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# Weed and arthropod populations in conventional and genetically modified herbicide tolerant fodder beet fields

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## Abstract

The introduction of genetically modified herbicide tolerant (GMHT) crops has raised concerns from both scientists and non-governmental organisations about possible effects on arable flora and fauna due to the changes in herbicide application and management that such crops involve. Three consecutive studies were performed, covering flora and fauna in fields of GMHT and conventional fodder beets over the season, at different locations and under different spraying regimes. At all locations and in the 3 years, a denser and more diverse weed flora and arthropod fauna were found in GMHT beets in early and mid-summer than in conventional beets when glyphosate-treatment occurred at or after label recommendation. Following the herbicide applications the GMHT fields had fewer weed species and seeds and lower weed densities and biomass than conventional fields. However, application of glyphosate earlier than recommended resulted in an extremely low weed diversity, density and biomass during the entire season. Timing of the first glyphosate applications, i.e. the duration of the herbicide free period, was essential in terms of biodiversity improvements. In the long term reduced production of weed seeds in GMHT fields may deplete the weed flora if the GMHT strategy becomes widely adopted.

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## 1. Introduction

Generally, effective weed control is a prerequisite for a high yield in low-competitive row crops such as beets (e.g. Jansen, 1972; Scott et al., 1979). In conventional beet fields, weeds are controlled by a mixture of selective herbicides. Conventional herbicides for control of dicots can only be used until the crop starts to develop true leaves and their efficacy decreases as the weeds grow. Conventional beet management, therefore, is very sensitive to weather

conditions around germination and weedy years with reduced yield may occur even though conventional beet fields normally look weed free. The development of GMHT beet varieties tolerant to the broad-spectrum herbicide glyphosate gives more flexibility in the timing of application. All weeds are sensitive to glyphosate although the susceptibility varies significantly among species and with growth stages (Kudsk and Mathiassen, 1998; Bückmann et al., 2000). Due to the efficacy of glyphosate, the management of GMHT crops has been argued to reduce weed and invertebrate populations (Hails, 2000; Schütte, 2002). The development of GMHT crops, however, offers the opportunity for delayed herbicide application compared with conventional application. This may

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allow for a period with more weeds in the field (Hails, 2002), likely to affect the fauna through changes in food availability, habitat structure and microclimate.

Over the last decades farmland biodiversity has generally declined as a consequence of intensified management (Green, 1990; Fuller et al., 1995; Andreassen et al., 1996; Rich and Woodruff, 1996; Chamberlain et al., 2000; Donald et al., 2000; Atkinson et al., 2002; Benton et al., 2002). The introduction of GMHT crops has raised concerns that the changes in weed management might exacerbate current trends (Krebs et al., 1999; DEFRA, 2002).

In autumn 1998, a number of GMHT crops were close to commercial release in the European Union, among them the GM glyphosate tolerant fodder beet studied here. However, concerns regarding biodiversity suspended the evaluation process. A number of national initiatives were taken to bridge the gap in knowledge and field experiments were established (e.g. Firbank et al., 1999; Firbank and Forcella, 2000). In some countries, e.g. Denmark, lack of public confidence in biotechnology and GMHT crops was taken seriously and the public was invited to visit the fields. The present studies, which formed part of the so-called Danish demonstration trials, compared GM glyphosate tolerant fodder beet with conventional to answer the question: does management of GMHT crops exacerbate or ameliorate the conditions for farmland wildlife compared to conventional management? Moreover, field monitoring was supplemented by an experiment to study the hypothesised beneficial effect on biodiversity from delayed herbicide application. The Danish demonstration trials were a common initiative between biotechnological companies (Danisco Seeds, DLF-Trifolium and Monsanto), the Danish Agricultural Advisory Centre and the Danish Forest and Nature Agency, i.e. the competent authority for regulation of GMOs in Denmark.

