NOVEL WEED MANAGEMENT OPTIONS IN GM HERBICIDE TOLERANT SUGAR BEET

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ABSTRACT

Methods of producing effective weed control with environmental benefits are limited with current selective herbicides and/or inter-row tillage; in most countries, weed control commences pre-emergence or at the cotyledon stage of weeds (and crop). GM herbicide tolerant (GMHT) sugar beet would allow treatment at later growth stages with glyphosate and offers opportunities to manage and manipulate weeds for environmental benefit. In order to enhance this advantage, we have developed a simple over-the-row band spraying technique using a conventional overall sprayer to control in-row weeds first and those between the rows, if and when necessary, with a later overall spray application. In 1999 and 2000, five experiments investigated the effect of weed management strategies on yield of glyphosate tolerant GM sugar beet. Glyphosate was applied at timings between 207 and 864 day degrees above 3°C (°Cd) after sowing and followed by a second application between 698 and 1022°Cd. In other treatments, glyphosate was applied in approximately 20 cm bands over the sugar beet rows at similar but fewer timings up to only 586°Cd. These were followed by a second but overall application between 401 and 811° Cd. Treatments were compared to untreated controls and programmes of current commercial herbicides commencing between 79 and 222°Cd. Yield reductions occurred if spraying was delayed after the critical period for weed competition, but the band spray technique allowed non-competitive weeds to remain between the rows until later in the season.

ABRÉGÉ - NOUVELLES OPTIONS DE GESTION DES ADVENTICES DANS LES BETTERAVES A SUCRE GÉNÉTIQUEMENT MODIFIES RÉSISTANTES AUX HERBICIDES

Les méthodes permettant un contrôle efficace des mauvaises herbes et se montrant bénéfiques pour l'environnement sont limitées par l'utilisation actuelle d'herbicides sélectifs et/ou par la préparation du sol entre les rangées de betteraves. Dans la plupart des pays, le contrôle des mauvaises herbes commence soit à la pré-émergence, soit au stade cotylédon des mauvaises herbes (ou des cultures). Les betteraves à sucre génétiquement modifiées résistant aux herbicides (Genetically Modified Herbicide Tolerant (GMHT)) doivent permettre un traitement avec du glyphosate à des phases de pousse plus tardives et offrent la possibilité de gérer et manipuler les mauvaises herbes

au bénéfice de l'environnement. Afin d'accroître cet avantage, nous avons développé une technique de pulvérisation simple, en bande juste au dessus des rangs de cultures. Cette technique nécessite un simple pulvérisateur global afin de détruire d'abord les mauvaises herbes se trouvant à l'intérieur rangs de cultures, puis celles se trouvant entre ces rangs, avec, si nécessaire, une pulvérisation additionnelle ultérieure. Durant les années 1999 et 2000, 5 expériences ont visé à démontrer les effets des stratégies de gestion des mauvaises herbes sur le rendement en betteraves génétiquement modifiées résistantes au glyphosate. Le glyphosate fut appliqué à des périodes comprises entre 207 et 864 "day degrees" (somme température °Cj) au dessus de 3°C (° Cd) après ensemencement et suivi d'une seconde application entre 698 et 1022°Cd.

