



Final Report

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The Directorate for Food, Fisheries and Agro Business
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1. Research program

Research in organic farming 2000-2005 (DARCOF II)

2. Project title and number

Management of perennial weed species in organic farming (MPW) FØJOII
Number I.8

3. Head of project

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4. Participating institutes

Danish Institute of Agricultural Sciences (DIAS)

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6. Project period (month, year)

Start of project: 2000
End of project: 2004

Slutrapporten sendes elektronisk til Forskningscenter for Økologisk Jordbrug
foejo@agrsci.dk senest 3 måneder efter projektets afslutning.

Slutrapporten vedlægges et dansk resumé.

7. Final report

A. Project summary

Introduction

Research on perennial weed species in organic cropping systems is quite limited, although these species are becoming an increasing problem, especially on dairy farms with high percentage of clover grass and in stockless cropping systems where cereals are dominating. Common mechanical control methods against annual weeds, such as weed harrowing and hoeing, only have limited effect on perennials because they only cause little damage to the root systems. Most perennials will easily regenerate from their roots and rhizomes that normally are placed deeper in the soil than the working depth of the implements.

Research on weed ecology and population dynamics of perennials will augment the current knowledge, and in combination with strategic experiments with non-chemical weed control methods, it will contribute to the development of novel and preventive weed management of perennials. This project focuses on *Cirsium arvense* (L.) Scop. and *Elymus repens* (L.) Gould because they have been identified as the main perennial weed species in organic crop rotations in Denmark both in terms of incidence and economic importance.

State of the art

Research on competition of *C. arvense* is limited and only carried out in conventional farming systems. However, different length and vertical placement of root fragments in the soil are known to have significant effect on the vegetative regeneration. Also, suppression of *C. arvense* can be significant when thistle-stems are cut in a crop that regrows quickly and possesses a strong suppressive ability. However, there have been no attempts to include this information into more strategic research aiming at merging the benefits of root and stem cutting with the suppressing ability of a plant cover, e.g. crop or catch crop.

Knowledge about the temporal and spatial dispersal of *C. arvense* patches can improve the understanding of the population dynamics of the species and lead to better management systems. So far, only few studies on the spatial and temporal processes of spread and establishment of *C. arvense* have been made in the USA and the Netherlands. No descriptive study has ever been made for *C. arvense* under Danish climate conditions. This information seems valuable, not only for comparison with findings at other locations, but also valuable to Danish farmers in general.

Deep soil tillage conducted in the post-harvest period might be an efficient method of controlling *C. arvense*. The effect will, however, depend on the timing and length of the tillage period and the presence of dormancy in *C. arvense*. Yet, post-harvest tillage is often omitted in organic farming because plants mostly cover the soil in that period, e.g. catch/cover crop, autumn-sown crops or perennial crops. Crop cover in the autumn is desirable in organic farming, owing to the need for retaining nitrogen in the cropping systems, and consequently opportunities for post-harvest tillage become limited.

Preliminary results from the ongoing crop rotation experiments in DARCOF I have shown surprisingly lower densities of *C. arvense* in the crop-rotation systems where catch crops are grown, even in the absence of post-harvest tillage. However, the hypothesis that catch crops can suppress *C. arvense* infestations needs to be studied more thoroughly. If the hypothesis is valid, a preventive strategy using catch crops can be developed.

The main control method for *E. repens* in organic cropping is stubble cultivation between harvest and ploughing, the post-harvest period. However, this method becomes more difficult to conduct because organic growers prefer to keep the soil covered with plants in most of the post-harvest period to retain nutrients in the upper soil horizons, as mentioned for *C. arvensis*. Experiments have indicated that a short period of intensive post-harvest cultivation of the soil, followed by the growing of a competitive catch crop and finally deep ploughing in the autumn can reduce *E. repens* infestations, even in crop rotations dominated by cereals. Thus, it seems that a short duration of post-harvest soil cultivation, followed by catch crop growing, could be combined to suppress *E. repens* infestations to tolerable levels and still meet the need for nutrient retention. However, several aspects need to be further studied in order to clarify the potential of this hypothesis. Aspects such as: the intensity of post-harvest soil cultivation needed for rhizome disintegration, the period soil cultivation has to take place, the competitiveness of different catch crops to suppress shoot growth and the influence of final deep burial of exhausted rhizome pieces. More information on these aspects could lead to better solutions for practical management of *E. repens*.

Work content

This project is focussing on important aspects of the ecology of *C. arvensis*: competitive ability against different crops; spread and dispersal of thistle patches; and impact of stem and root cutting on the regenerative capacity of *C. arvensis*. Research on these aspects gives additional valuable information about the economic importance of *C. arvensis* infestations in organic crops, the suppressive ability of crops and catch crops, the development of thistle patches in different crop rotations and the perspectives for stem or root cutting tactics against *C. arvensis*. In addition, this improves the fundamental knowledge of making more precise and effective management strategies against thistles. Regarding *E. repens*, an integrated control strategy, aiming at combining rhizome disintegration by soil cultivation in the post-harvest period with later catch crop growing to suppress shoot growth, was studied on a sandy soil. Results from these experiments were expected to add new angles to the management of *E. repens*.

The project is organised in four work packages as listed in Table A.1

Table A.1: Work package list (from application)

| No. | Work package title | Participants* | Budget (1,000 DKK) | Start | End | Deliverable No: |
|-----|--|-------------------|-----------------------|-------|------|---------------------------|
| 1 | The regenerative capacity and competitive ability of <i>C. arvensis</i> following different periods of shoot growth inhibition in spring | <u>ENG</u> BME | 592 | 2000 | 2004 | WP1D1- WP1D2- WP1D3 |
| 2 | The regenerative capacity and competitive ability of <i>C. arvensis</i> following different periods of shoot growth inhibition in late summer and autumn | <u>ENG</u> BME | 475 | 2000 | 2004 | WP2D1- WP2D2- WP2D3 |
| 3 | Annual dispersal rate of <i>C. arvensis</i> in a 4-year period under the influence of different levels of competition | <u>ENG</u> BME | 506 | 2000 | 2004 | WP3D1- WP3D2- WP3D3 |
| 4 | Integrated control of <i>E. repens</i> | <u>BME</u> ENG | 777 | 2001 | 2004 | WP4D1- WP4D2- WP4D3 |

* Responsible participants are underlined

Short description of each work package.

All experiments in the four work packages (WP 1-4) are conducted as randomised factorial block experiments on:

- 1) an organic field (sandy loam) at the Technical College in Slagelse for WP 1 and 2, heavily infested with *C. arvensis* and organically cropped for the last 15 years.
- 2) a conventional field (sandy loam) at Research Centre Flakkebjerg for WP3, with no presence of *C. arvensis*. The experimental area is cropped according to organic principles in the experimental period.
- 3) an organic field (sand) at Jyndevad Research Station under DIAS for WP 4.

WP1

The major objective is to study the regenerative capacity and competitive ability of *C. arvensis* following different periods of shoot growth inhibition by repeated hoeing in red clover or mowing in a grass clover mixture in spring and early summer.

Four field experiments were established in spring barley, two experiments with and without undersown red clover (established in 2001 and 2002) and two experiments with and without undersown grass clover mixture (established in 2000 and 2001). Shoot growth of *C. arvensis* was inhibited by hoeing in a row-sown red clover and by mowing in grass clover mixture: the hoeing and the mowing took place each time the thistle shoots were at their 3-6 leaves stage, and the treatments were stopped either at e.g. 1 June, 1 July and 1 August. These stoppages of thistle growth were done in plots with and without the clover crop to study the effect of crop suppression against the thistle in combination with the growth inhibition (the differences in length of the treatment period) by hoeing or mowing. The regenerative capacity and competitive ability of thistle were assessed in a subsequent spring barley crop as a result of treatments of different periods of growth inhibition in plots with and without red clover or grass clover mixture.