## 2. Materials and methods

Fourteen fields located all over Denmark were included in the trials that aimed at demonstrating transgenic crops to the public and comparing cultivation of conventional and GM-fodder beet. The size of the fields varied considerably, and only larger fields

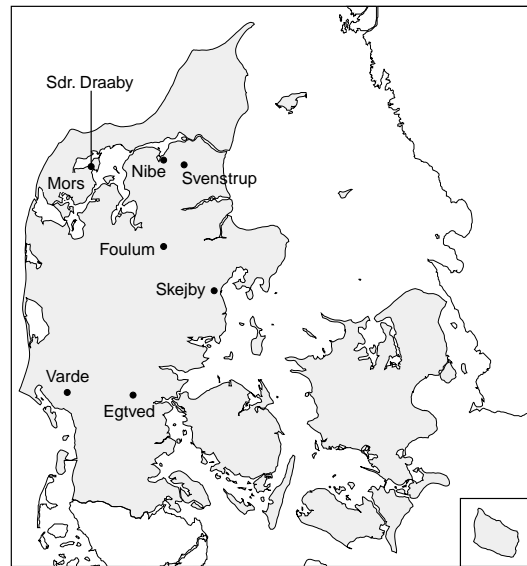


Fig. 1. Location of field sites. Two (Mors and Nibe) and six sites (Mors, Svenstrup, Foulum, Skejby, Egtved and Varde) were included in the 1999- and 2000-study, respectively. The 2001 experiment took place at the Mors field site, which was thus common to all three studies.

(>0.5 ha) were used for the present studies. In 1999, two sites were studied, i.e. Nibe near Aalborg and Sdr. Dråby on the island Mors in Limfjorden. In 2000, another five sites were included plus Mors already included in the 1999 study (Fig. 1). At each site the field was separated into two parts under either GM or conventional management. Within the conventionally managed half a beet cultivar normally grown in the area (Simplex, Troya or Magnum) was sown and managed in the way that the farmer would normally do. The glyphosate tolerant fodder beet used on the other half was cv. Simplex. Detailed information on management is summarised in Table 1.

A third year (2001) of study was devoted to an experimental investigation of the relationship between timing of the herbicide application and biodiversity responses. The experiment was set up at Sdr. Dråby on the island Mors (Fig. 1). A split block design was applied with four replicates of the following herbicide treatments: (a) conventional beet herbicides; (b) roundup ready (RR) as recommended (Monsanto, 1999); (c) RR, with first application earlier than recommended; (d) RR applied as late as possible. The

Table 1  
Treatments applied, time of applications, and sampling dates for weeds and arthropods in the years 1999–2001

Year/site	Sowing	Conventional herbicides		Glyphosate		Sampling dates	
		Application dates	Dosage (g/ha)	Application dates	Dosage (g/ha)	Weeds	Arthropods
<b>1999</b>							
Mors	24-04	13-05	128 g PMP + 700 g MM	07-06	810 g	01-06	01-06
		26-05	160 g PMP + 700 g MM + 250 g FPB	23-06	810 g	16-06 01-07	16-06 01-07
Nibe <sup>a</sup>	28-04	28-05	320 g PMP + 700 g MM	28-05	810 g	01-06	01-06
		05-06	320 g PMP + 700 g MM	10-06	810 g	16-06	16-06
					17-06	504 g	01-07
<b>2000<sup>b</sup></b>							
Mors <sup>c</sup>	28-04	30-04	128 g PMP + 700 g MM	01-06	810 g	26-06	26-06
		10-05	160 g PMP + 700 g MM				
		23-05	250 g FPB	20-06	810 g		
Varde	01-05	01-05	160 g PMP + 350 g MM + 10 g TSM	11-05	504 g	28-06	28-06
		11-05	80 g PMP + 315 g MM + 10 g TSM	02-07	504 g		
		30-05	80 g PMP + 315 g MM + 10 g TSM				
Skejby	19-04	05-05	100 g EF + 25 g DMP + 125 g PMP + 700 g MM	16-05	810 g	09-06	09-06
		15-05	100 g EF + 25 g DMP + 125 g PMP + 700 g MM	19-06	810 g		
		31-05	100 g EF + 25 g DMP + 125 g PMP + 700 g MM				
Egtved	22-04	09-05	160 g PMP + 1050 MM	10-06	1080 g	17-06	17-06
		19-05	192 PMP + 30 g CP				
		21-06	192 PMP + 30 g CP + 700 g MM	30-06	1080 g		
		27-06	192 PMP + 30 g CP + 10 g TSM				
Svenstrup	01-05	20-05	320 g PMP + 700 g MM	20-05	1080 g	21-06	21-06
		22-06	320 g PMP + 700 g MM	23-06	1080 g		
Foulum	05-05	16-05	192 g PMP + 120 g EF + 700 g MM + 375 g FPB	01-06	1080 g	27-06	27-06
		03-06	192 g PMP + 120 g EF + 700 g MM	29-06	1080 g		
		21-06	192 g PMP + 120 g EF + 700 g MM				
<b>2001<sup>b</sup></b>							
Mors, conventional	21-04	10-05	60 g PMP + 12 g DMP + 92 g EF + 700 g MM			22-05	22-05
		23-05	60 g PMP + 12 g DMP + 92 g EF + 700 g MM			21-06	21-06
		14-06	+75 g FPB			18-07	18-07
			+75 g FPB			09-08	
						23-10	
Mors, RR-label	21-04			14-06	810 g	22-05	22-05
				05-07	810 g	06-06	
						21-06	21-06
						03-05	
						18-07	18-07
Mors, RR-early	21-04			25-05	810 g	22-05	22-05
				27-06	810 g	21-06	21-06
						18-07	18-07
						09-08	
						23-10	
Mors, RR-late	21-04			27-06	810 g	22-05	22-05
				16-07	810 g	21-06	21-06
						12-07	
						18-07	18-07
						09-08	
				23-10			