KURZFASSUNG - NEUARTIGE OPTIONEN FÜR DAS UNKRAUTMANAGEMENT BEI GENETISCH MODIFIZIERTEN HERBIZIDTOLERANTEN ZUCKERRÜBEN

Methoden für eine effektive Unkrautbekämpfung mit Umweltvorteilen sind durch die aktuellen selektiven Herbizide und/oder Zwischenreihen-Bodenbearbeitung eingeschränkt; in den meisten Ländern beginnt die Unkrautbekämpfung vor dem Auflaufen oder im Keimstadium von Unkräutern (und Feldpflanzen). Genetisch modifizierte herbizidtolerante (GMHT) Zuckerrüben würden eine Behandlung mit Glyphosat in späteren Wachstumsstadien ermöglichen und Möglichkeiten zum Management und Umgang mit Unkraut im Hinblick auf Umweltvorteile bieten. Zur Steigerung dieser Vorteile haben wir eine einfache, die Reihen übergreifende Streifenspritztechnik entwickelt, mit der wir mit einem herkömmlichen Vielzweck-Spritzgerät zunächst in den Reihen wachsendes Unkraut und, falls erforderlich, zwischen den Reihen wachsendes Unkraut durch eine spätere Gesamtspritzbehandlung kontrollieren. In den Jahren 1999 und 2000 wurden in fünf Experimenten die Auswirkungen von Unkraut-managementstrategien auf den Ertrag von glyphosattoleranten genetisch modifizierten Zuckerrüben untersucht. Glyphosat wurde nach der Aussaat zu Zeitpunkten zwischen 207 und 864 Tagesgraden über 3 °C (°Cd) angewendet, gefolgt von einer zweiten Anwendung zwischen 698 und 1022 °Cd. Bei anderen Behandlungen wurde Glyphosat zu ähnlichen Zeitpunkten, jedoch seltener und nur bis zu 586 °Cd, in Streifen von ungefähr 20 cm auf den Zuckerrübenreihen ausgebracht. Auf diese folgte eine zweite Gesamtbehandlung zwischen 401 und 811 °Cd. Die Behandlungen wurden mit unbehandelten Kontrollen und mit Programmen aktueller kommerzieller Herbizide verglichen, deren Anwendung zwischen 79 und 222 °Cd beginnt. Es kam zu Ertragsreduktionen, wenn die Spritzbehandlung bis nach der kritischen Periode für Unkrautkonkurrenz verzögert wurde, jedoch ermöglichte die Streifenspritztechnik nicht konkurrierenden Unkräutern, bis zu einem späteren Zeitpunkt in der Saison zwischen den Reihen zu verbleiben.

INTRODUCTION

Sugar beet is a poor competitor with weeds in arable fields because it is slow growing early in the season and has a low canopy in its first year of a biennial life cycle. Good weed control is therefore essential to produce economically viable yields (Jansen, 1972), but this is not easy to achieve with current selective herbicides and/or inter-row tillage. Competition for resources is principally for light and weed control need not be carried out until the 6-8 leaf growth stage of the crop (Scott *et al.*, 1979). However, the weaknesses of current conventional herbicides and mechanical control systems dictate that weed control commences pre-emergence or at the cotyledon stage of weeds (and crop). Thus very few weeds are present throughout the season in most crops. The few crops that are weedy offer a food source and habitat for farmland birds (Wilson *et al.*, 1999; Watkinson *et al.*, 2000). When GM herbicide tolerant (GMHT) sugar beet was first introduced one of the major claims of the system was high levels of weed control (e.g. Read & Bush, 1998; Moll, 1997). It is the potential loss of these weedy crops, amid general alarm over population decline of farmland bird species in the UK (Chamberlain *et al.*, 2000), that prompted concerns about GMHT technology in the UK from English Nature (1998; 2000) (the organisation that advises government on the countryside) and environmental non-government organisations.

This work reported here set out to determine whether it would be possible to exploit the much greater flexibility and efficacy of the broad-spectrum herbicides, glyphosate and glufosinate-ammonium, to which GM tolerances have been produced in sugar beet. A simple over-the-row band spraying technique was developed to control in-row weeds first and those between the rows by a later overall spray application. This exploits both the temporal and spatial flexibility offered by the GMHT system, to allow weed control tailored precisely to avoidance of competition. This paper reports the results of five experiments designed to look at weed control and sugar yield from these systems. Such techniques can be used to produce a range of environmental benefits and some of these are quantified by Dewar *et al.* (2003) published in this issue.

MATERIALS AND METHODS

The effect of weed management strategies on yield of glyphosate tolerant GM sugar beet (L#77) were investigated in five experiments in East Anglia, UK. The soil types were typical of those on which sugar beet is grown in the UK (Table 1). Treatments of 1080 g a.i./sprayed ha glyphosate were applied either overall between 207 and 864 day degrees (°Cd), calculated using a base temperature (from Higham, Suffolk) of 3°C following sowing (°Cd), or over the sugar beet row only, between 207 and 586°Cd (Table 2). The overall treatments were followed by a second application between 698 and 1022°Cd and the band sprays followed by an overall application 401 to 811°Cd. The band spray treatments were approximately 20 cm wide and achieved by use of a normal spray boom with nozzle spacings of 50 cm (to match the sugar beet rows) and a reduced spray angle and boom height. Glyphosate treatments were compared to untreated controls and programmes of current commercial herbicides.

