Ministry of Environment and Energy
National Environmental Research Institute

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NERI Technical Report, No. 349

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2001

Niels Elmegaard
Marianne Bruus Pedersen
Department of Terrestrial Ecology

Data sheet

Title:	Flora and Fauna in Roundup Tolerant Fodder Beet Fields

Authors: Niels Elmegaard and Marianne Bruus Pedersen
Department: Department of Terrestrial Ecology

Serial title and no.: NERI Technical Report No. 349

Publisher: Ministry of Environment and Energy
National Environmental Research Institute ©
URL: http://www.dmu.dk

Date of publication: February 2001

Referees: Drs. Francesca Tencalla & Yann Fichet
Layout: Bodil Thestrup
Drawings: Kathe Møgelvang & Juana Jacobsen

Please cite as: Elmegaard, N. & Bruus Pedersen, M. 2001. Flora and Fauna in Roundup Tolerant Fodder Beet Fields. National Environmental Research Institute. 40 pp. Technical Report No. 349.

Abstract: Weed flora and arthropod fauna were investigated in fodder beet plots located on six sites in Jutland, Denmark in June 2000. On each site three treatments were represented viz. traditional beets (T), glyphosate tolerant beets (RR) treated with full Roundup Ready dosage RR100), RR beets treated with half the dosage applied in RR100 (RR50). Roundup Ready were applied later than the traditional herbicides and for a period of time the weed density were higher in RR plots until some time after the second Roundup Ready was applied, then the RR plots became very clean. The arthropod fauna responded to the change in the amount of weed present in the RR plots. It is believed that the faunal response is mainly governed by three mechanisms: 1) the herbivorous fauna component experience more host plants and more flowers in weedy plots, 2) a number of non-herbivorous arthropods prefer the more gentle microclimate in weedy plots and the more complex vegetation structure (web building spiders), 3) predators are attracted by the high prey density in weedy plots including birds.

Keywords: Weed, arthropods, herbicide regime, fodder beets, Roundup Ready, glyphosate tolerant, genetically modified beet.

Editing complete: January 2001

Financial support: Monsanto

ISBN: 87-7772-600-6
ISSN (print): 0905-815X
ISSN (electronic): 1600-0048

Paper quality: Cyclus Print
Printed by: Silkeborg Bogtryk
EMAS Reg. No. DK-S-0084
Number of pages: 40
Circulation: 200

Price: DKK 50,- (incl. 25% VAT, excl. freight)

Internet-version: The report is also available as a PDF-file from NERI's homepage

For sale at:

National Environmental Research Institute
Vejlsøvej 25
P.O. Box 314
DK-8600 Silkeborg
Denmark
Tel.: +45 89 20 14 00
Fax: +45 89 20 14 14

Miljøbutikken
Information and Books
Læderstræde 1
DK-1201 Copenhagen K
Denmark
Tel.: +45 33 95 40 00
Fax: +45 33 92 76 90
e-mail: butik@mem.dk
www.mem.dk/butik

Content

[Tom side]

Foreword

For demonstration purposes Monsanto, DLF-Trifolium, and Danisco Seed, in collaboration with The Danish Agricultural Advisory Centre, established field plots with glyphosate tolerant fodder beets on a number of farms all over Denmark in 1999 and 2000. The National Environmental Research Institute, Department of Terrestrial Ecology, has followed the trials in both years to get an impression of the consequences that the introduction of glyphosate resistant beets would have on flora and fauna in the fields.

In 1999, two of the experimental sites were visited three times. The results are reported at http://www.sns.dk/natur/bioteknologi/roundup_art.htm.

In 2000, six different fields were visited but only once (in June), in order to examine flora and fauna in field cultivated on different soil types, under different weather conditions and under different agricultural practice. The results from the work in 2000 are presented in this report.

The authors appreciate the help with the fieldwork we received from Mrs I. L. Lauridsen, Mrs. I. Møller, Mrs. A. Christiansen, Mr. J. G. Rytter and Drs. B. Strandberg and K.E.Nielsen.

We are grateful to the farmers for access to their fields and to the local agricultural advisory consultants for their co-operation.

We also want to thank the Agricultural Advisory Centre for pleasant collaboration and Drs. F. Tencalla, Y. Fichet and C. Kjær for comments on an earlier draft of the report.

Mrs. B. Thestrup and K. Møgelvang we thank for assistance with setting up the report.

The work was partly funded by Monsanto.

[Tom side]

Summary

A few studies have pointed out that the introduction of glyphosate tolerant beets might benefit the flora and fauna in beet fields without a reduction of the yield. The aim of the present study is to further evaluate this hypothesis by comparison of the weed flora and arthropod fauna in conventional and Roundup Ready beet fields. The study focusses on the differences in the herbicide regime applied and not on the fact that the Roundup Ready beet is developed by genetically engineering.

Fodder beet fields at six sites spread out over Jutland, Denmark, were included in the study. Five of the sites were part of a study planned and carried out be the National Agricultural Advisory Centre in collaboration with DLF-Trifolium, Monsanto and Danisco Seed. In each field three treatments were applied, viz. traditional herbicide regime (T), Roundup Ready applied at the dosage necessary to control the weed flora present evaluated by the farmer and the Advisory Consultant (RR100), and Roundup Ready applied in half the dosage used in RR100 (RR50). The plots were small, the experimental area covering approximately 0.5 ha in total at each site. Danish Institute of Agriculture at Foulum established the sixth site where only a traditional and a RR100 plot were present.

The fields were visited one time in June. Weeds were identified, counted and harvested, and dry weight was determined. The arthropod fauna was collected by means of a Dietrick Vacuum sampler, frozen down and identified in the laboratory.

In the traditional plots the herbicide applications began in early May. At one site the Roundup Ready application in the RR plots was performed at the same time but at the other sites the first RR treatment was 10-32 days after the first herbicide treatment in the T plot. The sites thus represent very different situations in term of herbicide application as a result of differences in farm management, weather conditions etc.

The results revealed that the implementation of Roundup Ready fodder beets may increase biodiversity in beet fields. In general, the weed flora and arthropod fauna in RR plots contained more individuals and species than the T plots in June. It is believed that this difference would benefit the avi-fauna during a period of time where food availability is critical to farmland birds. The results also illustrate the difference in flora and fauna between sites and the difference in field management. The use of Roundup as a weed-controlling agent is more powerful and efficient compared to conventional herbicide regimes in beet fields. When Roundup can be used in beet fields more weeds can be accepted for a period of time because control can be obtained in more developed weed vegetation. However, this improvement of conditions for flora and fauna relies on a delayed weed control. At one site, herbicides were applied at the same time in T plots and RR plots. In this case the conventional herbicide regime was

less efficient than RR treatment throughout the season, and consequently the flora and fauna had better conditions in the T plot.

On several of the sites, the reduction of dosage in the RR50 plots resulted in more weeds in term of density or size of plants. Thus, the conservation potential in RR-beets can be improved if dosage is reduced. At the studied sites there was a scope for dosage reduction without yield loss.

Use of insecticides in fields with delayed weed control will counteract the benefits to the fauna from the herbicide regime. In the present study insecticide was only used as seed dressing.

A dense and diverse weed flora is believed to benefit the fauna in several ways. Firstly, occurrence and density of the host affect herbivorous insect species thriving on specific weed species. Secondly, the microclimate and habitat structure of weedy spots attracts a number of arthropod species of different feeding guilds. Thirdly, the aggregation of arthropods for the aforementioned reasons may benefit predators including birds.

Dansk resumé

Konklusion

Dyrkning af Roundup-tolerante foderroer (RR-roer) kan forbedre vilkårene for flora og fauna i roemarkerne sammenlignet med traditionel roedyrkning. Benyttes RR-roer i roemarkerne, kan antallet af individer og arter i ukrudtsfloraen øges. Herved forbedres mulighederne for markens insektfauna, og markens fugle har glæde af både ukrudtet og insekterne. Sammenfattende tyder nærværende undersøgelser på, at der er mulighed for at øge naturindholdet i roemarker ved at benytte RR-roer. Driftlederens motivation for at benytte denne mulighed er afgørende for, i hvor høj grad potentialet udnyttes.