Herbicide abbreviations—PMP: phenmedipham; MM: metatriton; FPB: fluzifop-P-butyl; TSM: trisulfuronmethyl; EF: ethofumesat; DMP: desmedipham; CP: clopyralid.

<sup>a</sup> Field sprayed with insecticides.

<sup>b</sup> Beet seeds treated with seed dressing insecticide Gaucho WS 70 (Bayer).

<sup>c</sup> Field with pre-sowing treatment of 960 g glyphosate-trimesium/ha, 14 March, 2000.

GM glyphosate tolerant fodder beet cv. Simplex was sown in all plots, including the plots where conventional beet herbicides were applied. Each plot was 20 m × 20 m of which the central 18 m × 18 m was used for the biological sampling.

### 2.1. Biological samplings

Weeds and arthropods were sampled from 10 randomly selected non-overlapping units for each treatment. Weeds were sampled from 0.75 m × 0.75 m squares, except for 2000 (0.5 m × 0.5 m). Weeds rooted within the squares were identified and the number of plants was counted for each species or genus, separately. In 2000 and 2001, aboveground biomass was subsequently harvested. In 2001, weed seeds produced were harvested when mature. Arthropods were sampled by a Dietrick vacuum sampler (Dietrick, 1961), each sample consisting of 10 suctions of 10 sections alternately taken in and between rows. Samples were stored at –18 °C until the arthropods were identified. Samples were sorted to order, group, or species. In 2001, aphids, thrips, mites and springtails were not counted because of their low importance as bird food, and because the occurrence of springtails and mites in D-Vac samples depended too much on microclimatic conditions. As a consequence, these arthropod groups are left out of data analyses for all 3 years. Beets were harvested on 48 m<sup>2</sup> per plot for yield estimate on 23 October 2001.

Numbers and timing of samplings differed between years to optimise the use of available resources (Table 1). The 1999-samplings were designed to assess effects of management strategies on weed flora and arthropod fauna in early summer. The 2000-samplings aimed at confirming the results obtained in 1999 at each of the six sites, which were representative of soil types and climatic conditions in Jutland, Denmark. The 2000-samples represented post-application conditions for conventional plots. For GM-plots the sampling took place between first and second application of RR except for Mors that was sampled post-application. In 2001, the intention was to measure the effects of different herbicide treatments on weeds and arthropods during the whole crop season. Sampling dates were hence determined according to spraying dates. In RR-treated plots pre- and post-application samples were taken, whereas

only post-application samples were taken in the plots receiving conventional beet herbicides.

### 2.2. Data analysis

Statistical analyses are only presented for data collected in 2001. Results were tested for normality, and since data on weeds and arthropods were found not to fulfil the criterion, effects of herbicide treatment on number of weed species, weed density and biomass as well as arthropod abundance and diversity were analysed by the non-parametric Kruskal–Wallis test. Effects of herbicide treatment on beet yield were tested by analysis of variance, and means were compared using a *t*-test. All tests were evaluated at the 5% level. The SAS procedure NLIN (SAS Institute, 1988) was used to fit weed and arthropod data to the delay in spraying time achieved in the glyphosate tolerant beet plots compared to the conventionally treated beets.