Table 1 Experiment details

Experiment no. Soil type	1 SL	2 PL	3 SL	4 PL	5 ZyL
Drilling date	23/04/1999	28/04/1999	02/05/2000	02/05/2000	10/05/2000
Crop plants (000/ha) assessed between 904 and 1451°Cd					
Untreated n=4 (s.e.)	60.8 (3.49)	76.0 (2.30)	69.0 (2.99)	55.8 (10.22)	64.3 (6.42)
Mean of treated (s.e.)	67.4 n=56 (0.81)	90.3 n=60 (0.46)	72.4 n=60 (1.24)	79.6 n=60 (0.99)	76.2 n=60 (0.56)
Harvest °Cd	1,652	1,499	1,511	1,488	1,417

Table 2 Timing of glyphosate treatments from sowing (°Cd)

Experiment 1	Experiment 2	Experiment 3	Experiment 4	Experiment 5
First overall sprayed treatment				
254	231	240	294	207
319	302	285	364	285
482	451	354	480	401
531	503	480	630	551
586	542	563	672	593
630	583	630	811	669
666	608	748	864	732
725	709			
Band spray				
586	503	480 563	294 364	207 285
Overall spray following band				
585	503	563	480	401
639	542	630	630	551
666	582	748	672	593
725	608	630	630	551
	709	748	672	593
		811	811	669
		811	811	669

The conventional herbicide programmes varied at each site (Table 3) depending on the weed species present. In experiments 4 and 5 treatments started pre-emergence, but in the other

Table 3 Conventional herbicide sequences

Experiment & treatment	°Cd	Herbicide treatment
1, conventional 1	208	285 g a.i./ha phenmedipham
	491	7.5 g a.i. desmedipham, 226.5 g a.i. ethofumesate, 114 g a.i. phenmedipham + 700 g a.i./ha metamitron
1, conventional 2	254	875 g a.i. metamitron + 193.8 g a.i./ha phenmedipham
	491	300 a.i. ethofumesate, 240 g a.i phenmedipham + 700 g a.i./ha metamitron
2, conventional 1	167	15 g a.i. triflusulfuron-methyl, 12.5 g a.i. desmedipham, 75.5 g a.i. ethofumesate, 38 g a.i. phenmedipham + 1.0 l/ha adjuvant oil
	384	7.5 g a.i. desmedipham, 226.5 g a.i. ethofumesate, 114 g a.i. phenmedipham, 176 g a.i. lenacil + 0.5 l/ha adjuvant oil
	715	310 kg/ha sodium chloride
2, conventional 2	167	15 g a.i. triflusulfuron-methyl, 171 g a.i. phenmedipham + 176 g a.i. lenacil + 1.0 l/ha adjuvant oil
	384	399 g a.i. phenmedipham + 176 g a.i. lenacil + 1.0 l/ha adjuvant oil
	715	310 kg/ha sodium chloride
3	222	285 g a.i. phenmedipham + 176 g a.i. lenacil
	748	6.25 g a.i. desmedipham, 188.75 g a.i. ethofumesate, 95 g a.i. phenmedipham + 700 g a.i./ha metamitron
4	79	360 g a.i. paraquat + 240 g a.i./ha diquat
	294	171 g a.i. phenmedipham + 15 g a.i./ha triflusulfuron-methyl
	480	15 g a.i. triflusulfuron-methyl, 70 g a.i. clopyralid, 3.75 g a.i. desmedipham, 113.3 g a.i. ethofumesate, 57 g a.i. phenmedipham + 1.0 l/ha adjuvant oil
	811	6.25 g a.i. desmedipham, 188.75 g a.i. ethofumesate, 95 g a.i. phenmedipham + 200 g a.i./ha clopyralid
5	0	360 g a.i. paraquat + 240 g a.i./ha diquat
	207	3.75 g a.i. desmedipham, 113.3 g a.i. ethofumesate, 57 g a.i. phenmedipham + 176 g a.i./ha lenacil
	669	7.5 g a.i. desmedipham, 226.5 g a.i. ethofumesate, 114 g a.i. phenmedipham, 700 g a.i./ha metamitron + 1.0 l/ha adjuvant oil
	732	200 g a.i. cycloxydim + 1.6 l/ha adjuvant oil