Den øgede ukrudtsmængde fremkommer, fordi det er muligt at sprøjte betydeligt senere i roemarker med RR-roer end i i marker med traditionelt dyrkede roer. Hvis ikke der sprøjtes senere i marker med RR-roer end i traditionelle roemarker, er forholdene for flora og fauna bedst i de traditionelle marker, idet ukrudtsmængden så er størst her. Roundup er nemlig mere effektivt end de herbicider, man hidtil har anvendt i roer. RR-roens tolerance over for Roundup og den høje effektivitet af Roundup på mange forskellige arter er baggrunden for, at man kan tillade ukrudtet at udvikle sig mere inden der sprøjtes i marker med RR-roer. Den gavnlige effekt på naturindholdet i markerne ved at benytte RR-roer kan i mange tilfælde øges ved at reducere doseringen, uden at det går ud over roeudbyttet.

Sprøjtning med insekticid forringer imidlertid vilkårene for faunaen og kan derved ophæve de fordele, der kan være ved dyrkning af RR-roer. Udenlandske undersøgelser tyder dog på, at der er mindre behov for insekticidbehandlinger i RR-roer, hvor ukrudtsbekæmpelsen er forsinket nogle uger. Den øgede ukrudtsmængde i sådanne roemarker bevirker nemlig, at antallet af bladlusefjender forøges betydeligt, hvilket reducerer risikoen for bladlusangreb.

Formål

Det er tidligere påvist, at dyrkning af RR-roer kan forbedre forholdene for flora og fauna på enkelte lokaliteter. I nærværende projekt er det formålet yderligere at evaluere denne hypotese ved at sammenligne flora og fauna i marker med henholdsvis RR-roer og konventionelle roer på seks forskellige lokaliteter. Herved opnås et indtryk af variationen i flora og fauna under forskellige jordbunds- og klimatiske forhold, samt under forskellige driftsledere.

Metoder

Landskontoret for Planteavl, Landbrugets Rådgivningstjeneste, planlagde i samarbejde med DLF-Trifolium, Monsanto og Danisco

Seed at anlægge demonstrationsforsøg i 2000 på en række gårde (www.lr.dk/planteavl/informationsserier/gmoroer/index.htm). Fem af disse lokaliteter, Svenstrup, Mors, Skejby, Egtved, Varde, blev besøgt en gang i juni for at indsamle ukrudt og leddyr. Herudover blev der også foretaget indsamling ved Foulum på en forsøgsmark etableret af Danmarks JordbrugsForskning. Indsamlingen er foretaget på meget forskellige tidspunkter i forhold til ukrudtsbehandlingerne på de forskellige lokaliteter, men i alle tilfælde i højsæsonen for ynglende fugle. Forsøgsparcellerne var udlagt som traditionel herbicidanvendelse (T), RR-roer behandlet med Roundup Ready i netop den dosering der skønnes nødvendig for at kontrollere den forekommende ukrudtsflora (RR100), og RR-roer behandlet med halvdelen af doseringen i RR100 (RR50).

Ukrudtstætheden blev bestemt ved hjælp af en 0.25m^2 ramme kastet tilfældigt ca. 10 gange i hvert forsøgsfelt. Planterne blev bestemt til art, de blev talt og de overjordiske dele høstet til bestemmelse af tørvægt.

Leddyrsfaunaen blev indsamlet ved hjælp af en Dietrick Vacuum Sampler, der er en motoriseret jord-og vegetationssugemaskine. Ti prøver på hver 0,09 m^2 blev udtaget i hver parcel.

Resultat og diskussion

Der var gennemsnitligt højere ukrudtstæthed, større ukrudtsbiomasse og flere ukrudtsarter i RR-parcellerne (se Figur 2). På een lokalitet blev herbicidbehandlingen udført samtidigt i traditionelle og RR-parceller, hvilket resulterede i en højere ukrudtsbiomasse i T-parcellen (Svenstrup, Figur 2).

Arterne med den største tæthed blev kun delvist genfundet på listen over de mest betydende arter for biomassen.

Optællinger foretaget af Landbrugets Rådgivningstjeneste på de samme lokaliteter viser, at forskellen i ukrudtsmængden mellem RR-parceller og T-parceller reduceres, forsvinder eller bliver vendt om senere på sommeren efter den anden Roundup-behandling i RR-parcellerne (www.lr.dk/planteavl/informationsserier/gmoroer/ index.htm). Det samme blev observeret i en tidligere undersøgelse udført af Danmarks Miljøundersøgelser (www.sns.dk/natur/ bioteknologi/genartikler.htm).

Leddyrsfaunaen i roemarkerne reagerede på ændringer i ukrudtsmængden, men da faunaen (og floraen) er forskellig på lokaliteterne, er responsen også forskellig mellem lokaliteterne. I RR-parcellerne forekom flere bladlus på nogle lokaliteter, på andre var der flere thrips, fluer og myg, snyltehvepse, rovbiller, edderkopper eller bladbiller (se Tabel 7). Der er flere kendte årsager til, at faunaelementer foretrækker ukrudtsrige områder i dyrkede marker:

1) For det første er der grundlag for flere planteædende insekter, når der er mere ukrudt og flere forskellige plantearter. Et eksempel herpå er pileurtsbladbillen (*Gastrophysa polygoni*), der lever af vejpileurt og snerlepileurt. Er ingen af de to værtplanter tilstede, kan den ikke ek-

sistere, og jo flere der er, desto større bestand kan den opbygge. På lokaliteten i Skejby, hvor tætheden af pileurt var størst i parcellen behandlet med halv Roundup dosering (RR50) (se Tabel 3), forekom også pileurtsbladbillens larver i størst antal i RR50-parcellen, se Figur 3. På de øvrige lokaliteter blev denne billeart ikke fundet, selvom dens værtplanter forekom almindeligt. Årsagen hertil er formentlig, at billen er uddød på lokaliteter, hvor der sprøjtes med insekticider. Den er nemlig langsom til at kolonisere nye områder eller genetablere sig på lokaliteter, hvor den er uddød.

Hertil kommer at visse insektarter søger føde i planternes blomster. Blomstrende ukrudtsplanter kan således tiltrække for eksempel sommerfugle, svirrefluer og snyltehvepse.

2) For det andet er der et gunstigere mikroklima, hvor jorden er dækket af ukrudt. Det mildere klima foretrækkes af en række leddyr blandt snyltehvepse, løbebiller, rovbiller og edderkopper, fluer og myg. Mange netspindende edderkoppearter foretrækker endvidere levesteder med en mere kompleks vegetation.

3) For det tredje vil den større tæthed af leddyr, grundet de ovennævnte årsager, danne fødegrundlag for rovdyr blandt leddyrene og for agerlandets fugle.

[Tom side]

1 Background and aims

The development of new cultivation systems in agriculture calls for analysis of the environmental consequences. The introduction of genetically modified crops tolerant to the broad-spectrum herbicide glyphosate is no exception to that. Environmental consequences may have many different forms. The present study deals with the ecological effects of the herbicide regime on flora and fauna in fields sown with Roundup tolerant (Roundup Ready, RR) fodder beets. Thus the project does not focus on the fact that the beets are developed by genetically engineering, but on the change in herbicide use occurring in fields where traditional fodder beets are substituted by RR beets. Weed control by glyphosate in RR beet fields is efficient and often has superior performance compared to conventional herbicide regimes (Madsen and Jensen 1995; Buckmann et al. 2000).

Changes in herbicide regime affect the flora and fauna in the field. The weed flora can be expected to change with changes in the herbicide applied due to differences in species sensitivity towards different herbicides. Furthermore, the time of application influences the impact on the flora. The weed flora in turn affects the arthropod fauna. Some insect species thrive on one or more weed species; some exploit flowering plants (Cowgill et al. 1993). Predatory and fungivorous species may be attracted to weedy spots in search for food or shelter (Speight and Lawton 1976; Purvis and Curry 1984; Powell et al. 1985; Hald and Elmegaard 1989; Reddersen et al. 1998), and some species living on the crop may prefer a low weed density (Buckelew et al. 2000). Also the avi-fauna may be affected as the weed flora and arthropod fauna in the fields compose the food of many birds of arable land (Green 1984; Hill 1985; Stoate et al. 1998; Elmegaard et al. 1999). Dewar et al. (2000) report that delayed weed control in RR-sugar beets reduced pest aphids due to greater density of predators and parasitoids in weedy plots.