## 3. Results

In 1999 and 2000 more weed species occurred at higher densities and with a higher biomass in fields with GM-beets than in conventional beet fields, before RR applications (Fig. 2). In 2001 early application of glyphosate resulted in an extremely effective weed control with low weed density, diversity and biomass during the entire season (Fig. 2). Application made as recommended or later allowed for a dense weed cover and a rich arthropod fauna. Compared to both 2001 and 1999, 2000 was particularly weedy both under conventional and glyphosate treatment.

Differences for weeds between sites were generally smaller than between treatments (Fig. 2 and Table 2). The Mors site sampled after the second RR application had relatively low numbers of weed plants compared to the other sites in 2000 that were sampled between first and second applications (Fig. 2). The weed biomass at Mors, however, was among the largest recorded in 2000. At the localities with large weed biomass, i.e. Mors, Egtved and Foulum, glyphosate was applied 2–3 weeks later than at the other sites (Table 1) indicating that timing of first glyphosate application was most important for the development of the weed flora. Svenstrup differed from other localities in having significantly higher numbers of weed species (Fig. 2) and

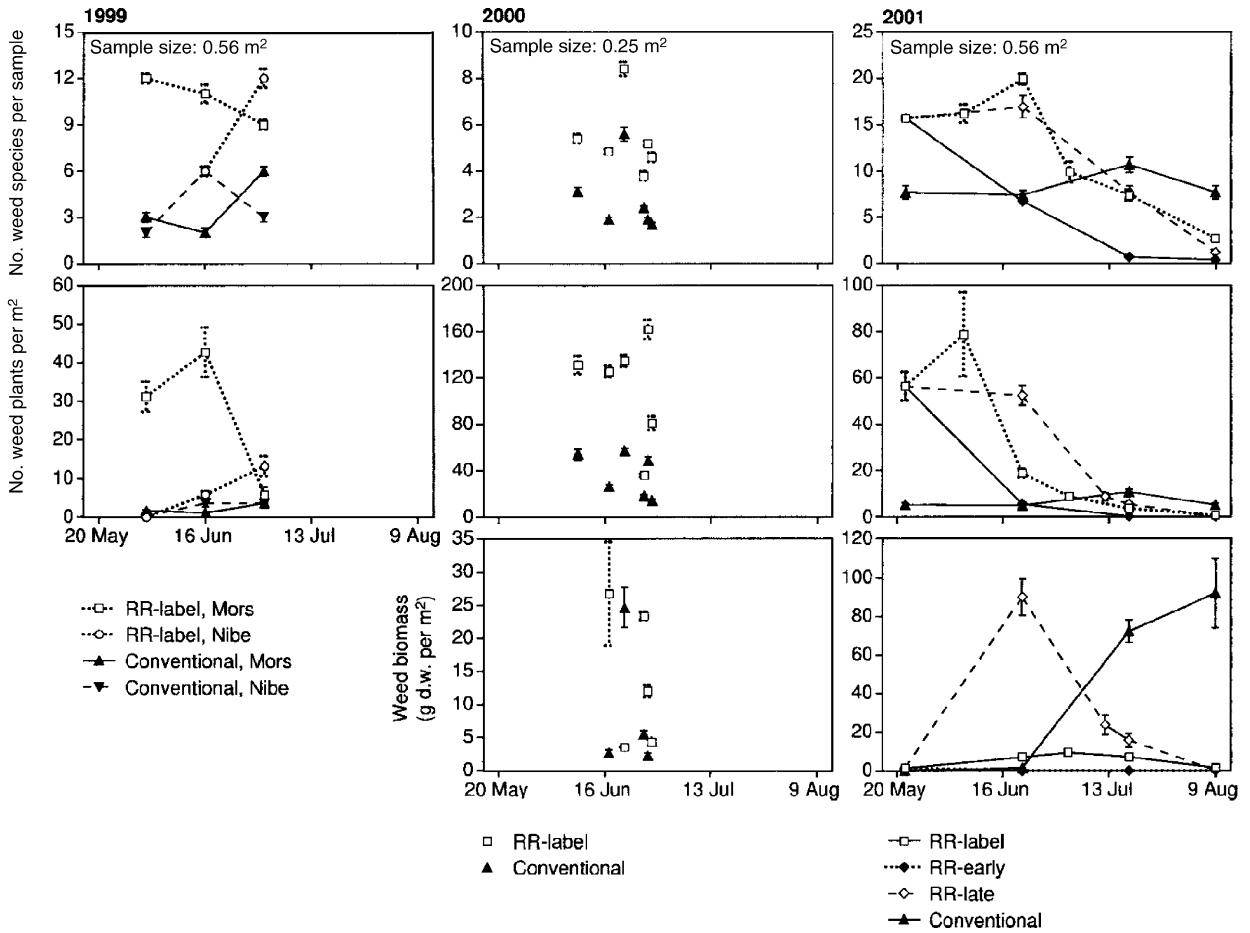


Fig. 2. Weed diversity, density and aboveground biomass ( $\pm$ S.E.M.) in fodder beet 1999–2001 under different herbicide treatment. Note that scales and sample size differ between years. Information on herbicides, dosages and time of application may be found in Table 1.

a larger weed biomass in the conventional than in the glyphosate-treated plot (Fig. 2). Weed density, however, was highest in the glyphosate-treated plot indicating that the mean plant weight was greater in the conventionally treated plot. Here conventional herbicides were applied late and at the same time as the first application of glyphosate, whereas glyphosate was applied at least 10 days later than the conventional herbicides at all other sites (Table 1).

The conventionally treated plots generally had a poor weed flora early in the season as a consequence of the early herbicide applications, but new plants were recruited later on. Although few, these plants grew and produced a significantly higher biomass in con-