Experiments treatments were mostly post-emergence starting between 79 and 222°Cd. The number of active ingredients ranged from 3 to 8, the simplest including phenmedipham, metamitron and ethofumesate (experiment 1, second conventional programme), and the most complex including those three plus paraquat, diquat, desmedipham, lenacil and cycloxydim (experiment 5). Other active ingredients used on the other sites included clopyralid, and triflusulfuron-methyl. The number of applications ranged from 2 to 4. In 1999, applications of some treatments, particularly in the two conventional programmes, were delayed by adverse weather conditions.

Overall sprays of glyphosate were applied as medium quality sprays (Southcombe *et al.*, 1997) at 200 l/ha spray volume and conventional sprays as fine quality at 100 l/ha (apart from salt which was applied as a coarse spray in 1100 l/ha). All treatments were replicated four times in randomised complete blocks.

The biomass of weeds present in each treatment was assessed on six occasions throughout the season, the earliest at the time of the first glyphosate applications in late May (240°Cd) and the latest in mid-August (1450 °Cd). Biomass was assessed using scores on a linear scale (0-10), where 0 = no living weeds and 10 = full biomass for the time of year and plant stage with no effect on plants. In band-sprayed plots the score was a mean of the sprayed area down the row and unsprayed area between the row. Where weed numbers were low, scores in untreated plots were sometimes less than 10. Sugar yield was assessed at harvest in late August/early September (1652 °Cd). This was earlier than commercial crops due to the constraints of the release consent and the audit requirements of British Sugar.

The environmental impact of all the conventional herbicide programmes was assessed by the Milieumeetlat system (Wevers, 2000). This is a scoring system based on the European requirements for the registration of pesticides. A score greater than 100 is considered unacceptable for an individual application in the Milieumeetlat system.

RESULTS

Between 12 and 22 different weed species were present on each experiment. *Chenopodium album* was an important weed on experiment 1-4 inclusive, *Fallopia convolvulus* (1, 2, 4) *Veronica persica* (1, 3, 4), *Sinapis arvensis* (2, 4), *Persicaria maculosa* (2, 5), volunteer cereals (1, 2), *Cirsium arvense* (2, 4), *Tripleurospermum maritimum* (1), *Persicaria lapathifolia* (5) and *Alopecurus myosuroides* (5).

All treatments significantly reduced weed numbers and biomass compared to the untreated plots (Table 4). Control from the overall glyphosate programmes was generally better than that from the conventional treatments, particularly in experiments 2 and 5. However, control from the conventional treatments, although not as good, was within current commercial expectation.

Delays in glyphosate treatment had a significant effect on final sugar yield (Table 5; Figure 1), and their effects on sugar yields can be described by the following equation:

$$Y = Yo + \alpha/(1+e^{\beta(X-Xo)}) \text{ (eqn1)}$$

where Y is the sugar yield, Yo the yield from the untreated plots, α the maximum reduction of sugar yield observed, β the rate of yield reduction due to delays in treatment. $Y_0+\alpha$ combines to represent the maximum obtainable sugar yield when weeds are effectively controlled to the full, Xo the thermal time at which the reduction of sugar yield is at half value of α, and X the thermal time from sowing. When α and Yo were allowed to vary from experiment to experiment, but the other parameters were fixed, the total variance accounted for (R^2) was 97.1% (d.f.=34).

The response of sugar yields from the band spray treatments could be described by a simple linear relationship:

$$Y = Y_p - \gamma X \text{ (eqn2)}$$

where Y is sugar yield, Yp the intercept indicating the potential yield at a given site in a given year, γ the slope measuring the reduction of sugar yield per unit of delay in thermal time from sowing, and X the thermal time from sowing. Comparison of regressions from all sites showed that each had a different Yp, indicating the varied amount of weed presence, but a common slope γ, which was not significantly different from 0. These relations accounted for 90.2% of the total variance (d.f.=18) in the observed sugar yields (Table 5; Figure 1). Thus, delays in overall sprays following band treatments resulted in the same amount of sugar yield reduction per unit of thermal time in each trial.