Bruus Pedersen and Strandberg (2000) registered the flora and arthropod fauna in two fields with conventionally and Roundup Ready (RR) fodder beet plots. More weeds were found in the RR plots than in the conventionally grown beets in early summer. The difference disappeared later in the season after the second Roundup application. For the arthropod fauna, the results were more difficult to interpret, because only two fields were included in the study, one of which was sprayed with insecticides.

The present study aims at resolving whether the increased number of weed plants in RR beets early in the season is a general phenomenon, and whether this will result in more arthropods. Therefore, six field sites were included in the study. Sampling took place at one occasion in each field, in June. At that time many birds in arable land are breeding and sensitive to the density of food items. In the present study the weight of the weed plants was measured in several fields because plant biomass may be a better indicator of the food resource available than density of plant specimens of unknown size. The six fields were managed by six different managers in collaboration with advisory consultants. Thus, the study comprises different decision processes and provides to some extent a simulation of a general implementation of RR beets. The fact that the beets are not yet allowed marketed in Denmark and EU implied that the RR beets had to be destroyed before harvest.

2 Methods

Six fields were included in the study, situated at six different sites in Jutland, Denmark (Figure 1), viz. Skejby at Aarhus, Egtved near Vejle, Varde in Western Jutland, Foulum near Viborg, Svenstrup near Aalborg, and on the island Mors in Limfjorden.

In each field, three different treatments or herbicide regimes were represented: RR-beets treated with full Roundup dosage (RR100), defined as the dosage necessary to control the weed flora present, RR beets treated with half of that dosage (RR50, not included at Foulum), and beets treated with traditional herbicides (T). The experimental fields were 0.3-0.5 ha except at Foulum where the field was 2 ha. The RR50 plots were typically less than 500 m^2.

The Danish Agricultural Advisory Centre, except at Foulum, planned the experiments. The centre also conducted a number of pest surveys: weed density before first herbicide spraying in T plots, weed density before first herbicide spraying in RR plots, weed density after second herbicide spraying in RR plots, weed density before fields were harrowed, thrips (% of beet plants), mangold fly larvae (*Pegomya betae* Curt., % of plants), number of beet plants with sign of attacks by mangold beetles (*Atomaria spp*.), beet carrion beetle (*Aclypea opaca*) and plant bugs (Heteroptera) before first spraying with glyphosate, peach-potato aphid (*Myzus persicae*, numbers /25 plants) and bean aphids (*Aphis fabae*, % of plants) in early August. Registrations of weed beets, mildew, *ramularia*, rust, yellow spot virus and quality of the beets were also carried out. All data collected by the Advisory Centre is available at the Internet at the web site for experiments with RR beets and results presented in (Pedersen 2000).

The RR-beet cultivar sown was Simplex, whereas in the traditionally cultivated plots beet cultivars drilled were Simplex, Troya or Magnum. Information on beet cultivar, soil type, previous crop, manure treatment and sowing date is given in Table 1. Information about herbicide treatment is presented in Table 2. The fields were not sprayed with other pesticides. Beet seeds were all treated with the seed dressing insecticide Gaucho WS 70 (Bayer) with the active ingredient imidacloprid.

For each treatment, 10 samples of weeds and arthropods were collected, except for Skejby (4-7 weed samples) and Egtved (7-9 samples), where plots were very small or homogeneous. Points of plant sampling were chosen by throwing a frame of 0.25 m^2 at random, covering the plot. At each sampling point, the weeds present were identified at species or genus level, and each species or genus was counted separately. Subsequently, the total above ground weed biomass was harvested (except at Skejby). For approximately three samples per plot (depending on a subjective estimate of the variation in species composition and plant size within species), the harvested plants were divided into species. The weeds were dried at 60°C, and the dry weight was determined. Nomenclature follows Hansen (1991).

A Dietrick Vacuum Sampler (D-vac) (Dietrick 1961) was used to collect arthropods (colour plate p. 19). A sample consisted of 10 suctions lasting 10 seconds each, taken at sampling points covering the plot. Suctions were alternately carried out in the beet rows (often covering a beet plant) and between rows. At Egtved only nine samples were collected due to small plot size. The samples were stored at -18°C. Arthropods were identified to species, genus, family or order, depending on taxonomic difficulties, resources and importance of the species.

Figure 1. The six field sites included in the study.

2.1 Data analyses

Number of weed plants, number of species and biomass were analysed by analysis of variance, and means were compared by Tukey's HSD t-test.

D-vac-samples were compared between treatments by a Students T-test performed on log (x+1) transformed data.

Table 1. Soil type, previous crop, manure, beet cultivar in T- plots and dates of sowing.

Location	Soil type*	Previous crop	Manure/slurry	Beet cultivar in T plot	Sowing date (MM-DD)
Mors	7	Spring barley (silage)	50 t stable manure, 2000-03-20, 25 t cattle slurry, 2000-04-10	Troya	04-28
Varde	3	Winter rye	35 t cattle slurry, 2000-04/15	Magnum	05-01
Skejby	7	Spring barley		Troya	04-19
Foulum	2	unknown	35 t cattle slurry	Simplex	05-05
Egtved	5	Spring barley	20 t stable manure, 2000-03-11 20 t liquid cattle manure, 2000-04-20	Simplex	04-22
Svenstrup	2	Winter wheat	25 t cattle slurry, 2000-04-25	Troya	05-01

*Soil type according to Danish Standards (JB-number). 1= sandy (75-100% sand), 7=clayish (15-25% clay).

Table 2. Drilling date, herbicide treatment in Traditional and Roundup Ready plots (rate and date), and date of collection of flora and fauna samples.

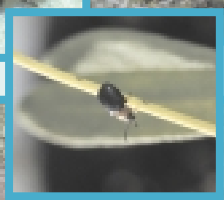
Site (sown)	Pesticide rate (ha^{-1}) used in T plot	Date (MM-DD)	Pesticide rate used in RR plots (RR100/RR50)	Date RR plot (MM-DD)	Flora & fauna samples (MM-DD)
Mors (04-28)	960 g glyphosate-trimesium ,	03-14	960 g glyphosate-trimesium	03-14	06-26
	128 g phenmedipham+ 700 g metamitron	05-10	810 g/505 g glyphosate	06-01	
	160 g phenmedipham+ 700 g metamitron	05-23	810g /505 g glyphosate	06-20	
	250 g fluazifop-P-butyl	06-08			
Varde (05-01)	160 g phenmedipham+ 350 g metamitron 10g triflusulfuron-methyl	05-01			06-28
	80 g phenmedipham+315 g metamitron+ 10g triflusulfuron-methyl	05-11	504 g/252 g glyphosate	05-11	
	80 g phenmedipham+315 g metamitron+ 10g triflusulfuron-methyl	05-30	504 g/252 g glyphosate	07-02	
Skejby (04-19)	100g ethofumesat+25g desmedi-pham+125g phenmedipham+ 700g metamitron	05-05			06-09
	100g ethofumesat+25g desmedi-pham+125g phenmedipham+ 700g metamitron	05-05	810 g/505 g glyphosate	05-16	
	100g ethofumesat+25g desmedi-pham+125g phenmedipham+ 700g metamitron	05-31	810 g/505 g glyphosate	06-19	
Foulum (05-05)	192g phenmedipham+ 120g ethofumesat+ 700g metamitron	05-16			06-27
	375g flaziphob-P-butyl	06-01	1080g/540 g glyphosate	06-01	
	192g phenmedipham+ 120g ethofumesat+ 700g metamitron	06-03			
	192g phenmedipham+ 120g ethofumesat+ 700g metamitron	06-21	1080g/540 g glyphosate	06-29	
Egtved (04-22)	160 g phenmedipham+ 1050 g metamitron	05-09			06-17
	192 g phenmedipham+ 30g clopyralid	05-19			
	192 g phenmedipham 700g metamitron+30g clopyralid	05-19	1080g/540 g glyphosate	06-10	
	192 g phenmedipham 700g metamitron+30g clopyralid+ 10g triflusulfuron-methyl	06-21	1080g/540 g glyphosate	06-30	
Svenstrup (05-01)	320g phenmedipham+ 700g metamitron	05-20	1080g/540 g glyphosate	05-20/05-18	06-21
	320g phenmedipham+ 700g metamitron	06-22	1080g/540 g glyphosate	06-23/06-19	

Field study of effects of two herbicide regimes on weeds and arthropods in fodder beets

The field sites included in the study.