ventional than in RR-treated plots from mid-July ( $P < 0.0001$ , Fig. 2). The weed flora in glyphosate-treated plots peaked before the RR applications irrespective of the application time, and diversity, density and biomass decreased thereafter. The effect of RR versus conventional treatment was demonstrated by the declining ratios recorded from late June to early August (Table 2), except for Nibe 1999 that may be explained by the extremely early application of glyphosate on the same day as conventional herbicides. In 2001, all glyphosate treatments resulted in full weed control later in the season and no production of seeds. In conventionally treated plots seeds accounted for 10–20% of the above-ground weed biomass.

Table 2  
Effects\* of herbicide treatment, year and locality variation on weed diversity, density and biomass

Year	Treatment	Herbicide effect	Maximum year effect	Maximum locality effect
<b>Weed diversity</b>				
1999		1–5.5		
	RR-recommended			1.8
	Conventional			3
2000		1.5–2.7		
	RR-recommended			2.2
	Conventional			3.2
2001	RR-recommended	2.7 (late June) 0.7 (mid-July) 0.4 (early August)		
	RR-early	0.9 (late June) 0.06 (mid-July) 0.05 (early August)		
	RR-late	2.3 (late June) 0.7 (mid-July) 0.1 (early August)		
Mors	RR-recommended		2.3	
	Conventional		4.5	
<b>Weed density</b>				
1999		1.6–38.8		
	RR-recommended			7.2
	Conventional			3.3
2000		2.0–5.6		
	RR-recommended			4.5
	Conventional			4.0
2001	RR-recommended	3.8 (late June) 0.3 (mid-July) 0.1 (early August)		
	RR-early	1.1 (late June) 0.01 (July and August)		
	RR-late	10.5 (late June) 0.5 (mid-July) 0.03 (early August)		
Mors	RR-recommended		9.7	
	Conventional		5.0	
<b>Weed biomass</b>				
2000		0.1–10.1		
2000	RR-recommended			7.5
	Conventional			10.8
2001	RR-recommended	5.3 (late June) 0.09 (mid-July) 0.02 (early August)		
	RR-early	0.1 (late June) 0.0001 (mid-July) 0.0005 (early August)		
	RR-late	67.6 (late June) 0.2 (mid-July) 0.002 (August)		
Mors	RR-recommended		3.3	
	Conventional		13.3	

\* Ratio calculated as RR vs. conventional within locality and year; Mors as the richest vs. poorest year within treatments; max locality as richest vs. poorest locality within year and treatment.

