Danish Research Centre
for Organic Farming

Midterm Status Report 2002 and Application for Continuation in 2003

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1. Research program

Research in organic farming 2000-2005 (DARCOF II)

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2. Project title and number

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

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3. Head of project

Senior scientist Bo Melander, Department of Crop Protection, DIAS

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4. Participating institutes

Danish Institute of Agricultural Sciences (DIAS)

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5. Other project staff

Ph.D. student Rikke Klith Jensen, Department of Crop Protection, DIAS

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6. Project period (month, year)

Start of project: 2000
End of project: 2004

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7 Midterm description of the project, its results and progress, and application for continuation in 2003

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 diary 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 re-grows 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 about 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 DARCOFI 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 *Elymus 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. arvense*. 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 nutrients. 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 have 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. arvense*: competitive ability against different crops; spread and dispersal of thistle patches; and impact of stem and root cutting on the regenerative capacity of *C. arvense*. Research on these aspects will add valuable information to the economic importance of *C. arvense* 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. arvense*. In addition, this will improve 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, will be studied on sandy soils. Results from these experiments are 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 DKr)	Start	End	Deliverable No:
1	The regenerative capacity and competitive ability of *C. arvense* following different periods of shoot growth inhibition in spring	<u>RKJ</u> BME	592	2000	2004	WP1D1- WP1D2- WP1D3
2	The regenerative capacity and competitive ability of *C. arvense* following different periods of shoot growth inhibition in the late summer and autumn	<u>RKJ</u> BME	475	2000	2004	WP2D1- WP2D2- WP2D3
3	Annual dispersal rate of *C. arvense* in a 4-year period under the influence of different levels of competition	<u>RKJ</u> BME	506	2000	2004	WP3D1- WP3D2- WP3D3
4	Integrated control of *E. repens*	<u>BME</u> RKJ	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. arvense* 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. arvense*. 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. arvense* 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 have been 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. arvense* is inhibited by hoeing in a row-sown red clover and by mowing in grass clover mixture: the hoeing and the mowing take place each time the thistle shoots are at their two-leaf stages, and the treatments are stopped either at 1 June, 1 July, and 1 August. These stoppages of thistle growth are 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 will be assessed in a spring barley crop the following year as a result of treatments on different periods of growth inhibition in plots with and without red clover or grass clover mixture.

WP2

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

Two experiments have been established, one in 2001 and one in 2002. Two factors are under investigation:

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 are repeatedly stubble-cultivated after harvest until 1 October while those with an undersown grass clover are mowed each time the thistle shoots have developed two true leaves after harvest.

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

WP3

The major objective is 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. arvense* have been 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 is measured over time in a period of 4 years.

WP4

The major objective is 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* have been established in the spring of 2001 and 2002, respectively, to give two experiments by sowing seeds of *E. repens* in a wide-spaced spring barley crop. In the autumn 2001/2002, aboveground vegetation is mowed and removed, and the experimental area is ploughed. Spring barley is then sown in the spring of 2001/2002 and just after harvest in August, the experimental area is 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 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. fodder radish (*Raphanus sativus*)
c. mixture of red clover and rye grass

Factor 3) timing of ploughing, two levels:

a. late autumn
b. spring.

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

B. Objectives and expected achievements

The objective of the project is 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. Midterm results and progress

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

WP1
All four experiments have successfully been established. The plots were cut every second week from start of growing in spring to obtain different periods of shoot inhibition. The results from the first experiment, established in 2000, with repeated cuttings in plots with and without grass clover showed that a long shoot inhibition period with 6 repeated cuttings had a better effect on *C. arvense* than a short shoot inhibition period, as shown in figure 1.