Glyphosate first applied overall sometime between 240 and 320°Cd, gave the best yields in each trial (range 5.9-6.7 t/ha) - on average 9.7% greater than the conventional treatments, although the differences were only significant at sites 2 and 5. Yields from the band spray treatments were not significantly different to the conventional programmes.

The calculations using the Milieumeetlat system (Table 6) suggest that all herbicides were within the acceptable limits for water organisms, but lenacil in experiments 2, 3 and 5 and clopyralid in experiment 4 were above the limits for deeper water, and lenacil (experiments 2 and 5) and paraquat plus diquat (experiments 4 and 5) were above the limits for soil organisms. Scores ranged from 32 to 218 for water organisms, 11 to 960 for soil organisms, and 155 to 16540 for deeper water. The equivalent scores for glyphosate treatments were 0, 5-6 and 0 respectively.

CONCLUSION

Sugar yields from all five trials were lower than would normally be expected from a commercial crop (range 4.9-6.1 t/ha in plots treated with conventional herbicides). This was a result of the imposed early harvest in late August or early September to comply with the British Sugar GM audit requirements. Yield reductions in the untreated plots compared to the conventionally-treated ones ranged from 24 to 88%.

Yield reductions ranging from 5-15% in conventional treatments in previous trials (Brants *et al.*, 1998, Wilson et al., 2002) have been attributed partially to the slight, but occasionally important phytotoxic effects of conventional

*Table 4 Weed biomass (using 0-10 linear visual score where 0=none, 10= complete cover) between 7 and 25 August and total weed numbers/m^2 from quadrat counts between 26 July and 3 August. * ov = overall treatment, bd = treatment commencing with band application, figure refers to dd above 3°C from sowing.*

Experiment 1			**Experiment 2**			**Experiment 3**			**Experiment 4**			**Experiment 5**		
Trmt*	Biomass	Total weeds/m²	Trmt*	Biomass	Total weeds/m²	Trmt*	Biomass	Total weeds/m²	Trmt*	Biomass	Total weeds/m²	Trmt*	Biomass	Total weeds/m²
Untr	10.0	29.4	Untr	9.8	32.0	Untr	5.5	29.2	Untr	10.0	75.9	Untr	9.8	70.1
Conv	0.8	13.0	Conv	4.8	19.0	Conv	0.6	8.0	Conv	0.5	4.4	Conv	3.0	42.1
Conv	1.0	9.4	Conv	3.3	20.6									
254 ov	0.3	10.4	231 ov	1.0	1.0	240 ov	0.4	5.2	294 ov	0.5	5.5	207 ov	0.5	5.8
319 ov	0.3	7.8	302 ov	1.0	2.4	285 ov	0.4	1.4	364 ov	0.5	1.4	285 ov	0.4	1.1
482 ov	0.1	3.6	451 ov	2.0	2.4	354 ov	0.0	0.3	480 ov	0.0	0.0	401 ov	0.0	0.0
531 ov	0.0	2.4	503 ov	1.0	0.6	480 ov	0.1	0.3	630 ov	0.9	0.0	551 ov	0.0	0.6
586 ov	0.3	1.0	542 ov	1.3	2.4	563 ov	0.4	1.9	672 ov	1.6	0.8	593 ov	0.0	2.8
630 ov	0.1	2.6	583 ov	1.3	2.2	630 ov	0.1	0.3	811 ov	4.7	2.5	669 ov	0.0	0.0
666 ov	0.0	2.6	608 ov	1.0	3.4	748 ov	0.5	5.8	864 ov	6.3	4.1	732 ov	0.3	3.3
725 ov	0.1	4.0	709 ov	2.8	12.0									
			503 bd	1.0	1.8	563 bd	0.5	2.5	480 bd	0.1	1.1	401 bd	0.0	1.7
585 bd	0.4	2.6	542 bd	1.0	4.8	630 bd	0.4	0.8	630 bd	0.5	0.3	551 bd	0.3	3.6
639 bd	0.1	4.0	582 bd	1.3	3.2	748 bd	0.5	4.7	672 bd	0.6	1.9	593 bd	0.4	7.4
666 bd	0.3	1.4	608 bd	1.7	8.0	630 bd	0.5	0.8	630 bd	0.5	1.4	551 bd	0.0	0.0
725 bd	0.5	8.2	709 bd	1.8	13.8	748 bd	0.5	4.7	672 bd	0.8	0.8	593 bd	0.5	3.0
						811 bd	0.5	1.4	811 bd	1.0	2.2	669 bd	0.1	0.6
S E D (45 d.f.)	* 41 d.f.	±2.02		±1.32	±2.24		±0.10	±0.36		±0.49	±0.30		±0.48	±3.17
CV%	28.1	42.9		41.7	39.2		11.0	23.6		37.9	19.0		47.6	36.5