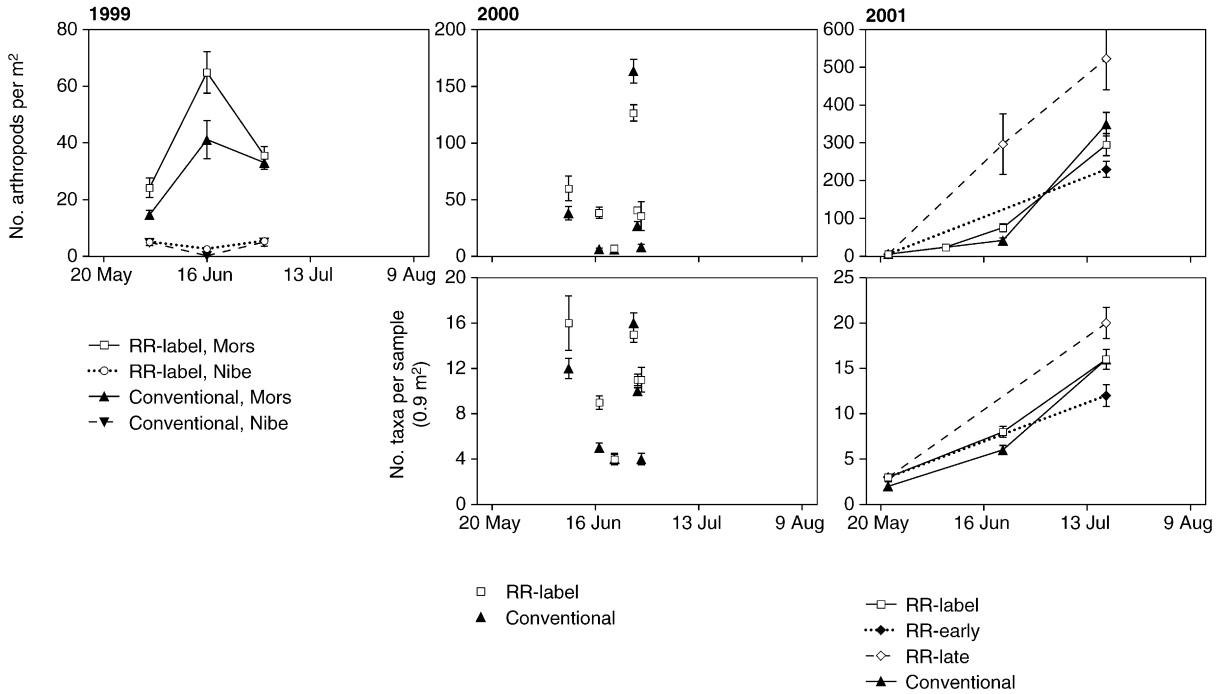


Fig. 3. Arthropod abundance and diversity ( $\pm$ S.E.M.) in fodder beet 1999–2001 under different herbicide treatment. Note that aphids, thrips, mites and springtails are not included and that scales difference between years. For information on herbicides, dosages and time of application cf. Table 1.

Arthropod abundance and diversity increased over the season (Fig. 3), except at Nibe 1999, where insecticides were applied in June and early July. Arthropod abundance and diversity differed considerably between sites and more than between treatments (Fig. 3, Table 3). Mors was generally arthropod rich, though numbers varied between years (Table 3). Differences between treatments were generally smaller for arthropods than for weeds both in terms of abundance and diversity (Table 3). Arthropod numbers and diversity were generally higher in glyphosate-treated beets than in fields treated with conventional herbicides, except at Mors in 2000 where the reverse was true (Fig. 3). In 2001 no significant differences were found in May whereas later in the season significant differences were found, i.e.  $P < 0.0001$  and  $P = 0.0007$  for density and diversity, respectively, on June 21 and  $P < 0.0001$  for both density and diversity in July. Glyphosate treatment as recommended resulted in a slight increase of both abundance and diversity in June 2001 compared to conventional treat-

ment, whereas both arthropod abundance and diversity increased substantially in June and July in plots under delayed glyphosate treatment (Fig. 3, Table 3). Arthropod abundance was related to average weed biomass with an  $R^2$  of 0.68 for the linear relationship for all sampling dates together. Arthropod abundance was only slightly (negatively) related to average weed density with an  $R^2$  of 0.15. The relationship between arthropods and weed biomass was in general better described by a quadratic equation,  $ax^2 + bx + c$ , with negative value for “a” (Table 4).

For information on the response of single groups or species of plants and arthropods, please see Bruus Pedersen and Strandberg (2000); Elmgaard and Bruus Pedersen (2001); Strandberg and Bruus Pedersen (2002).