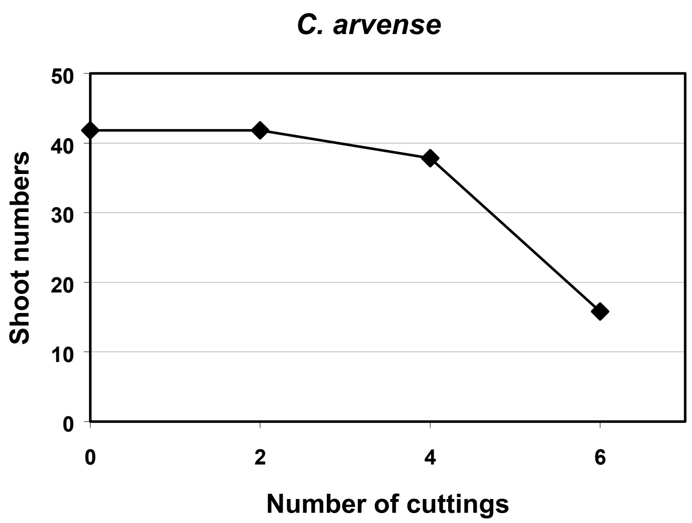

Figure 1. Relationship between number of cuttings/mowing from spring and shoot numbers of *C. arvense* the previous year in spring barley.

WP2
Both experiments with whole crop have been successfully conducted so far. Based on the preliminary results from the first experiment, the responses of harvest time and subsequent tillage or mowing have shown remarkably high effects, as shown in Table 1.

Table 1. The effects on *C. arvense* (%) from repeated treatments with either mowing or tillage after harvest time in whole crop with and without undersown grass.

	With under sowngrass (mowing)	Without undersown grass (tillage)
Early harvest	89	99
Normal harvest	91	98
Late normal harvest	91	94
Mean	*91*	*97*

The average thistle infestation in the experiment before the treatments were conducted was a dense population of 18 shoots per square metre. All the treatments had an effect higher than 90% on *C. arvense* and repeated tillage was found to be slightly better than repeated mowing, although the differences were not considered as significant. In addition, the effects on *C. arvense* were very high regardless of harvest times and subsequent period of tillage. A good reason for that could be the rather high numbers of post-harvest treatments. All plots were treated every second week after harvest until 1 October, e.g. the latest harvest date with the shortest shoot inhibition period had in total 7 post-harvest tillage or mowing treatments.

In conclusion, the results from this experiment show that repeated post-harvest treatments every second week until 1 October are highly effective against *C. arvense*. This also indicates that *C. arvense* did not develop any dormancy within this period.

WP3

This year´s measurements of spread and dispersal rates of thistle patches have shown a remarkable ability to spread and produce new shoots within a year in spring barley but not in grass clover. Shoot development from the autumn-placed root fragments in year 2000 showed new shoot emergence of 1-3 m in spring barley, which was much more than expected. This high risk of a very rapid dispersal of *C. arvense,* especially in a crop with low suppression abilities, should therefore be considered in a management situation.

WP4

In the first experiment (*E. repens* stand established in 2001), the stubble cultivations have been successfully conducted according to factor 1 as described above under WP4 under work content. Next year will show the overall effect of stubble cultivation, suppression from a catch/cover crop, and ploughing time in the subsequent barley crop. The second experiment was started this spring and a dense *E. repens* stand appears to develop.

C.2 Fulfilment of deliverables and milestones

(To be completed for each work package)

WP 1. The regenerative capacity and competitive ability of *C. arvense* following different periods of shoot growth inhibition in spring	Time schedule according to application	Deviations, if any
Task		
1. Planning, design, and establishment of field experiments	April 2001 and April 2002	
2. Measurement of shoot emergence	Sept 2001 and Sept 2002	
3. Regression and time series analysis		
Deliverables		
1. Annual progress reports	Oct 2001 and Oct 2002	
2. Scientific contribution on the effect of cutting of *C. arvense* in national or international conferences/workshops		
3. Scientific contribution on the regenerative capacity of *C. arvense* following different periods of shoot growth inhibition in spring in a peer-reviewed journal		
Milestones		
1. Experimental design and protocol	Jan 2001 and Jan 2002	
2. Establishment of field experiments	April 2001 and April 2002	
3. Conducting and finalising the shoot growth inhibition and data capture	Aug 2001 and Aug 2002	
4. Choice of regression and time series models		