Collection of arthropod samples by D-vac.

Gastrophysa polygoni, larvae and imago, a common insect on the weeds *Polygonum aviculare* and *P. convolvulus*.



Roundup tolerant (RR100) beets at Varde on June 28, 48 days after the first Roundup treatment. Note the wilted weeds on the ground. The beets seem to have suffered from a dense weed cover before Roundup treatment.

Traditionally cultivated fodder beets at Foulum

Traditionally cultivated beets at Foulum on June 27. Weed density is low (cf. next page).

Roundup tolerant fodder beets at Foulum

Roundup tolerant (RR100) beets at Foulum on June 27, 26 days after the first Roundup treatment. Weed density is moderate-to-high (cf. previous page).

Traditional and Roundup tolerant beets at Egtved

Traditionally cultivated beets at Egtved on June 17.
Weed density is low-to-moderate.

Roundup tolerant (RR100) beets at Egtved on June 17,
7 days after the first Roundup treatment. Weed density is high, and the weeds are large compared to the traditionally cultivated plot (left).

3 Results and discussion

3.1 Plants

The sampling was carried out at very different points in time in relation the herbicide treatment (Table 2) and the herbicide treatments were carried out at very different dates.

3.1.1 Weed density

A higher average density of weed plants (T=9.1, RR100=27.9, RR50=34.2), average weed biomass (T=2.0, RR100=3.6, RR50=9.9) and average total number of weed species per plot (T=8.8, RR100=13.0, RR50=13.6) were registered in RR plots compared to T plots (Figure 2).

At Varde (colour plate p. 19) and Skejby the weed density was highest in the RR50 plots (12 and five times as many as the T plots, respectively) followed by the RR100 plots which had significantly higher densities (six times and twice as many, respectively) than the T plots.

At Egtved (colour plate p. 22) and Mors the RR plots had weed densities five and two times higher, respectively, than the T plots, but no significant differences between RR50 and RR100 plots were observed. At Foulum (colour plates pp. 20-21) weed density was approximately three times higher compared to T plots. At Svenstrup weed density was two times higher in the RR100 plot compared to both the T plot and the RR50 plot.

3.1.2 Diversity and dominance

The picture described for weed density was also seen when considering the number of weed species identified per sample (Figure 2, Table 4).

At Svenstrup more weed species were registered than at the other sites (Tabel 3).

In Table 5, the most abundant species at each site and treatment are presented. Couch grass (*Elytrigia repens*) was only dominant in T plots, never in RR plots. The same was not true for other common weeds such as *Viola*, *Poa annua*, *Lamium* sp., *Chenopodium album*, *Polygonum* sp. and *Cirsium arvense*. At Skejby, Foulum and Egtved, the three most abundant species were fairly similar for the three treatments, whereas at the other sites there were more discrepancies, not only between traditionally grown beets and RR beets, but also between the two dosages in RR beets. Common to all plots, the three most abundant weeds accounted for more than 50% of the total weed number.

Table 3. Average number of weeds per sample (0.25m^2) t the six field sites. "T" refers to traditionally sprayed beets, "RR100" to Roundup tolerant beets treated with full dosage, and "RR50" to Roundup tolerant beets treated with half dosage. "a" or "p" following the species name indicates whether the weed is annual or perennial.

	Mors			Varde			Skejby			Foulum		Egtved			Svenstrup		
	T	RR100	RR50	T	RR100	RR50	T	RR100	RR50	T	RR100	T	RR 100	RR 50	T	RR 100	RR 50
Aethusa cynapium a							0.1										
Anagallis arvensis a									0.5							0.1	
Artemissia sp. p											0.2				0.1	0.3	
Brassica sp. a				0.5	0.2	0.5			0.5						0.4		0.2
Capsella bursa-pastoris a					1.3	1.3					4.7		0.3			0.2	
Chenopodium album a	0.7	0.2		0.2	1.5	3	0.4	8.4	16.5		0.1				1.9	11.9	3.1
Cirsium arvense p															2.5	0.8	3.3
Elytrigia repens p	1.6	0.4	0.3	1.5	0.4	4.2				2.1					0.9	0.1	
Equisetum arvense p									1								
Erodium cicutarium a																	0.1
Euphorbia sp. a			0.3														
Fumaria sp. a															0.2	0.2	0.1
Galeopsis sp. a											1.4						
Galinsoga sp. a																	0.1
Galium aparine a							0.7	1	2.8								
Geranium sp. a															0.1		
Gnaphalium uliginosum a					0.2	2.6											
Hordeum vulgare a												0.1			0.2	0.6	0.2
Juncus bufonius a					0.2	0.2					0.3						
Lamium sp. a	1.4	2	2.8					0.2	0.3		0.3		0.9	3.7			
Lapsana communis a	0.1	0.2	0.1														
Lolium sp. a/p	0.1		0.1													0.2	
Matricaria sp. a	0.3	0.3	0.4	0.2	1.1	5.5			0.3				0.1		0.1	0.9	0.1
Myosotis sp. a								0.2	0.3		0.3		0.4		0.1	1.8	1.5
Papaver sp. a															0.6	1.3	
Plantago sp. p					0.1	0.4											
Poa annua a	0.1	3.1	2	0.2	11.6	16.5		0.2	0.3	0.9	14.1	5.4	25.3	17.6	0.6	3.7	1
Polygonum aviculare a		0.2					6.1	0.2	5.8							0.4	0.1
Polygonum convolvulus a			0.1	0.8	0.5	1.5	2.9	5.8	11.5	0.2	0.9	0.1	0.1		0.7	0.4	1.7
Polygonum persicaria a						0.2											
Sinapis arvensis a							3.3	15.2	22.5								
Solanum nigrum a																	0.2
Sonchus sp. a								0.2	5								
Stellaria media a					0.2	0.2					0.3		2	2.9	0.1	0.4	0.2
Taraxacum sp. p	0.1	0.1	0.3		0.2	0.2						0.3			6.4	4.7	0.8
Trifolium sp. p					0.9	1.1									0.1	0.1	0.1
Urtica urens a		0.1			0.6	4.7										0.1	0.3
Veronica sp. a	0.1					2					0.5	0.2	0.9		0.3	3.3	2.5
Vicia/Lathyrus a																	0.1
Viola sp.a/p	0.1	2.4	3.3					1.4	4	9	16.2	0.3	1.4	4.9	2.6	1.3	0.8

Table 4. Outcome of ANOVA test of effect on the weed flora of the different treatments, viz. Roundup tolerant beets sprayed with half dosage (RR50, not at Foulum), Roundup tolerant beets sprayed with full dosage (RR100), and traditionally grown beets (T). Significance is given as p-value, and the means are compared when differences are significant (p<0.05).

Site	No. plants per sample	No. species per sample	Biomass
Mors	0.011 RR50=RR100>T	0.0031 RR50=RR100>T	0.013 RR50≥RR100≥T
Varde	<0.0001 RR50>RR100>T	<0.0001 RR50>RR100>T	0.0005 RR50>RR100=T
Skejby	<0.0001 RR50>RR100=T	<0.0001 RR50>RR100>T	-
Foulum	0.001 RR100>T	<0.0001 RR100>T	0.0078 RR100>T
Egtved	<0.0001 RR50=RR100>T	<0.0001 RR50=RR100>T	0.21
Svenstrup	0.0025 RR100>RR50=T	0.028 RR100≥RR50≥T	0.064

Table 5. Most abundant weed species per site and treatment followed by the average percentage out of the total **number** of plants in the samples in brackets.