As a supplement to the experiment with repeated hoeing and red clover, an experiment with repeated hoeing and spring barley undersown with white clover was established in 2001 and 2002, using the same hoeing strategy as in the red clover experiment.

WP2

The major objective was to study the regenerative capacity and competitive ability of *C. arvensis* following different periods of shoot growth inhibition by repeated post-harvest cultivations or repeated post-harvest mowing of an undersown catch crop after different harvest times of a whole crop.

Two experiments were established, one in 2001 and one in 2002. Two factors were investigated:

Factor 1. Catch/cover crop (grass-clover mixture) undersown in the whole crop (barley-pea mixture, 1:1), two levels:

- a. with
- b. without

Factor 2. Harvest time of the whole crop, three levels:

- a. 10 June (very early)
- b. 1 July (normal)
- c. 20 July (late normal)

The plots without undersown grass clover were repeatedly stubble-cultivated after harvest until 1 October while those with an undersown grass clover were mowed each time the

thistle shoots had developed two true leaves after harvest.

The thistle response to the two factors was investigated, as in WP1, in a subsequent spring barley crop the year after the treatments by assessing the thistle growth.

WP3

The major objective was to study the growth, spread and dispersion rate of thistle patches over a period of four years at two levels of crop competition.

Root fragments of *C. arvensis* were buried in the autumn 2000 after ploughing the experimental area. Shoot emergence from the fragments were arranged to take place at two levels of crop competition, one in spring barley and one in grass clover mowed regularly. The spatial distribution of shoot emergence was measured over time in a period of 4 years.

WP4

The major objective was to study and evaluate an integrated strategy based on mechanical disintegration of *E. repens* rhizomes followed by catch crop growing to control *E. repens* infestations.

Stands of *E. repens* were established in the spring of 2001 and 2002, respectively, to give two experiments (I and II) by sowing seeds of *E. repens* in a wide-spaced spring barley crop. In the autumn 2001/2002, aboveground vegetation was mowed and removed, and the experimental area was ploughed. Spring barley was then sown in the spring of 2002/2003, and just after harvest in August, the experimental area was divided into plots according to the experimental factors under consideration. They were:

Factor 1) mechanical disintegration of rhizomes, five levels:

- a. untreated
- b. disintegration and loosening by ploughing to only 10 cm soil depth
- c. strong disintegration by power-take-off driven (p.t.o.) rotary cultivation
- d. disintegration and loosening by stubble cultivation
- e. loosening and uprooting by a newly developed Danish implement, the "Kvik-Up", that is based on a cutting and digging tool element and a rotating tool element for uprooting.

Factor 2) catch crop growing, three levels:

- a. no catch crop
- b. mixture of fodder radish (*Raphanus sativus* L.) and westerwolds ryegrass (*Lolium multiflorum* Lam. var. *westervoldicum* Mansh.)
- c. mixture of red clover (*Trifolium pratense* L.) and winter vetch (*Vicia villosa* Roth)

Factor 3) timing of ploughing, two levels:

- a. late autumn
- b. spring.

E. repens responses to the treatments were assessed the following year, 2003/2004, in spring barley sown on the experimental area.

B. Objectives and expected achievements

The objective of the project was to augment the knowledge about crop-weed competition, population dynamics and mechanical control of the two main perennial weed species *Cirsium arvense* (L.) Scop. and *Elymus repens* (L.) Gould in organic farming. The knowledge can be integrated in weed management systems for these species, e.g.

- using catch crops to deplete and compete for nutrients, light and water
- strategic control of thistle patches
- hampering the growth and regenerative capacity by stem or root cutting tactics
- cultivation tactics to eradicate or weaken the regenerative capacity of roots and rhizomes.

C. Progress and results

C.1 Description (summary) of main results and conclusions

WP1

Repeated mowing

The two experiments focusing on effects of repeated mowing in combination with suppression induced by a grass/white clover mixture were successfully completed in 2002 (hereafter A1) and 2003 (hereafter A2), respectively. In both cases the use of the grass/white clover significantly lowered the biomass of *C. arvense* (fig. 1). In experiment A1, a linear regression fitted well to the data explaining 69% and 60% of the variation of aboveground *C. arvense* biomass, when mowed in the unsown stubble and in the grass/white clover mixture, respectively. Hence, the above-ground biomass was reduced from 275 g/m² in non-treated plots to 80 g/m² where mowing was carried out six times during the growing season. In plots with the combined treatment (mowing plus grass/white clover), the biomass was reduced from 170 g/m² to 30 g/m². In experiment A2, the suggested regression lines fitted significantly to the data from the unsown stubble only, explaining 32% of the variation. However, the maximum number of mowing, six, reduced the aboveground *C. arvense* biomass by 64% and 69% in unsown stubble and in grass/white clover mixture, when compared to no mowing (fig. 1). The lower initial population size in experiment A2 caused a relatively higher variation, and a power analysis showed that with the given number of replicates an interpretation suggesting no relation between mowing and biomass of *C. arvense* in the plots with grass/white clover could be erroneous.

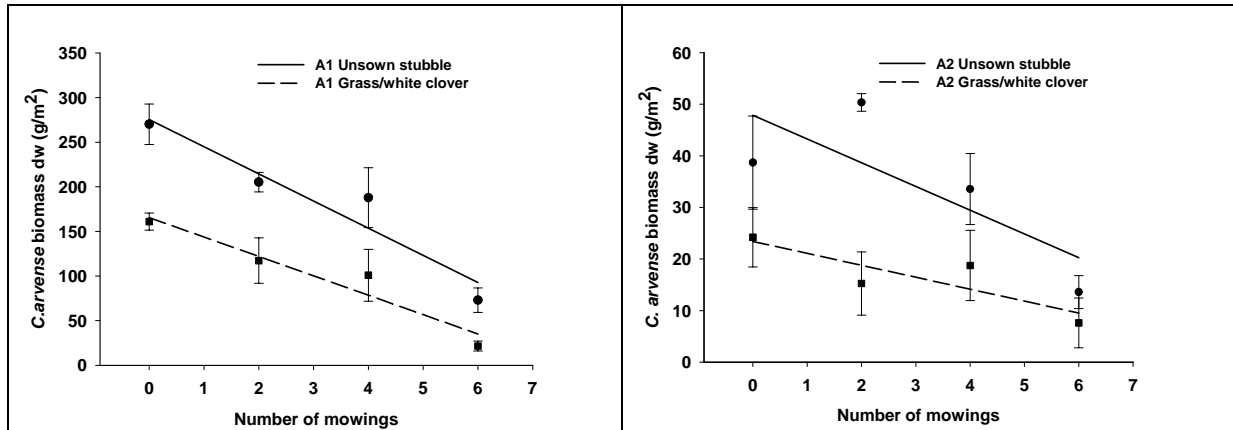


Fig. 1. Effects of repeated mowing and the use of a grass/white clover mixture on the aboveground biomass of *C. arvensis* in spring barley in the subsequent year.

In both experiments there were a good correlation between the aboveground biomass of *C. arvensis* and the grain yield (fig. 2), explaining 90% of the variation in grain yield. The relatively high regression coefficients in A2 indicate that *C. arvensis* had a stronger impact on yield here, even though the aboveground biomass was lower in these particular plots. However, a regression analysis of *C. arvensis* biomass and the number of spikes of *E. repens* counted in the same plots showed a strong positive correlation between biomass and number of spikes (fig. 3). Hence there was a coincidental appearance of *C. arvensis* and *E. repens*, which most likely explains the apparent paradox with a relatively higher impact of *C. arvensis* at a low degree of infestation.