Table 5 The estimates and their standard errors (s.e.) of parameters in equation 1 describing yields from the overall sprayed treatments and equation2 describing yields from the band sprayed treatments

Overall sprayed treatments				
Expt.	Y_0 (s.e.)	X_0 (s.e.)	α (s.e.)	β (s.e.)
1	2.6274 (0.4085)	683.4 (19.27)	3.9745 (0.5624)	0.0097 (0.0019)
2	0.2702 (0.4321)	683.4 (19.27)	5.2385 (0.5730)	0.0097 (0.0019)
3	4.7461 (0.3941)	683.4 (19.27)	1.1459 (0.5133)	0.0097 (0.0019)
4	0.4385 (0.3802)	683.4 (19.27)	5.4711 (0.5867)	0.0097 (0.0019)
5	2.8701 (0.4104)	683.4 (19.27)	4.3118 (0.5492)	0.0097 (0.0019)
Band sprayed treatments				
Site	Y_p (s.e.)	γ (s.e.)		
1	6.4135 (0.4291)	-0.0008 (0.0005)		
2	5.9190 (0.4836)	-0.0008 (0.0005)		
3	6.0546 (0.4315)	-0.0008 (0.0005)		
4	5.8842 (0.3998)	-0.0008 (0.0005)		
5	7.1755 (0.3531)	-0.0008 (0.0005)		