Site	Traditional	RR100	RR50
Mors	*Elytrigia repens* (35) *Lamium* sp. (30) *Chenopodium album* (15)	*Poa annua* (34) *Viola* sp. (27) *Lamium* sp. (22)	*Viola* sp. (34) *Lamium sp.* (29) *Poa annua* (21)
Varde	*Elytrigia repens* (44) *Polygonum convolvulus* (24) *Brassica* sp. (15)	*Poa annua* (64) *Chenopodium album* (8) *Capsella bursa-pastoris* (7)	*Poa annua* (38) *Matricaria* sp. (13) *Urtica urens* (11)
Skejby	*Polygonum aviculare* (45) *Sinapis arvensis* (24) *Polygonum convolvulus* (21)	*Sinapis arvensis* (46) *Chenopodium album* (26) *Polygonum convolvulus* (18)	*Sinapis arvensis* (32) *Chenopodium album* (23) *Polygonum convolvulus* (16)
Foulum	*Viola* sp. (74) *Elytrigia repens* (17) *Poa annua* (7)	*Viola* sp. (41) *Poa annua* (36) *Capsella bursa-pastoris* (12)	-
Egtved	*Poa annua* (84) *Taraxacum sp.* (5) *Viola* sp. (5)	*Poa annua* (80) *Stellaria media* (6) *Viola* sp. (5)	*Poa annua* (61) *Viola* sp. (17) *Lamium* sp. (13)
Svenstrup	*Taraxacum* sp. (436 *Viola* sp. (15) *Cirsium arvense* (14)	*Chenopodium album* (36) *Taraxacum* sp. (14) *Poa annua* (11)	*Cirsium arvense* (20) *Chenopodium album* (19) *Veronica* sp. (15)

3.1.3 Weed biomass

Weed biomass was proportional to weed density at Mors, Varde, Foulum and Egtved (Figure 2, Table 4). At Egtved, the difference in biomass between the two RR-treatments indicated in Figure 2 was not significant (Table 4). At Svenstrup, the weed biomass was greater in the T plot than in the RR plots although the weed density was highest in the RR100 plot (Figure 2) indicating that the mean weight of weed plants was greater in the T plot. At that site, the first application of traditional herbicides and Roundup took place at the same time, whereas at all other sites Roundup was applied at least ten days later than the traditional herbicides (Table 2). Applied at the same time, Roundup resulted in a stronger growth retarding effect on the weeds present.

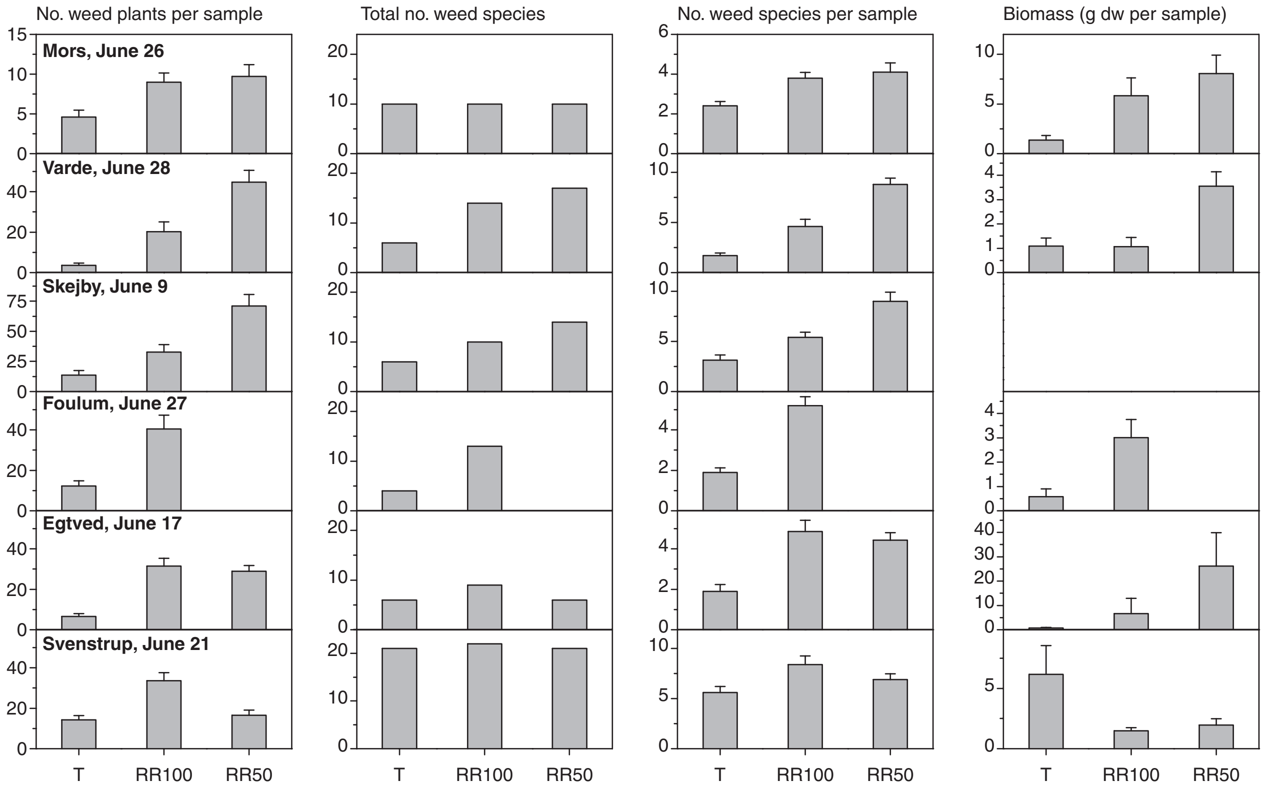


Figure 2. Number (means and SE) of weed plants per sample of 0.25 m^2 (first column from the left), total number of plant species per treatment (second column), number of plant species per sample (third column) and total weed biomass per sample (right column, no data for Skejby) at the six sites. At each site three herbicide regimes were represented, viz. Roundup tolerant beets sprayed with half dosage (RR50, not at Foulum), Roundup tolerant beets sprayed with full dosage (RR100), and traditionally sprayed beets (T). Within each field and treatment, 10 samples were collected, except for Skejby (4-7 samples) and Egtved (7-9 samples). Labels indicating sampling site in the left column are valid for all four columns. Note that scales may differ between sites.

An attempt was made to estimate the relative biomass of the various weed species on the basis of the collected biomass samples, which were only separated into species for approximately three samples per plot. In a few cases, lacking data for the average biomass per specimen of single species in RR100 plots were substituted with data from RR50 plots and vice versa, because the plant size was generally quite similar within the RR plots. However, such extrapolations present a possible error, especially in the case of Egtved. The predominant species in terms of biomass (Table 6) were to some extent overlapping species, which occurred in the highest densities (Table 5). At least one of the three most numerous species was among the three species contributing most to the biomass, except for two plots (Varde RR50 and Svenstrup T). However, there were also several differences among the three dominant species between the two measures, as indicated in Table 6. The measure of biomass is to be preferred in investigations of food web etc. as a better indicator of the available resources. There is a considerable uncertainty attached to weed density as indicator of available plant resources.

Table 6. The three weed species estimated to have the highest biomass per area (g dw per 0.25 m^2). No data on biomass were available for Skejby. Bold-face characters indicate that the species was not among the three most numerous species in the plot (cf. Table 5).

Site	Traditional	RR100	RR50
Mors	*Elytrigia repens* (0.7) ***Veronica* sp.** (0.04) ***Lolium* sp.** (0.03)£	*Lamium* sp. (2.3) *Viola* sp. (0.5) ***Urtica urens*** (0.5)	*Lamium sp.* (2.5) *Viola* sp. (0.6) ***Polygonum convolvulus*** (0.2)
Varde	*Polygonum convolvulus* (0.4) *Elytrigia repens* (0.2) *Brassica* sp. (0.03)	*Chenopodium album* (0.3) *Poa annua* (0.1) *Capsella bursa-pastoris* (0.1)	***Elytrigia repens*** (0.8) ***Chenopodium album*** (0.3) ***Capsella bursa-pastoris*** (0.3)
Foulum	*Viola* sp. (0.08) *Poa annua* (0.005) ?	*Viola* sp. (0.3) ***Galeopsis* sp.** (0.3) *Capsella bursa-pastoris* (0.3)	-
Egtved	*Poa annua* (0.2) *Viola* sp. (0.002) ***Taraxacum* sp.** (0.0006)	*Poa annua* (7.7)* ***Capsella bursa-pastoris*** (1.3) ***Polygonum convolvulus*** (1.0)	*Poa annua* (5.3) *Lamium* sp. (1.4) ***Stellaria media*** (1.0)
Svenstrup	***Elytrigia repens*** (0.9) ***Brassica* sp.** (0.3) ***Matricaria* sp.** (0.1)	***Polygonum aviculare*** (0.2) *Chenopodium album* (0.1) ***Cirsium arvense*** (0.1)	*Cirsium arvense* (0.4)$ ***Polygonum aviculare*** (0.06) ***Polygonum convolvulus*** (0.04)

* Average biomass per plant from plants collected at RR50, because of lack of data for RR100 plots.
$ Average biomass per plant from plants collected at RR100, because of lack of data for RR50 plots.
£ No data available for *Chenopodium album*, because it was not represented in the biomass samples at species level.
? No further data available.