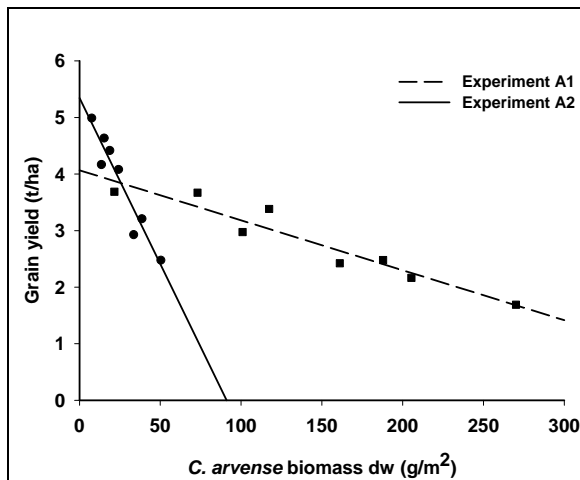


Fig. 2. Relationship between biomass of *C. arvensis* and grain yield of spring barley.

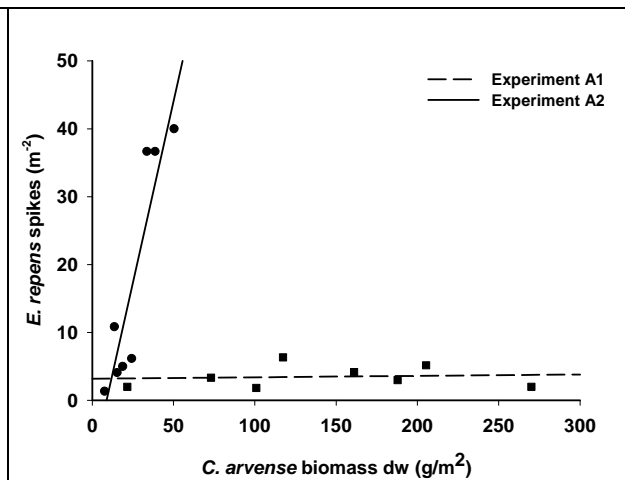


Fig. 3. Relationship between biomass of *C. arvensis* and number of spikes of *E. repens*.

Repeated hoeing

As above the experimental work on effects of repeated hoeing and the use of a suppressive crop, in this case red clover, was successfully completed in 2003 (hereafter B1) and in 2004 (hereafter B2). The use of red clover decreased the aboveground biomass of *C. arvensis* in experiment B1 only. However, the lack of effect in experiment B2 is most likely explained by a poor establishment of red clover in that particular experiment. Hence, rather than disregarding the positive effect of red clover with respect to increase the interspecific competition, our results emphasize the importance of a good establishment if an effect has to be achieved.

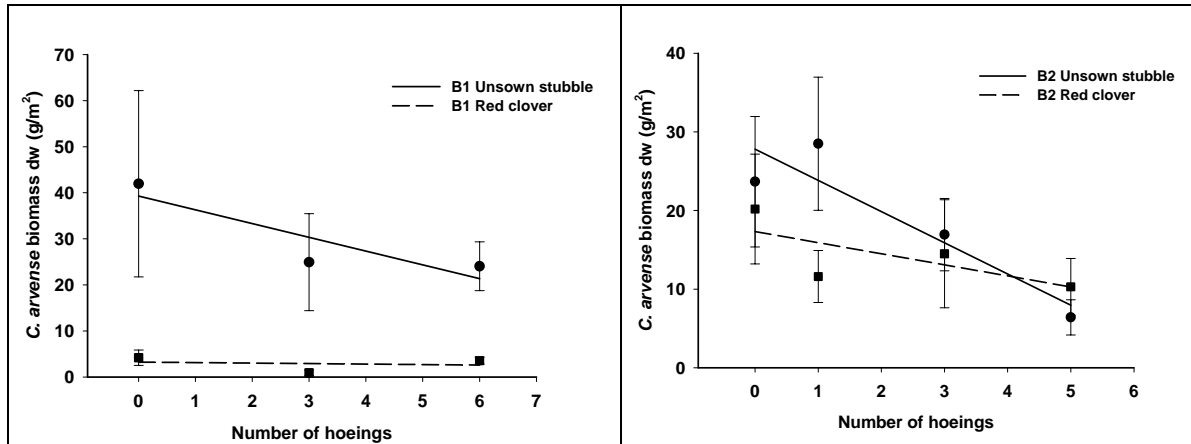


Fig. 4. Effects of repeated hoeing and the use of red clover mixture on the aboveground biomass of *C. arvense* the subsequent year.

With respect to the effect of hoeing, regression analyses showed that in one case only, the unsovn stubble in B2, the number of hoeing explained the differences in the aboveground biomass (fig. 4). However, a power analysis showed that the acceptance of no effect could be erroneous. This lack of power is most likely explained by the same reason as in experiment A2.

The difference in the degree of *C. arvense* infestation between plots in B1 and B2 was not as big as between A1 and A2. However, the impact of *C. arvense* on grain yield resembled that of experiment A, with *C. arvense* in one experiment, B1, having a greater impact than in B2 (fig. 5). As in experiment A, this difference is most likely explained by a coincidental infestation of *E. repens* (fig. 6).

The supplement experiment with hoeing in spring barley with undersown white clover showed in both years a linear relationship between the numbers of hoeing and the aboveground biomass of *C. arvense*. The experimental setup did not allow any analysis of competitive effect induced by catch crop (<http://orgprints.org/3944/>).

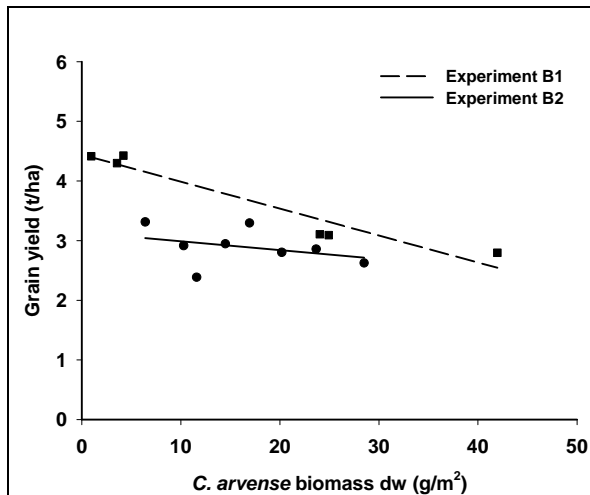


Fig. 5. Relationship between biomass of *C. arvense* and grain yield of spring barley

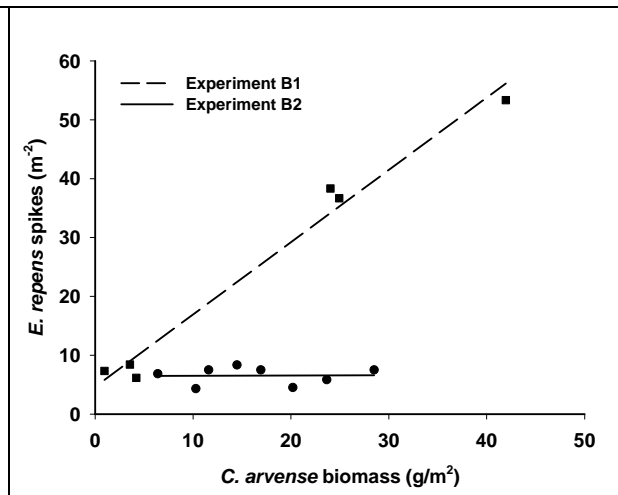


Fig. 6. Relationship between biomass of *C. arvense* and number of spikes of *E. repens*.