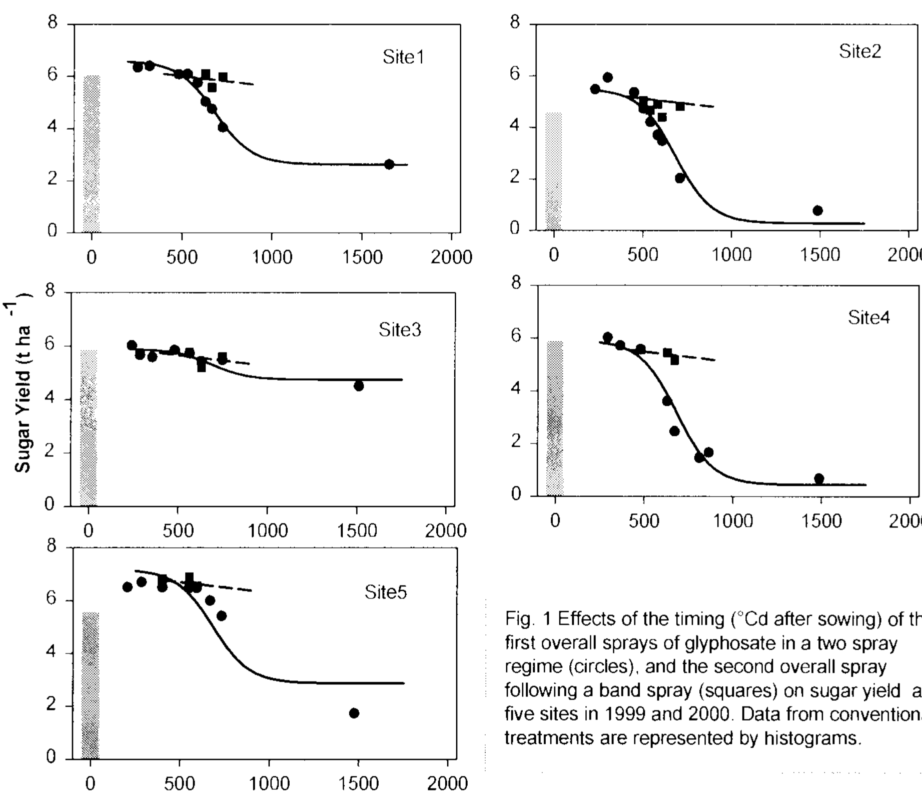

Fig. 1 Effects of the timing (°Cd after sowing) of the first overall sprays of glyphosate in a two spray regime (circles), and the second overall spray following a band spray (squares) on sugar yield at five sites in 1999 and 2000. Data from conventional treatments are represented by histograms.

Table 6 Summary of total environmental scores (using Milieumeetlat system) for herbicide programmes

Experiment	1	2	3	4	5
	Water organisms				
Glyphosate overall	0	0	0	0	0
Glyphosate band & overall	0	0	0	0	0
Conventional 1	32	114	122	110	218
Conventional 2	54	188			
	Soil organisms				
Glyphosate overall	6	0	6	0	0
Glyphosate band & overall	5	0	5	0	0
Conventional 1	11	488	28	458	733
Conventional 2	11	960			
	Deeper water				
Glyphosate overall	0	0	0	0	0
Glyphosate band & overall	0	0	0	0	0
Conventional 1	155	1965	16540	281	8000
Conventional 2	191	1965			

(Scores based on 31 December 2000 Millieumeetlat version, except lenacil, which is based on the 1997 report)

herbicides on the beet plants themselves. Some of the yield improvements from the glyphosate treatments in the experiments reported here were probably also a result of better weed control throughout the season.

These results suggest that weed control with overall glyphosate applications should commence around 275°Cd for optimum yield return and before 535°Cd if significant yield loss is to be avoided. This broadly agrees with previous work (Scott *et al.*, 1979; Wilson, 1999; Schweizer & Dexter, 1987). Results from the band-spray treatments suggest that, following a first spray applied at between 207 and 530°Cd after sowing, the second could be applied much later between 586°Cd and 725°Cd (average 656°Cd) before significant reductions in yield compared to the conventional regime occur.

The glyphosate programme used the maximum dose recommended on draft labels, and conventional treatments, especially in 1999, were less intensive compared to most commercial treatments used that season as a result of the later sowing. The Milieumeetlat scores showed that the adoption of GMHT sugar beet would reduce environmental contamination from weed control in sugar beet. However, many current programmes do not pose an unacceptable risk.

Adoption of GMHT would result in economic savings (May, 2003). However, apart from a reduction in direct environmental contamination, other environmental benefits are possible. Those on invertebrates are reported by Dewar *et al.* (2003), but the presence of weeds in bands would also reduce the risk of wind erosion and may, by offering alternative food source, result in less bird grazing of young beet seedlings. The presence of weeds might also reduce the incidence of aphid attack (Dewar *et al.*, 2000a) or the build up of potato cyst nematodes where these and volunteer potatoes are present in a sugar beet crop (Dewar *et al.*, 2000b).

The use of band spray techniques to leave weeds during the growing season, or a mirror image of this technique (overall spray first and band spray last) are techniques that could be adopted for a relatively small cost to the community by growers to improve wild life on farm. The timing of sprays, techniques used and the field areas selected for treatment could be targeted to predetermined environmental goals.

ACKNOWLEDGEMENTS

We thank Paul Drinkwater for allowing trials on his farms, Jan Wevers of IRS, Bergen op Zoom, Netherlands for Milieumeetlat system calculations, Kevin Sawford, Hazel Davidson and Stephen Goward for technical assistance, Ray Bugg and John Booth for applying the treatments and harvesting the plots and to Dr John Pidgeon and Dr Alan Dewar for their discussions and encouragement. This work was partially funded by Monsanto plc. Broom's Barn is a division of Rothamsted Research which is a grant-aided Institute of the BBSRC.

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