3.2 Fauna

The most common arthropods in the sampled beet fields were springtails (Collembola), aphids (Aphidae), flies and midgets (Diptera), beetles (Coleoptera), mites (Acarina), spiders (Aranea) and parasitic wasps (Hymenoptera: Apocrita) (Table 7).

The abundance in the samples reflects both the real density in the field (numbers per unit area) and the effectiveness of the method applied in sampling different arthropod species. Particularly for springtails and mites, it is our experience that the proportion of the population found on the soil surface is very much influenced by the microclimate and may fluctuate considerably during the day (Elmegaard, unpublished material). These arthropods are in their entire life cycle adapted to a life in the soil, and most of the species only come to the surface when the risk of desiccation is low. When population density is high, the topsoil is humid due to weed coverage or recent rain, and the sunlight is not to strong, one can collect relatively many springtails and mites by D-Vac sampling. Comparisons of population densities between fields are therefore only sound if the microclimate among other things is similar.

The arthropod fauna varies considerably between fields (Table 7). In the table there has been made no compensation for the lower number of sub-samples taken at the field site Egtved (9 instead of 10). The difference in densities between sites has many sources such as zoogeography, topography, soil properties, crop history, farm management and the stochasticity of many ecological processes.

The impact of the herbicide regime on the fauna very much depends on the spatial and temporal distribution of the arthropod species and which resources they exploit. Below we have commented on the abundance of some of the most important arthropod groups in the different plots and field sites.

3.2.1 Heteroptera

The Heteroptera fauna in beet fields often includes herbivorous species living on the crop and on various weed species. The heteropterans may therefore potentially benefit from a higher weed density. The heteropterans overwinters outside the cultivated field in hedges, banks, etc. and immigrates into the fields in spring. Plant bug damage to beet-crops is typically more severe in the field edge closest to the hibernating sites. The Advisory Centre counted the number of beet plants with plant bugs prior to the first spraying with Roundup and did not find any anywhere.

The density of plant bugs in the D-vac samples was low on most field sites, except Skejby where more than 80% of the total material was sampled (Table 7). At this site the abundance of heteropterans followed the weed density and diversity (Figure 2). Most of the plant bugs sampled were larvae. Among the few adults collected cabbage bug (*Eurydema oleracea*), leaf bug (*Piesma maculatum*) and Miridae spp. were identified.

3.2.2 Aphids

The aphids in the D-vac samples were not identified to species. At Foulum, Egtved, and Skejby aphids were significantly more abundant in RR plots. At Mors there were fewer aphids in the RR100 plot compared to the T plot and the RR50 plot, and at Svenstrup the aphid density was highest in the T plot. Except for Mors, the aphid density was correlated to weed biomass (Figure 2). The extension service counted the number of plants with the peach-potato aphid (*Myzus persicae*) and bean aphids (*Aphis fabae*) in August. No peach-potato aphids were observed, but from 0-10% (mean of all field sites 4%) of the beets had colonies of bean aphids. There was no difference between treatments in aphid infestation in August, and densities did not correlate with density estimates obtained by D-vac in June.

As aphid density in June to some extent covaried with weed biomass and not with bean aphid density in august, we find it likely that the aphids in June were predominantly species associated with the weeds. This in agreement with the results of Dewar et al. (2000) who found many leaf curling plum aphids (*Bradychaudus helichrysi*) in weedy plots.

3.2.3 Thysanoptera

Thrips were only found in significant numbers at Egtved. Here the density was higher in the RR plots compared to the T plot. The extension service counted the number of beet-plants with thrips before the first Roundup spraying in May - June. They also found the highest infestation at Egtved (5%), and no difference between treatments. At Varde thrips were registered on 1-2 % of the beets, with no difference between treatments. On the three other surveyed sites thrips were not found.

3.2.4 Lepidoptera

At Skejby the density of caterpillars was relatively high in the RR plots. It is likely that the butterfly fauna benefited from the weeds present here. The caterpillars were not identified to species, but the material contained predominantly moth-like species. Butterflies are mainly caught as larvae in D-vac samples. The density of caterpillars is normally too low to allow for comparisons between treatments. This is regretful as the larvae are very important as food item for birds and the butterflies themselves are an important contribution to biodiversity from a human point of view.

3.2.5 Diptera

The distribution of flies and midgets in the plots does not follow any clear patterns. Many of the species are as larvae living of decaying organic matter in the soil. Some of these species apparently reflect differences in treatment in the present study. The herbivorous species may reflect the weed flora, and in the material there is a tendency for cecidomyids to respond to treatment.

The Advisory Centre counted the number of mangold fly larvae (Beet fly, *Pegomya betae*) at five of the sites before the first Roundup spraying in May-June. No larvae were observed anywhere.

3.2.6 Apocrita

The density of parasitic wasps seems to have been affected by treatment, most likely via the weed flora. Host-density (Dewar et al 2000) and nectar availability (Baggen and Gurr 1998) may influence the distribution of parasitoids. The host species provide food for the larvae and the flowers provide food for the adults. Only imagines are collected in D-vac samples. It is likely that the observed increase in weed density and diversity has resulted in an increase in both nectar supply and host density in form of other arthropods benefiting from the richer weed flora.

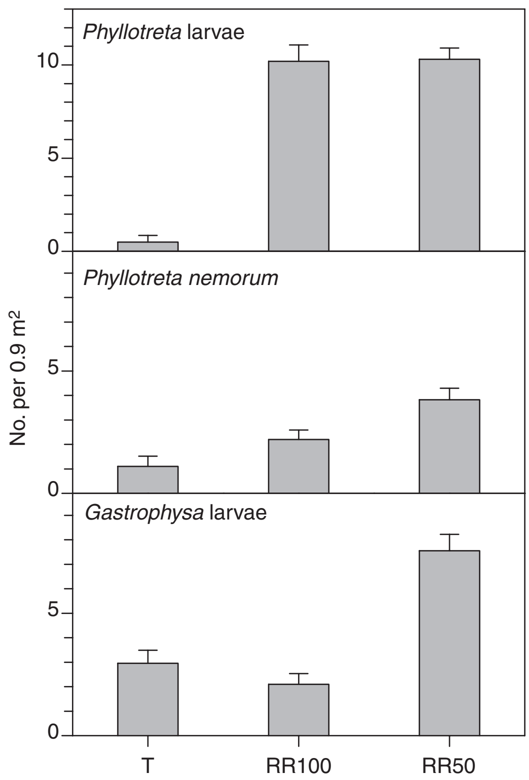


Figure 3. Density of *Gastrophysa polygoni* larvae, flea beetle larvae and *Phyllotreta nemorum* in the traditional (T) fodder beet plot, RR100 plot and RR50 plot at Skejby. Bars indicate standard error of means.

3.2.7 Coleoptera

There is no clear pattern of density in relation to treatment for any of the families except Chrysomelidae at Skejby. The herbivorous beetles often respond significantly to changes in weed density and species composition (Reddersen 1997). At Skejby a large number of knotgrass beetle larvae (*Gatrophysa polygoni*) (Figure 3 and colour plates p. 19), flea beetle larvae (Figure 3), mangold and sugar beet flea beetle (*Chaetocnema concinna*), *Phyllotreta nemorum* (Figure 3), *P. undulata* and *P. nigripes* were found. We have never sampled such high numbers of flea beetle larvae before because the larvae are leaf and root miners. The high numbers sampled at Skejby probably was a consequence of the Roundup application three weeks prior to D-vac sampling, which killed most of the weeds, forcing the larvae to leave their host plant. The weeds were brown and dry when the site was visited.