Perspectives

In general, there was a clear and unambiguous tendency that an increased number of shoot removals increased the control of *C. arvense* proportionally. Hence, within one growing season it is possible to achieve a high weeding effectiveness, particularly if the mechanical weeding is used in

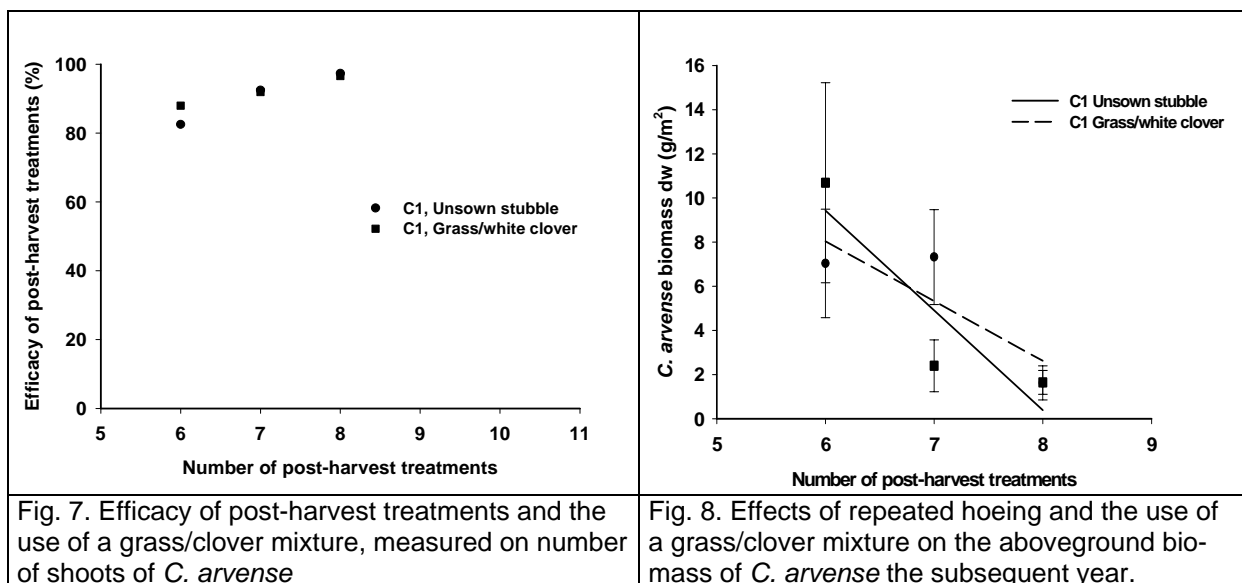
combination with a competitive crop. However, a considerable number of mowing and hoeing passes were necessary to achieve high weeding effectiveness. Such intensive and costly strategies may not find immediate acceptance among organic growers and future research should therefore consider how to minimize treatment intensity. It would thus be necessary to get a better understanding of the carbohydrate dynamics of *C. arvense* in response to growth disturbance by mowing and/or tillage under the influence of crop competition. Apart from studies in the field, this would require more basic studies involving chemical analyses of the source/sink allocation of carbohydrates, and hence, a better understanding of the mechanisms behind vulnerability in relation to time and phenology.

The absence of significance in B1 and partly B2 are probably due to low infestation levels of *C. arvense* ranging from 5-40 g m⁻² in the untreated plots. Such low infestations gave rise to considerable variation making it difficult on one hand to obtain significant regressions and on the other hand to confirm the H₀-hypothesis, as showed by a “power analysis”. This clearly reflects the difficulty of conducting organic field experiments with a perennial weed that ideally should occur in dense and uniform stands to provide statistically detectable results, although much effort was spent on finding an appropriate site for the present experiments.

WP2

Post-harvest treatments

The experimental work on effects of post-harvest treatments has been completed successfully in 2002 (hereafter C1) and 2003 (hereafter C2), respectively. The post-harvest treatments in C1 and C2 had a strong effect on the presence of *C. arvense*. Within one growing season only the number of aboveground shoots of *C. arvense* was reduced by more than 80% to just below 100% in plots treated from six to eight times in C1 (fig. 7) and from above 90% to just below 100% in plots treated six to ten times in C2 (fig. 9). The outcome of this impact corresponded to a biomass of *C. arvense* in the range of 2-10 g/m² and 1-6 g/m² in C1 and C2, respectively. In C1 there was a significant relationship between the number of post-harvest treatments and the biomass of *C. arvense*, whereas no such correlation was found in C2 (fig. 8 and 10).



In none of the C experiments was there any effect of using a competitive catch-crop, most likely

reflecting that the strong impact of the numerous post-harvest treatments alone out-levelled the catch-crop effect shown in experiments A and B. Likewise, the lack of relationship between the biomass of *C. arvensis* and the grain yield emphasize that even the lowest number of post-harvest treatment reduced the competition of *C. arvensis* to a non-measurable level (fig. 11).

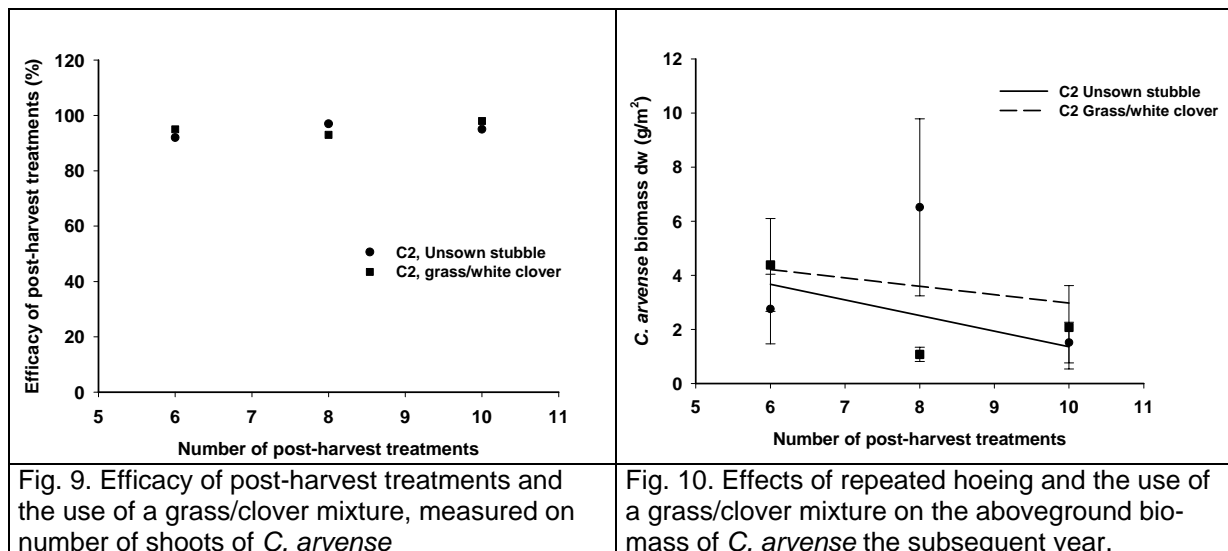


Fig. 9. Efficacy of post-harvest treatments and the use of a grass/clover mixture, measured on number of shoots of *C. arvensis*

Fig. 10. Effects of repeated hoeing and the use of a grass/clover mixture on the aboveground biomass of *C. arvensis* the subsequent year.