The window between the first application of conventional beet herbicides and the first application of glyphosate varied considerably between fields, i.e. from 1 to 48 days. For RR applied as recommended when the weeds had 4–6 leaves, the window was

Table 3  
Effects<sup>a</sup> of herbicide treatment, year and locality variation on arthropod diversity and density

Year	Treatment	Herbicide effect	Maximum year effect	Maximum locality effect
<b>Arthropod diversity</b>				
2000	RR-recommended	0.9–2.8	–	4
	Conventional	–	–	4
2001	RR-recommended	1 (July)–1.3 (June)	–	–
	RR-early	0.75 (July)	–	–
	RR-late	1.25 (July)–2 (June)	–	–
2000 and 2001	RR	–	1.9	–
	Conventional	–	2.7	–
<b>Arthropod density</b>				
1999	RR-recommended	1.0–13.5	–	24
	Conventional	–	–	187
2000	RR-recommended	0.78–6.5	–	18
	Conventional	–	–	27
2001	RR-recommended	0.85 (July)–1.8 (June)	–	–
	RR-early	0.66 (July)	–	–
	RR-late	1.5 (July)–7 (June)	–	–
1999–2001	RR	–	5	–
	Conventional	–	2	–

<sup>a</sup> Ratio calculated as RR vs. conventional within locality and year; Mors as the richest vs. poorest year within treatments; max locality as richest vs. poorest locality within year and treatment.

Table 4  
Relationship<sup>a</sup> between arthropod abundance and weed biomass in 2001 calculated on basis of data for all herbicide treatments

Group	$R^b$ linear relation	$R^b$ quadratic relation
Linyphiidae	0.0076	0.55
Apocrita	0.26	0.72
Brachycera and Cyclorrhapha	0.035	0.62
Nematocera	0.035	0.37*
Delphacidae, adults	0.52	0.76*
Cicadellidae, adults	0.033	0.52
Heteroptera	0.020	0.54
Carabidae	0.0011	0.58
Aleocharinae	0.0068	0.53
Staphylinidae	0.0019	0.60
Chrysomelidae	0.52	0.93
Curculionidae	0.057	0.53
Clavicornia <sup>b</sup>	0.091	0.85
All arthropods	0.68	0.71*

<sup>a</sup> “*a*” of the equation  $ax^2 + bx + c$  is negative, except where marked with \*.

<sup>b</sup> Collective term for mould beetles, ladybirds, pollen beetles, etc.

35 days in 2001. Both weed biomass and arthropod abundance increased exponentially ( $P < 0.0001$ ) with delay of herbicide application (Fig. 4).

No significant difference ( $P = 0.27$ ) in root yield of cv. ‘Simplex’ was found among treatments, although mean root biomass tended to be higher in plots under early application of glyphosate.

#### 4. Discussion

The present studies showed that GMHT beets allow for the presence of weeds in the field for up to 2 months (mid-May to mid-July) without any yield loss as measured in 2001, which is not possible under conventionally management (Scott et al., 1979; Schweizer and Dexter, 1987). The weed biomass recorded in 2000 did not exceed what was found in plots with late glyphosate application in 2001 when no yield reduction was found. Weed density is known to be negatively related to crop yield (Zimdahl, 1999), and since it was much higher in 2000 than in 1999 and 2001 reductions in crop yield in 2000 cannot be ruled out. After glyphosate treatment in the GMHT beets, the

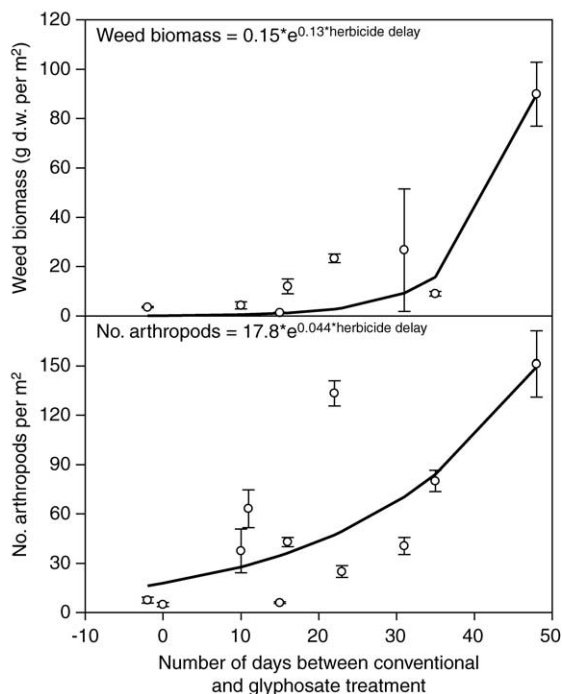


Fig. 4. Relationship between spraying, weed biomass and arthropod abundance (data points = average figures  $\pm$  S.E., the curve being the best exponential fit).

difference was reversed and conventional fields had higher weed density, diversity and biomass compared to GMHT beet.