The chrysomelid fauna reflects the weed flora: The knotgrass beetle lives on knotgrass (*Polygonum aviculare*) and black bindweed (*P. convolvulus*). The mangold and sugarbeet flea beetle lives on species of Polygonacea and sugar beet. At Skejby it was only found in the T- and RR50% plot. The importance of the weed flora to this species is not clear from our results. The Phyllotreta-species identified all have cruciferous host plants. *Polygonum*-species and the cruciferous *Sinapis arvense* were among the predominant weed species in all plots at Skejby (Table 3 and 4). The density of *S. arvense* and *P. convolvulus* was highest in the RR50 plot followed by the RR100 plot and the lowest density was found in the T plot. This pattern was also seen for adult *P. nemorum*, but not among the *Phyllotreta* -larvae or the *Gastro-*

physa -larvae (Fig 3). The density of *P. aviculare* was lowest in the RR100 plot (Table 4).

Only a few pygmy mangold beetles (*Atomaria linearis*) were found in D-vac samples and none were found by the extension service (Pedersen 2000). The beet carrion beetle (*Aclypea opaca*) was only found very scarcely by the D-vac sampler. The Advisory Centre registered the beet carrion beetle on up to 10% of the beet plants. The occurrence was independent of treatment and did not pose a problem.

Many beetle species could be expected to respond to weed density due to changes in microclimate and prey density. Such responses have been reported for carabids and staphylinids (Speight and Lawton 1976; Powell et al. 1985; Chiverton and Sotherton 1991). In D-vac samples mainly small carabids are collected as many of the larger species are to heavy to be efficiently registered. At the majority of field sites the density of most beetle families was too low to allow for sound comparisons of densities between treatments.

3.2.8 Aranea

The spiders were more abundant in RR plots at several field sites, i.e. Foulum, Egtved, Mors, and Skejby. We assume that a more favourable microclimate and more complex habitat structure in weedy plots have caused an aggregation of spiders (Rypstra et al. 1999). Also the density of certain prey items may influence the distribution of spiders.

Table 7. Total numbers of various arthropod groups collected by D-vac at six field sites. At each site three treatments were represented: Traditional, RR100 and RR50. Numbers followed by the same letter is not different at the 5% level (Student T-test on log(x+1)).

Site	Date (MM-DD)	Treat-ment	Colem-bola	Heterop-tera	Auchenor-rhyncha	Aphidae	Thysan-optera	Lepi-doptera	Diptera	Apocrita	Cara-bidae	Staphy-linidae	Elateri-dae	Chrysome-lidae	Curculio-nidae	Other Coleoptera	Acarina	Aranea	Sum
Mors	06-26	T	6.310	2	0	1.226 a	14 a	4	703 a	66	24	324 a	3	0	1	30	214 a	92 a	9.013
Mors	06-26	100	6.880	3	3	351 b	4 b	2	346 b	62	25	156 b	0	0	3	11	417 b	103 a	8.366
Mors	06-26	50	8.770	3	11	1.000 c	8 b	7	641 ab	135	45	208 b	4	0	8	25	433 b	143 b	11.441
Varde	06-28	T	22 a	0	0	3	1	3	49 a	2	0	11 a	1	0	1	0	6 a	1	100 a
Varde	06-28	100	334 b	5	1	5	0	2	115 b	14	11	35 ab	2	0	0	36	67 b	13	640 a
Varde	06-28	50	36 a	1	0	5	5	1	77 c	8	3	30 b	2	0	0	2	11 ab	3	184 a
Skejby	06-09	T	6.970 a	12	1	48 a	2	4	98 a	12 a	10 a	6 a	0	87 a	1	4	28	70 a	7.353
Skejby	06-09	100	11.550 ab	26	3	133 a	1	20	72 a	25 a	37 b	13 a	0	154 b	1	9	27	134 ab	12.205
Skejby	06-09	50	20.250 b	59	4	214 b	1	14	50 a	55 a	24 a	13 a	3	225 c	0	20	30	157 b	21.119
Foulum	06-27	T	2.425	5	5	69 a	10	0	149 a	20 a	6	31 a	0	0	0	1	8 a	15 a	2.744
Foulum	06-27	100	2.682	1	4	251 b	15	4	174 a	29 a	3	59 a	1	1	2	11	30 b	48 b	3.315
Egtved	06-17	T	56 a	0	2	16 a	11 a	0	21 a	10 a	1	0	3	0	0	2	7	1 a	130
Egtved	06-17	100	688 b	1	11	369 b	551 b	1	170 b	74 b	0	8	5	0	0	4	17	19 b	1.918
Egtved	06-17	50	108 c	3	9	222 b	298 b	1	172 b	81 b	1	4	3	0	0	2	12	10 b	926
Svenstrup	06-21	T	10	0	4	24 a	1	0	31 ab	16	0	0	0	0	1	0	2	0	89
Svenstrup	06-21	100	8	0	2	10 ab	1	1	43 a	13	1	0	0	0	0	2	2	0	83
Svenstrup	06-21	50	4	0	1	5 b	0	3	15 b	5	0	0	0	0	0	0	3	0	36
Sum			67.103	121	61	3.951	923	67	2.926	627	191	898	27	467	18	159	1314	809	79.662

4 General discussion

The weed survey revealed that on average the weed flora in RR plots is richer in terms of plant density, biomass and species than the T plots when measured in June. On one site, the biomass of weeds was almost significantly higher in the T plot. Here the herbicide treatment was carried out at the same time and as a result of the superior efficacy of Roundup Ready, the weed plants were smaller in the RR100 plot. The weed counts made by the Advisory Consultants (Pedersen 2000) also show higher densities of weed plants in the T plot at that site. Often, the plant density, biomass and the number of species were greater at the RR50 plots compared with the RR100 plots, but not always significantly, and sometimes the weed measures were similar for the two treatments. Thus, the impact of reducing the dosage is not the same on all field sites. This is what could be expected, as the weed size and species composition was not the same on different sites and the circumstances during and after spraying differed between sites.

The duration of the difference in the weed flora between plots with traditional beets and RR beets is reflected in the weed survey carried out by the advisory consultants (data available at the web site). They counted number of weed plants three times on five of the sites: before the traditional herbicide treatment, before first Roundup treatment and two weeks after second Roundup treatment. Their data for early-to-midsummer are consistent with the data presented here. After the second Roundup treatment, the increased number of weeds in RR plots compared to traditionally grown beets in early summer was reduced, vanished or became negative during the growing season. The differences between RR plots and T plots can be explained by the delayed treatment in RR plots. Furthermore, some of the herbicides used in T plots are applied very early because they are taken up via the roots of the emerging seedlings. Glyphosate acts through the green parts of the plants. The second Roundup treatment reduced the difference or turned the RR plot less weedy than the T plot. These circumstances explain why more weeds were seen in the RR plot than in the T plots in June, but not later in the season.

The arthropod fauna is not expected to be affected directly by the Roundup treatment or by the Roundup Ready fodder beet, Simplex, it self. Such a difference would imply a toxic effect of glyphosate on the fauna and a change in the host plant quality of the beet, respectively. Roundup is rarely found to have any toxic impact on arthropods (Giesy et al. 2000). Considering the low dosages used in the present study we find it unlikely that any significant toxic effect has occurred. Differences in host plant quality of the beets between the plots would only have very limited importance in the present study as few insects actually were feeding on beet. The main impact on the fauna of introducing RR-beets is expected to stem from differences in weed growth and species composition of the weeds due to the different herbicide regime associated with RR-beets.

The response of the arthropod fauna to the richer weed flora in the RR plots in June differed between sites (Table 7). In some fields the parasitic wasps were more numerous in the weedy plots, in other fields the dipterans, aphids, thrips, staphylinids, etc. Two main types of responses are believed to have occurred.

Firstly, the herbivorous insect fauna (plant bugs, aphids, thrips, butterflies, leaf beetles) may benefit from the higher biomass and number of host species in weedy plots. Examples are the herbivorous beetles found very numerously at the Skejby site. The knotgrass beetle is very sensitive to insecticide spraying (Kjær et al. 1998, Jagers op Akkerhuis et al. 1999), and probably suffers a great risk of local extinction in fields sprayed with insecticide. It also has a poor dispersal power in terms of colonising host plant patches. That may explain why this species is only found on one site, despite the presence of its host plants at all sites. More surprising to us is the poor immigration of beetles living on cruciferous plants, because many of these species like the pollen beetle (*Meligethes aeneus*), have very strong dispersal powers and are known to find host plants across the country. The weather conditions during the spring and early summer may have influenced the migration and phenology of these species. It is possible that application of the RR-herbicide regime over several years may increase the response of the herbivorous insect fauna because slowly immigrating species like the knotgrass beetle are more likely to find the host plants in time. This is, however, uncertain and depends on insecticide application frequency and whether the species has sufficient time to reproduce during one season.