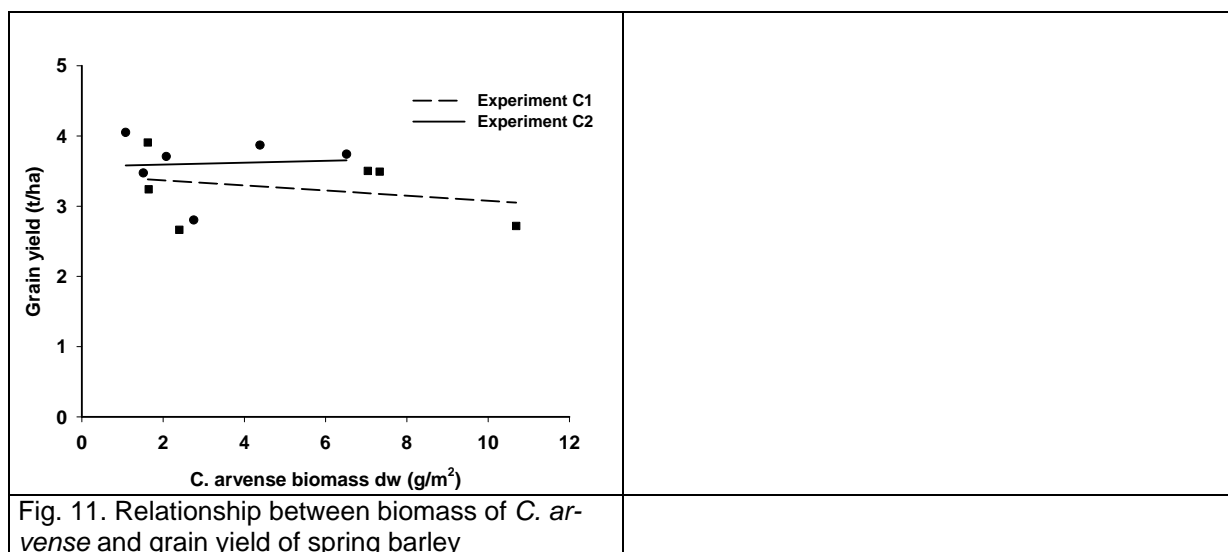


Fig. 11. Relationship between biomass of *C. arvensis* and grain yield of spring barley

Perspectives

As it was the case in experiments A and B, the used weeding strategies in the C experiments had a strong effect on the growth of *C. arvensis*, most likely reducing the populations to a level beyond any notable competitive interference with the crop. In fact, it seems that post-harvest treatments made dispensable the use of a competitive catch crop. At the time the experiments were initiated, it was expected that a spring-summer campaign would be more effective as opposed to a post-harvest campaign carried out in the summer-autumn. However, new studies confirm the present results and suggest that post-harvest treatments may be an alternative worth considering. Post-harvest control against *C. arvensis* appears easier to conduct as opposed to the spring-summer period where dense crop stands may easily obstruct machinery-based control options, simply causing too much crop damage. However, also with this type of weeding strategy it is necessary to

consider how to minimize the treatment intensity in order to ensure the operational applicability in practice. Also repeated stubble cultivation is controversial in organic cropping due to the desire of having the soil plant covered most of the year, which mostly favours the use of a mowing strategy rather than a tillage based strategy.

WP3

As mentioned in the midterm status report 2003, the growth of belowground *C. arvensis* was higher than expected. For this reason it has been impossible to relate the aboveground shoots to the buried root fragments from which they originated. Hence, treatment-mediated differences in the spatial distribution have not been assessable.

WP4

Mechanical disintegration (factor 1)

Mechanical disintegration in the stubble (factor 1) was successfully conducted in both experiments. However, only a limited fraction of the rhizomes were laid bare on the soil surface with stubble tine cultivation and the Kvik-Up showing the strongest ability to uproot the rhizomes (fig. 12).

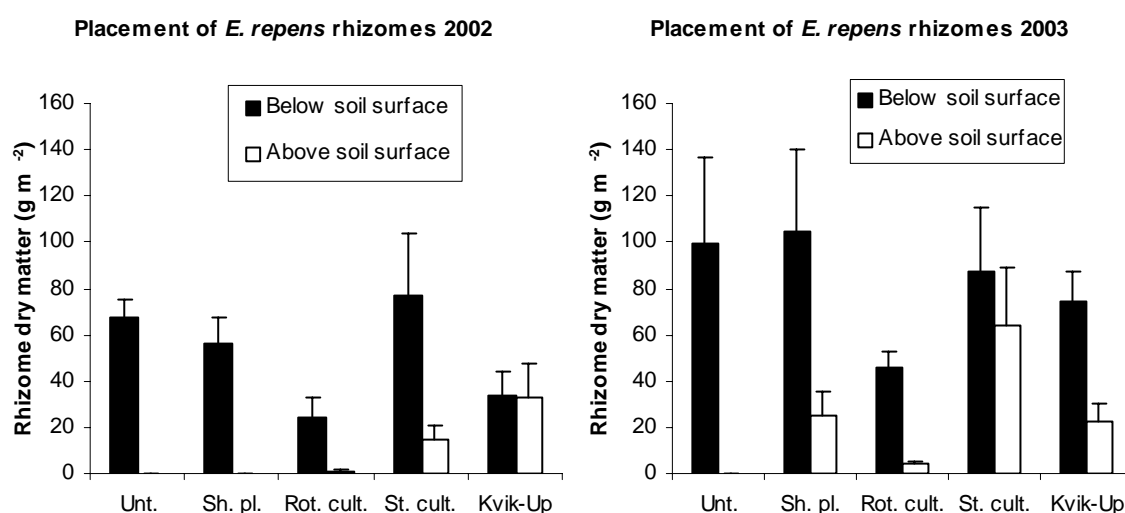


Fig. 12. Placement of rhizome dry matter after mechanical disintegration and uprooting of *E. repens* rhizomes. Unt = untreated, Sh. pl. = shallow ploughing, Rot. cult. = p.t.o.-driven rotary cultivation, St. cult. = stubble tine cultivation, Kvik-Up = the 'Kvik-Up' harrow. Vertical bars are standard errors.

Power-take-off driven rotary cultivation disintegrated the rhizomes most strongly reaching an average rhizome length of 14 cm, while the other treatments reached a length of 30 cm.

Catch crop growing (factor 2)

The weather was generally dry and warm in the post harvest periods of 2002 and 2003 resulting in poor catch crop establishment. Also subsequent growth of catch crop, *E. repens* and other weeds during the autumn was affected by the dry weather, and total aboveground plant biomass (dry matter) was only in the range of 30-100 g m⁻², corresponding to 0.3-1 t ha⁻¹, by the beginning of November. In spite of that, the tillage caused by shallow ploughing and rotary cultivation gave a significantly better catch crop establishment and growth with no difference between the

radish/ryegrass mixture and the clover/vetch mixture than the other mechanical treatments causing tillage. Weed growth in 2002 was significantly lower in the radish/rye grass mixture than in the other catch crop or when no catch crop was present. However, there was no difference in the suppressive ability against weeds in the autumn 2003.

E. repens responses assessed the following year, 2003/2004

Results from the two years' experiments assessed in spring barley in the following year varied considerably. None of the three factors had affected *E. repens* in the experiment ended in 2004 because of wet and cold weather conditions during most of the summer 2004, presumably promoting *E. repens* growth to an extent where the effects of the previous year's treatments were eliminated. However, effects were evident in the experiment ended in 2003 where p.t.o.-driven rotary cultivation gave the highest growth reduction compared to untreated (fig. 13A), but compared to the infestation level prior to starting the strategy, the reduction was only roughly 40%.