Arthropod abundance and diversity responded like the weeds to changes in spraying practice, although the differences between treatments were smaller. Contrary to the weeds, arthropod numbers and diversity varied more between sites than between herbicide treatments, reflecting the importance of other factors such as microclimatic conditions, insecticides, management history, field size, and surrounding habitats. As for invertebrate populations and weeds in the farm scale evaluations (FSE; Brooks et al., 2003), total arthropod abundance was correlated to weed biomass. However, the development in arthropod populations was not synchronous with the development in weed biomass, since arthropod numbers increased when beet developed dense covers and weed biomass decreased. Crop development may hence be a better predictor of arthropod abundance than weed biomass or density.

The results are in accordance with Firbank et al. (2003) and Heard et al. (2003a,b) who found more weeds in GMHT beet, spring oilseed rape and maize before herbicides were applied than in conventional crops, the effect being reversed after treatment except for maize.

The timing of the first application of glyphosate was extremely important with regard to flora and fauna. Avoidance of insecticide spraying is a prerequisite for any increase in arthropod diversity and density. Applications of glyphosate according to recommendation resulted in a larger and more diverse flora and fauna in GMHT plots compared with conventional plots in early summer. In 2001, the first application could be further postponed for 2 weeks without any significant effect on beet root yield but with very positive effects on flora and fauna. However, the farmer's readiness to wait that long with application is uncertain. Among the 66 farmers participating in the FSE, 20 sprayed the GMHT beet first 36–42 days after sowing, and 39 later on (Champion et al., 2003). GMHT beet on Mors was sprayed first 40 days after sowing according to recommendations. A trade-off between weed infestation and timing of herbicide application may be expected, farmers having low infestations spraying late. A shift in the farmer's conception of weeds and timing of herbicide application may be necessary. In conventionally grown beets, weeds often cause yield loss, and early herbicide application is a prerequisite for a high yield (Scott et al., 1979; Schweizer and Dexter, 1987). Farmers growing GMHT beet will need to accept weeds in the field for a longer period, knowing that this does not necessarily result in yield loss. Band spraying as tested in UK (Dewar et al., 2003) also allowed weeds in the field for a longer period resulting in higher weed and insect biomass without yield reductions. Reduction of glyphosate dosages may also result in a more dense and diverse flora and fauna (Elmegaard and Bruus Pedersen, 2001). Reducing the total amount of glyphosate to decrease costs and pesticide use will lead to very early applications of glyphosate (Rydahl, 2000). This may reduce the risk of leaching to the groundwater, but will also reduce weed and arthropod abundance and diversity.

Effective weed control by glyphosate resulted in a complete lack or very reduced production of weed seeds, independent of spraying time. In contrast, the application of conventional herbicides allowed for

recruitment of weeds that produced seeds. FSE found a three-fold reduction of seed rain in GMHT beet compared to conventional beet, lower seedbank densities for 19 out of 24 species, and an overall decline in seedbank of 7% in one year (Heard et al., 2003a,b). The effect of reduced seed production in GMHT beet may shift the flora towards less glyphosate-sensitive species, density and biomass also being altered with long-term effects on weed populations. Although changes in seedbanks may not be as large as the 20% reduction hypothesised by Watkinson et al. (2000) for *Chenopodium album* L., they may not be negligible and Heard et al. (2003b) argued that large decreases in densities of arable weeds may occur in the longer term. If the density and species diversity of weeds was reduced, it would be reflected in the abundance and diversity of the arthropod fauna. The positive effect of GHMT beet on biodiversity in early summer found in the present study may disappear. Furthermore, reductions in weed seeds may also have consequences for wintering birds. Based on a mathematical model using seed production of *C. album* and skylark (*Alauda arvensis* L.) populations Watkinson et al. (2000) predicted that GMHT beets may have severe negative effects on farmland birds. Long-term effects of reduced weed seed production in GMHT crops should not be ruled out especially if one or several such crops cover large areas.

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