Secondly, a number of arthropods from other feeding guilds (parasitic wasps, staphylinids, dipterans, carabids, and spiders) apparently are attracted to the more protected microclimate in weedy plots (references above). The structure of the habitat may also play a role, particularly for the web-building spiders. Many of these species are predators and may also benefit from the higher density of potential prey in these spots.

For many birds, such as the skylark (*Alauda arvensis*) (Elmegaard et al. 1999) June is an important month in terms of breeding activity and the availability of arthropod food items. Where the arthropod fauna exploits a richer weed flora it is very likely that many farmland birds will benefit as well (Moreby 1997). Therefore a replacement of traditional beets with RR beets will elevate the biodiversity potential early in the season, whereas there will probably be no beneficial effect when the Roundup treatment is completed. The potential for a greater biodiversity can be effectuated if the first Roundup application is delayed compared to conventional herbicide regimes. If the weed densities become to high, the beets will suffer from the competition and the yield is reduced (Dewar et al. 2000). In the present study the second Roundup Ready application may have been applied too late to prevent a yield loss in some of the fields. The late spraying may be due to the bad weather conditions, but also the lack of economic incentive as the crop had to be destroyed, may have played a role. Due to the efficacy of glyphosate as weed controlling agent compared to the conventional herbicide regimes, it is, however, possible to give more "room" to the wild plants in the beet field. In many cases the dosage can be reduced to further benefit the flora and fauna. It should be kept in mind that any benefit from RR-beet cultivation on arthropods will be severely reduced or disappear if and when insecticides are used. However, the need for insecticide sprayings seems to be reduced in fields with more weed (Dewar et al. 2000).

5 References

Baggen, L.R. & Gurr, G.M., 1998. The influence of food on Copidosoma koehleri (Hymenoptera : Encyrtidae), and the use of flowering plants as a habitat management tool to enhance biological control of potato moth, Phthorimaea operculella (Lepidoptera : Gelechiidae). Biological Control, 11(1): 9-17.

Bruus Pedersen, M. & Strandberg, B., 2000. Roundup-tolerante foderroer kan give mere ukrudt og dermed måske grundlag for flere insekter i markerne [Roundup-tolerant fodder beets can result in more weeds which may benefit the insects]. Danish Forest and Nature Agency. http://www.sns.dk/natur/bioteknologi/roundup_art.htm

Buckelew, L.D., Pedigo, L.P., Mero, H.M., Owen, M.D.K. & Tylka, G.L., 2000. Effects of Weed Management Systems on Canopy Insects in Herbicide-Resistant Soybeans. Journal of Economic Entomology, 93(5): 1437-1443.

Buckmann, H., Petersen, J., Schlinker, G. & Marlander, B., 2000. Weed control in genetically modified sugar beet - two year experiences of a field trial series in Germany. Zeitschrift Fur Pflanzenkrankheiten Und Pflanzenschutz-Journal of Plant Diseases and Protection: 353-362.

Chiverton, P.A. & Sotherton, N.W., 1991. The effects on beneficial arthropods of the exclusion of herbicides from cereal crop edges. Journal of Applied Ecology, 28: 1027-1039.

Cowgill, S.E., Wratten, S.D. & Sotherton, N.W., 1993. The Effect of Weeds on the Numbers of Hoverfly (Diptera, Syrphidae) Adults and the Distribution and Composition of Their Eggs in Winter Wheat. Annals of Applied Biology, 123(3): 499-515.

Dewar, A.M., Haylock, L.A., Bean, K.M. & May, M.J., 2000. Delayed control of weeds in glyphosate-tolerant sugar beet and the consequences on aphid infestation and yield. Pest Management Science, 56(4): 345-350.

Dietrick, E.J., 1961. An improved backpack motorised fan for suction sampling of insect populations. Journal of Economic Entomology, 54(2): 394-395.

Elmegaard, N., Andersen, P.N., Odderskær, P. & Prang, A., 1999. Food supply and breeding activity of Skylarks in fields with different pesticide treatment. In: N.J. Adams and R.H. Slotow (Editors), 22 International Ornithological Congress. Johannesburg: BirdLife South Africa, Durban, pp. 1058-1069.

Giesy, J.P., Dobson, S. & Solomon, K.R., 2000. Ecotoxicological Risk Assessment for Roundup Herbicide. Review of Environmnetal Contamination and Toxicology, 167: 35-120.

Green, R.E., 1984. The feeding ecology and survival of partridge chicks (Alectoris rufa and Perdix perdix) on arable farmland in East Anglia. Journal of Applied Ecology, 21: 817-830.

Hald, A.B. & Elmegaard, N., 1989. Unsprayed marginal zones in cereals. Some results and prospects concerning nature conservation and agronomy, 6th Danish Plant Protection Conference, pp. 40-50.

Hansen, K.D.F., 1991. Dansk Feltflora [Key to the Danish Flora]. Gyldendal, Copenhagen.

Hill, D.A., 1985. The Feeding Ecology and Survival of Pheasant Chiks on Arable farmland. Journal of applied Ecology, 22: 645-654.

Jagers op Akkerhuis, G.J.A.M., Damgaard, C., Kjær, C. & Elmegaard, N., 1999. Comparison of the toxicity of dimethoate and cypermethrin in the laboratory and in the field when applying the same bioassay. Environmental Toxicology and Chemistry, 18(10): 2379-2385.

Kjær, C., Elmegaard, N., Axelsen, J.A., Andersen, P.N.& Seidelin, N., 1998. The Impact of Phenology, Exposure and Instar Susceptibility On Insecticide Effects On a Chrysomelid Beetle Population. Pesticide Science, 52(4): 361-371.

Madsen, K.H. & Jensen, J.E., 1995. Weed control in glyphosate-tolerant sugarbeet (Beta vulgaris L.). Weed Research, 35: 105-111.

Moreby, S.J., 1997. The effects of herbicide use within cereal headlands on the availability of food for arable birds, Brighton Crop Protection Conference, Brighton, pp. 1197-1202.

Pedersen, C.Å. (Editor), 2000. Oversigt over Landsforsøgene. Forsøg og undersøgelser i de landøkonomiske foreninger. Landskontoret for Planteavl, Landbrugets Rådgivningscenter, Århus.

Powell, W., Dean, G.J. & Dewar, A., 1985. The influence of weeds on polyphagous arthropod predators in winter wheat. Crop Protection, 4(3): 298-312.

Purvis, G. & Curry, J.P., 1984. The influence of weeds and farmyard manure on the activity of Carabidae and other ground-dwelling arthropods in a sugar beet crop. Journal of Applied Ecology, 21: 271-283.

Reddersen, J., 1997. The Arthropod Fauna of Organic Versus Conventional Cereal Fields in Denmark. Biological Agriculture & Horticulture, 15: 201-211.

Reddersen, J., Elmholt, S. & Holm, S., 1998. Indirect Effects of Fungicide and Herbicides on Arthropods. 44, Danish Environmental Protection Agency, Copenhagen.

Rypstra, A.L., Carter, P.E., Balfour, R.A. & Marshall, S.D., 1999. Architectural features of agricultural habitats and their impact on the spider inhabitants. Journal of Arachnology, 27(1): 371-377.

Speight, M.R. & Lawton, J.H., 1976. The influence of Weed-Cover on the Mortality Imposed on Artificial Prey by Predatory Ground Beetles in Cereal Fields. Oecologia, 23: 211-223.

Stoate, C., Moreby, S.J. & Szczur, J., 1998. Breeding ecology of farmland Yellowhammers Emberiza citrinella. Bird Study, 45: 109-121

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Denmark
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DK-8600 Silkeborg
Denmark
Tel: +45 89 20 14 00
Fax: +45 89 20 14 14

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Grenåvej 12-14, Kalø
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Denmark
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