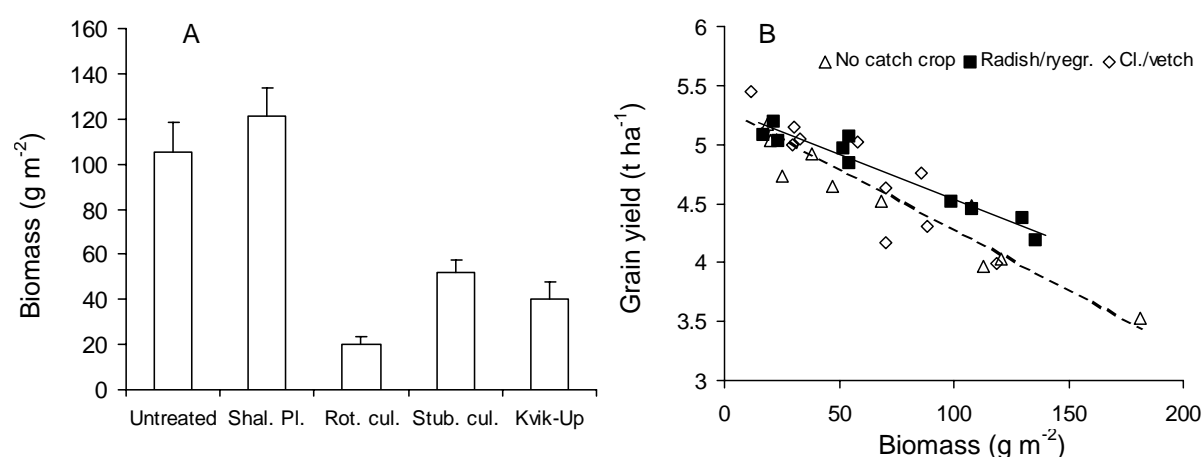


Fig. 13. A: Effects on aboveground *E. repens* biomass assessed close to barley harvest following previous year's mechanical treatments (factor 1) in experiment I. B: Regression analyses of spring barley yield related to *E. repens* biomass in the year after conducting treatment 1-5 under factor 1 in expt I. (---) is no catch crop and the clover/vetch mixture, and (—) is the radish/ryegrass mixture.

The radish/rye grass mixture, which suppressed weed growth most in the autumn 2002, also appeared to have affected the crop's ability to compete with *E. repens* in the subsequent year as shown in Fig. 13B where barley grain yield is related to the amount of *E. repens* biomass that followed the treatments (1-5) under factor 1. The radish/ryegrass mixture had strengthened crop growth more than no catch crop and the clover/vetch mixture, probably by providing the crop with more nutrients as a result of better nutrient uptake during the post-harvest period and a subsequent better release of nutrients after incorporation into the soil. Timing of ploughing (factor 3) had generally no effect.

Perspectives

Other cognate Danish investigations undertaken by the Danish Agricultural Advisory Service showed very high and consistent reductions of *E. repens* infestations, leading to 91-99% efficacy compared to the infestation level prior to starting the treatments. Catch crop growing in late summer and autumn was preceded by a mid-summer fallow period lasting 4-6 weeks, where repeated soil cultivations were conducted to fragment, weaken and desiccate the rhizomes. This strategy was even more effective than common *E. repens* control with repeated stubble cultivations in the post-harvest period. The mid-summer fallow cultivation period gave a much stronger weakening and desiccation of rhizomes than in the short-term mechanical treatment in the pre-

sent study. Probably the treatments in this investigation would have shown more marked effects, if catch crop establishment and growth had been more successful.

However, the strategy with a mid-summer fallow period with intensive cultivation may lead to undesirable nutrient loss on sandy soils through leaching, which subsequently may give rise to crops that are less competitive against *E. repens*. In addition, the grower will have to desist from growing a full-season cash crop. These aspects should be counterbalanced against the urgency for *E. repens* control and other possible control options. The present study with a short duration of post-harvest mechanical disintegration appears to be most relevant for low infestation levels of *E. repens*, mainly aimed at maintaining infestations at controllable levels, whereas an intensive mid-summer cultivation period would be more appropriate where infestations have become large and need to be reduced considerably and quickly in order to preserve yield of future crops.

General comments on WP1-4

The project has certainly increased our experience of the establishment and conduction of field experiments with these difficult weed species. Especially *C. arvensis* is difficult to handle because of its heterogeneous and patchy occurrence in colonies. However, we have achieved valuable knowledge about raising *C. arvensis* under semi-field conditions and which aspects we need to pay particular attention to when making field experiments. We consider ourselves to be much more skilled and experienced for future studies.

In addition, we have identified new gaps in knowledge and made suggestions on new management strategies relevant for future research. This has been more comprehensively reviewed in the application *Effective control of perennial weeds and intra-row weeds in organic cropping through novel technology and new management strategies*, recently submitted for DARCOF III.

C.2 Fulfilment of deliverables and milestones

(To be completed for each work package)

| WP 1. The regenerative capacity and competitive ability of <i>C. arvensis</i> following different periods of shoot growth inhibition in spring | Time schedule according to application | Deviations, if any | Fulfilled |
|---|--|--------------------|-----------------|
| <i>Deliverables</i> | | | |
| 1. Annual progress reports | Oct 2001, 2002 and 2003 | | Yes |
| 2. Scientific contribution on the effect of cutting of <i>C. arvensis</i> in national or international conferences/workshops | Aug 2004 | | See 1 & 2 in E1 |
| 3. Scientific contribution on the regenerative capacity of <i>C. arvensis</i> following different periods of shoot growth inhibition in spring in a peer-reviewed journal | Ultimo 2004 | | See 3 in E1 |
| <i>Milestones</i> | | | |
| 1. Experimental design and protocol | Jan 2001 and Jan 2002 | | Yes |
| 2. Establishment of field experiments | April 2001 and April 2002 | | Yes |
| 3. Conducting and finalising the shoot growth inhibition and data capture | Aug 2001 and Aug 2002 | | Yes |
| 4. Choice of regression and time series models | | | Yes |

| WP 2. Shoot emergence pattern and competitive ability of <i>C. arvensis</i> following different periods of shoot growth inhibition in autumn | Time schedule according to application | Deviations, if any | Fulfilled |
|---|--|--------------------|-----------|
| | | | |

| | | | |
|---|---------------------------|--|-------------|
| <i>Deliverables</i> | | | |
| 1. Annual progress reports | Oct 2001, 2002 and 2003 | | Yes |
| 2. Scientific contribution on the effect of post-harvest tillage on <i>C. arvensis</i> in national or international conferences/workshops | Jan 2004 | | See 4 in E2 |
| 3. Scientific contribution on the regenerative capacity of <i>C. arvensis</i> following different periods of shoot growth inhibition in autumn in a peer-reviewed journal | Ultimo 2004 | Delayed, submission scheduled to 31 May 2005 | |
| <i>Milestones</i> | | | |
| 1. Experimental design and protocol | Jan 2001 and Jan 2002 | | Yes |
| 2. Establishment of field experiment | April 2001 and April 2002 | | Yes |
| 3. Conducting and finalising the shoot growth inhibition and data capture | Oct 2001 and Oct 2002 | | Yes |
| 4. Choice of regression and time series model | | | Yes |

| | | | |
|--|--|--------------------------------|-----------|
| WP 3. Annual dispersal rate of <i>C. arvensis</i> in a 4-year period under the influence of different levels of competition | Time schedule according to application | Deviations, if any | Fulfilled |
| <i>Deliverables</i> | | | |
| 1. Annual progress reports | Oct 2001, 2002 and 2003 | | Yes |
| 2. Scientific contribution on the spatial and temporal dispersal of <i>C. arvensis</i> in national or international conferences/workshops | Cancelled | Data published in agr. journal | |
| 3. Scientific contribution on the annual dispersal rate of <i>C. arvensis</i> in a 4-year period under the influence of different levels of competition in a peer-reviewed journal | Cancelled | Data published in agr. journal | |
| <i>Milestones</i> | | | |
| 1. Experimental design and protocol | Sept 2000 | | Yes |
| 2. Achievement of <i>C. arvensis</i> in a regular grid | Cancelled | See WP3 in C.1 | No |
| 3. Conducting and finalising the crop sequence and data capture | Cancelled | See WP3 in C.1 | No |
| 4. Choice of regression and time series model | Cancelled | See WP3 in C.1 | No |

