 + 1.1	-	-	-	s. purse pale persicaria nightshade
49	Decimate 10	-	-	s. purse pale persicaria	s. purse pale persicaria nettle
50	Stomp+Ramrod 3.3+9	-	-	-	s. purse nightshade
51	Stomp+Ramrod 3.3+9	Goltix 1.7	-	-	-
52	Stomp+Centium 3.3+0.25	Goltix 1.7	nightshade		a few groundsel
53	Stomp+Centium 3.3+0.25	Betanal 1.8	nightshade	groundsel	s. purse groundsel pale persicaria