| | | | |
|--|--|--------------------|-------------------|
| WP 4. Integrated control of <i>Elymus repens</i> | Time schedule according to application | Deviations, if any | Fulfilled |
| <i>Deliverables</i> | | | |
| 1. Annual progress reports | Oct 2001, 2002 and 2003 | | Yes |
| 2. Scientific contributions in national or international conferences/workshops/magazines | Ultimo 2004 | | See 5,6,7,8 in E1 |
| 3. Scientific contribution in a peer-reviewed international journal drafted | Ultimo 2004 | See * in D | No |
| <i>Milestones</i> | | | |
| 1. Experimental design and protocol | April 2001 | | Yes |

| | | | |
|--|-----------------------|--|-----|
| 2. Achievements on rhizome disintegration and distribution in the soil profile of first and second experiments | Aug 2002 and Aug 2003 | | Yes |
| 3. Achievements on catch crop suppression of <i>E. repens</i> in first and second experiments | Oct 2002 and Oct 2003 | | Yes |
| 4. Achievements on the final control of <i>E. repens</i> following the integrated strategy in first and second experiments | Aug 2003 and Aug 2004 | | Yes |
| 5. Final choice of statistical approach to describe data | | | Yes |

* Deviations are to be further discussed in D

D. Description of deviations and subsequent adjustments of plans

* As explained in C.1 for WP4, the integrated strategy only affected *E. repens* growth weakly, and data are not considered suitable for publishing in a peer-reviewed journal. However, information from the investigations has been published through other media and will be communicated whenever relevant at future national and international events.

Apart from the suggested peer-reviewed papers, Hatcher and Melander reviewed in Weed Research the current physical and biological methods for the control of both annual and perennial weeds.

E. Project publications and other products

1. Products from Organic Eprints archive

Peer-reviewed and accepted

English

Fogelfors, Håkan; Brandsætter, Lars Olav; Graglia, Scientist Enrico; Vanhala, Petri; Salonen, Jukka and Håkansson, Sigurd (2003) [Dormancy of vegetative reproduction in some perennial weeds](#). Paper presented at Nordic Association of Agricultural Scientists 22nd Congress, Turku, Finland, July 1-4; Published in Niemeläinen, Oiva and Topi-Hulmi, Mari, Eds. *Nordic Agriculture in Global Perspective*, page 97. Tampere University Print, Tampere Finland.

²Graglia, Enrico and Melander, Bo (2005) [Mechanical control of *Cirsium arvense* in organic farming](#). Paper presented at 13. European Weed Research Society Symposium, Bari, Italy, 20-23 June.

¹Graglia, Enrico; Melander, Bo; Grøndal, Henrik and Jensen, Rikke K. (2004) [Effect of repeated hoeing on growth of *Cirsium arvense*](#). Paper presented at XII International Conference on Weed Biology, Dijon, France, 30 August - 2 September 2004; Published in *XII International Conference on Weed Biology*, page pp. 107-112.

Hatcher, Lecturer Paul and Melander, Senior scientist Bo (2003) [Combining physical, cultural and biological methods: prospects for integrated non-chemical weed management strategies](#). *Weed Research* 43(5):pp. 303-322.

⁸Melander, Bo; Rasmussen, Ilse A and Bertelsen, Inger (2005) [Integration of *Elymus repens* control and post-harvest catch crop growing in organic cropping systems](#). Paper presented at 13th European Weed Research Society Symposium, Bari, Italy, 19 - 23 June 2005.

Submitted for peer-review but not yet accepted**English**

³Graglia, Enrico; Melander, Bo and Jensen, Rikke (2005) [Mechanical and cultural strategies to control *Cirsium arvense*](#). [preprint]

Not peer-reviewed**English**

Hatcher, Scientist Paul and Melander, Scientist Bo (2004) [Combining physical and cultural weed control with biological methods – prospects for integrated non-chemical weed management strategies](#). Paper presented at 6th EWRS Workshop on Physical and Cultural Weed Control, Lillehammer, 8-10 March; Published in *Proceedings of the 6th EWRS on Physical and Cultural Weed Control*, page 30.

⁵Melander, Bo; Rasmussen, Ilse A and Bertelsen, Inger (2004) [Common Couch-grass control with less tillage](#). *DARCOFenews*(4). Online at <<http://www.darcof.dk/enews/dec04/couch.html>>

Melander, Senior Scientist Bo (2003) [The importance of crop competition in physical and cultural weed control strategies](#). Paper presented at Workshop of the EWRS working group: Crop-weed interactions, Viterbo, Italy, 10-12 April 2003; Published in *Proceeding of the workshop*, page 11.

Dansk - Danish

Graglia, Enrico (2004) [Erfaringer med tidselbekæmpelse på Flakkebjerg](#). Paper presented at Plan-
teproduktion 2004, Herning, 13-14 January 2004; Published in *Månedsmagasinet Mark* 1, page
pp. 57-58.

Graglia, Enrico (2003) [Bekæmpelse af Ager-Tidsel i sædskiftet](#). In *Aktuel Økologi*, September, No
7, page pp. 4-5. Familie Landbruget.

Graglia, Enrico and Melander, Bo (2004) [Regulering af rodukrudt](#).

Graglia, Dr. Enrico (2003) [Ager Tidsel kan bekæmpes uden kemi](#). In *Landbrugsavisen*, 22. August,
page pp. 28-28.

Graglia, Scientist Enrico (2003) [Succesfuld bekæmpelse af Ager-Tidsel - uden kemi](#). In *Nyhedsbrev-
et Danmarks JordbrugsForskning*, July, No 3, page pp. 1-2. Danmarks JordbrugsForskning.

Graglia, Scientist Enrico and Melander, Senior Scientist Bo (2003) [Tidslerne får det glatte lag](#). In
Økologisk Jordbrug, 27. June, No 292, page 15. Økologisk Landsforening.

Grøndal, Henrik; Graglia, Enrico and Jensen, Rikke K. (2003) [Har Ager-Svinemælk og Ager-
Tidsel skudhvile?](#) Poster presented at Dansk Plantværnskonference; Published in *DJF rapport -
Markbrug*(89), page pp. 357-358.

⁶Melander, Bo; Rasmussen, Ilse A and Bertelsen, Inger (2004) [Nye strategier til at bekæmpe kvik](#).
DARCOFenews(6). Online at <<http://www.foejo.dk/enyt2/enyt/dec04/kvik.html>>

⁷Melander, Bo; Rasmussen, Ilse Ankjær; Holst, Niels and Bertelsen, Inger (2004) [Ikke-kemisk ukrudtsbekæmpelse - mekanisk og termisk](#), in *Ukrudtsbogen*, chapter 4, page pp. 207-226. Danmarks JordbrugsForskning.

Rasmussen, Ilse Ankjær; Holst, Niels; Graglia, Enrico; Hansen, Preben Klarskov; Melander, Bo; Mathiassen, Solvejg Kopp; Kudsk, Per; Jensen, Peter; Boelt, Birte and Madsen, Katrine Hauge (2004) [Ukrudtsøkologi og -biologi](#), in *Ukrudtsbogen*, chapter 2, page pp. 19-42. Danmarks JordbrugsForskning.

This list was generated on **Thu May 12 06:36:54 CEST 2005**.

2. Other products (oral presentations, public meetings, field days, etc.)

2 Feb 2001, first meeting in the Nordic NJF-group (Sweden) Coming Danish activities and experiments with *C. arvense* and *E. repens*, including current knowledge about the management of those two species in organic cropping in Denmark. Presented by *Rikke Klith Jensen* and *Bo Melander*.

25 Sep 2001, - Presentation on modelling shoot emergence of Canada thistle at the University of Minnesota, St Paul, Department of Agronomy and Plant Genetics, USA, presented by *Rikke Klith Jensen*.

3-4 Feb 2002, second meeting in the Nordic NJF-group (Denmark) Modelling shoot emergence of *Cirsium arvense* based on soil temperature by *Rikke Klith Jensen* and 2) A new implement for mechanical control of perennials by *Bo Melander*.

28-31 Feb 2002, – Four meetings were arranged by the Danish Agricultural Advisory Centre in Aarhus for advisers, teachers, and employers of agricultural trade organisations in four different cities in Denmark. *Rikke Klith Jensen* gave, at each of the four meetings, an oral presentation on the biology and control of *C. arvense*.

14 Aug 2002, – Oral presentation of the shoot emergence dynamics of Canada thistle at the North Central Soil Conservation Research Lab Field Day at Swan Lake Research Farm, Minnesota, USA, presented by *Rikke Klith Jensen*.

8 Sep – 12 Oct 2002. Bo Melander visited Australia and New Zealand (based on an invitation) and gave 16 seminars on various subjects of weed control in organic farming and farming systems aiming at reducing herbicide dependence. Also more general information about the development of organic farming in Denmark and the Danish pesticide policy was given to the audiences that included researchers, advisors, farmers and authorities. A report from the tour is available in English at http://orgprints.org/1494/01/AUS_NZ_report.pdf and a short article in Danish at http://orgprints.org/1664/01/Haarde_betingelser.pdf.

2-3 Feb 2003, third meeting in the Nordic NJF-group (Norway) Danish results from the joint experiment on dormancy in *C. arvense* and *Sonchus arvensis*. Presented by *Enrico Graglia*. General discussions on the progresses in the ongoing research projects in each country.

10 April 2003, - oral presentation on the importance of crop competition in physical and cultural weed control strategies. Presented by *Bo Melander* at the EWRS-workshop on crop/weed interaction held in Viterbo, Italy.

14 January. Enrico Graglia. Oral presentation at Plantekongres 2004, Herning. Erfaringer med tidselbekæmpelse på Flakkebjerg.

430 Aug – 2 sep 2004 Enrico Graglia. Oral presentation at XII International Conference on Weed Biology, Dijon, France. Effect of repeated hoeing on growth of *Cirsium arvense*.

17-19 Feb 2005, fifth meeting in the Nordic NJF-group (Norway) Danish results from the joint experiment on dormancy in *C. arvense* and *Sonchus arvensis*. Presented by *Enrico Graglia*. General information about final results in projects ended recently.

* 25-75% financed by DARCOF

** 5-25% financed by DARCOF

F. Scientific education

PhD student *Rikke Klith Jensen* decided to stop her PhD study in January 2003 and shortly afterwards she resigned from the Danish Institute of Agricultural Sciences for personal reasons. Consequently, all PhD-activities associated with the project have been cancelled while tasks formerly discharged by *Rikke K. Jensen* in the project were handed over to scientist and PhD *Enrico Graglia*.

G. National and international cooperation

A Nordic working group with participants from four Nordic countries, Finland, Norway, Sweden, and Denmark, has been established as a NJF working group (www.njf.nu). The group is dealing with issues on the management of perennial weeds in organic farming. The group has held five meetings: Uppsala (SE) 2001, Flakkebjerg (DK) 2002, Ås (NO) 2003, Jokioinen (FIN) 2004 and Ås (NO) 2005. A joint experiment studying the dormancy of *C. arvense* and *Sonchus arvensis* in late summer and autumn was started in spring 2002. The results of the joint experiment were presented at the NJF Congress, Turku, Finland, in June 2003. The results are also planned for publishing in a peer-reviewed journal.

There has also been strong interactions with the working group *Physical and Cultural Weed Control* (www.ewrs.org/ewrs-pwc.htm), which is connected to the *European Weed Research Society*.

H. Critical reflection on the project

In the beginning of the project, we had great difficulties finding people with extensive expertise on experimentation with especially *C. arvense*. Research on non-chemical control of perennials has suffered for decades from the extensive use of effective herbicides in conventional agriculture and from the fact that organic farming is still a relatively small agricultural sector. We did contact a few scientists who we believed were great experts on the subject. However, they turned out to be extremely reserved with very little interest in interacting with other scientists. This was a major reason for us to establish a Nordic working group, in which we could discuss our scientific approaches with colleagues from the other Nordic countries. They all happened to commence research on perennials in organic farming as a consequence of perennials being a Scandinavian problem in organic farming. Since then, we have also established close contacts with colleagues in Germany and the USA with special interest in *C. arvense*.

As mentioned earlier, field experimentation with perennial weed species can be very difficult. Considerable variation occurred in our experiments making it difficult to detect effects statistically. Improvements of the experimental design, the statistics used and careful selections of appropriate sites for field experiments are all relevant measures that can improve research. However, strong confounding effects may still cause problems as we saw with the proliferation of *E. repens* in an experiment meant for *C. arvensis*. Of course, such interfering factors make interpretations of results difficult. In general, other factors interfering with experimental factors are difficult to control or exclude in organic experiments, as opposed to conventional field experimentation where for example selective herbicides can be a helpful option. In spite of that, we believe that research aiming at developing new and more effective management strategies need to be validated under organic cropping conditions irrespective of the obstacles that may occur. The strength of a strategy is only proven if it acts consistently under true organic cropping conditions where various factors may affect the outcome of a strategy. However, the more underlying information needed to develop efficient strategies are most favourably undertaken in controlled environments, e.g. growth chambers and glasshouses, to gain a better understanding of the mechanisms behind the effects caused by a strategy. Such an approach has been suggested for both *C. arvensis* and *E. repens* in the application *Effective control of perennial weeds and intra-row weeds in organic cropping through novel technology and new management strategies* for DARCOF III.

In this project, and during visits to other researchers abroad, the importance of strong networking became evident for us. Research in organic farming is still in its infancy in most parts of the world and much time and money may easily be wasted due to significant errors that probably could have been avoided if researchers had interacted more frequently beforehand. Experimentation under organic conditions can be very difficult, and thus the importance of having a forum where problems can be raised and discussed becomes extremely important. Therefore, we strongly encourage DARCOF and other granting bodies to support and encourage national and international collaboration in organic research, for example by making it a major criterion for obtaining funding. DARCOF has already done a lot in this respect, and we can only add: this is an important path to follow.

8. Budget

A. Account for any change in budgets**B. Budget for the whole project (1,000 DKK)**

| Year: | Original budget | Consumption before 2003 | Consumption 2003 | Consumption 2004 | Total |
|----------------------|-----------------|-------------------------|------------------|------------------|-------|
| Man-months | | | | | |
| Scientific personnel | 42 | 23 | 9 | 10 | 42 |
| Technical personnel | 21 | 14 | 6 | 1 | 21 |

| Year: | Original budget | Consumption before 2003 | Consumption 2003 | Consumption 2004 | Total |
|---|-----------------|-------------------------|------------------|------------------|-------|
| Salaries | | | | | |
| Scientific personnel | 1,237 | 630 | 273 | 334 | 1,237 |
| Technical personnel | 424 | 273 | 128 | 23 | 424 |
| Other operational costs | 232 | 144 | 73 | 15 | 232 |
| Equipment | 65 | 65 | | | 65 |
| Others (please specify) | | | | | |
| Direct costs | | | | | |
| Indirect costs (20% of direct costs) | 392 | 223 | 95 | 74 | 392 |
| Total | 2,350 | 1,335 | 569 | 446 | 2,350 |

Comments:

9. Signatures and stamps

| Name | Institute | Date | Signature |
|---|--|---------------|-----------|
| Head of project Senior scientist <i>Bo Melander</i> | Danish Institute of Agricultural Sciences, Department of Integrated Pest Management, Research Centre Flakkebjerg | 30 March 2005 | |