WP 2. Shoot emergence pattern and competitive ability of *C. arvense* following different periods of shoot growth inhibition in autumn	Time schedule according to application	Deviations, if any
Task		
1. Planning, design, and establishment of field experiment	April 2001 and April 2002	
2. Measurement of shoot emergence	Sept 2001 and Sept 2002	
3. Regression and time series analysis		
Deliverables		
1. Annual progress reports	Oct 2001 and Oct 2002	
2. Scientific contribution on the effect of post-harvest tilling of *C. arvense* in national or international conferences/workshops		
3. Scientific contribution on the regenerative capacity of *C. arvense* following different periods of shoot growth inhibition in autumn in a peer-reviewed journal		
Milestones		
1. Experimental design and protocol	Jan 2001 and Jan 2002	
2. Establishment of field experiment	April 2001 and April 2002	
3. Conducting and finalising the shoot growth inhibition and data capture	Oct 2001 and Oct 2002	
4. Choice of regression and time series model		

WP 3. Annual dispersal rate of *C. arvense* in a 4-year period under the influence of different levels of competition	Time schedule according to application	Deviations, if any
Task		
1. Planning, design, and establishment of field experiment	April 2001 and April 2002	
2. Annual temporal and spatial measurements	Sept 2001 and Sept 2002	
3. Regression and time series analysis		
Deliverables		
1. Annual progress reports	Oct 2001 and Oct 2002	
2. Scientific contribution on the spatial and temporal dispersal of *C. arvense* in national or international conferences/workshops		
3. Scientific contribution on the annual dispersal rate of *C. arvense* in a 4-year period under the influence of different levels of competition in a peer-reviewed journal		
Milestones		
1. Experimental design and protocol	Sept 2000	
2. Achievement of *C. arvense* in a regular grid	Sept 2000	
3. Conducting and finalising the crop sequence and data capture	Sept 2001 and Sept 2002	
4. Choice of regression and time series model		

WP 4. Integrated control of *Elymus repens*	Time schedule according to application	Deviations, if any
Task		
1. Planning, design, and establishment of field experiments	April 2001 and April 2002	
2. Conduction of field experiments and data capture	Aug 2001	
3. Data analysis and publishing		
Deliverables		
1. Annual progress reports	Oct 2001and Oct 2002	
2. Scientific contributions in national or international conferences/workshops		
3. Scientific contribution in a peer-reviewed international journal drafted		
Milestones		

1. Experimental design and protocol	April 2001	
2. Achievements on rhizome disintegration and distribution in the soil profile of first and second experiments	Aug 2002	
3. Achievements on catch crop suppression of *E. repens* in first and second experiments	Oct 2002	
4. Achievements on the final control of *E. repens* following the integrated strategy in first and second experiments		
5. Final choice of statistical approach to describe data		

C. Description of deviations and subsequent adjustments of plans

There are no significant deviations and the project is progressing as planned.

E. Project publications and other products

1. Articles in international, scientific journals with review procedures

2. Papers presented at congresses, symposiums, etc.

3. Reports, articles in agricultural journals, etc.

4. Oral presentations, public meetings, field days, etc.

2 Feb 2001, first meeting in the Nordic NJF-group (Sweden) – Oral presentations of 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 Sept 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) – Oral presentation of 1) Modeling 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*.

11-13 March 2002, EWRS workshop on Physical Weed Control in Pisa (Italy) – Poster presentation of a degree-day model of *Cirsium arvense* predicting shoot emergence from root buds, by *Rikke Klith Jensen*, David Archer & Frank Forcella.

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*.

F. Scientific education

***Rikke Klith Jensen* has started a Ph.D. study on *C. arvense* and has been in USA for a 3-month leave from July to October 2001 and a 2-month leave from July to August 2002, visiting Dr. Frank Forcella and Dr. Dave Archer at the USDA-ARS North Central Conservation Research laboratory in Morris, MN.**

A model to predict shoot emergence of *C. arvense* based on accumulated temperature sums has been developed as a result from this study leave stay using shoot emergence data from trials in Denmark and USA. In addition, contact has been established with Dr. W.W. Donald, USDA-ARS Columbia, USA, who has an extensive knowledge and research experience with *C. arvense.*

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. The group is dealing with issues on the management of perennial weeds, particularly in organic farming. A joint experiment studying the dormancy of *C. arvense* and *Sonchus arvensis* in late summer and autumn has been started this spring. A second meeting was held at Research Centre Flakkebjerg on 3-4 February 2002. The major purpose of that meeting was to present and coordinate the joint activities. Also current activities on perennial weed research accomplished in the Nordic countries were discussed. The third meeting is planned to take place in Norway 2003, mainly to discuss the preliminary results of the joint experiment and the research activities on perennials in all the Nordic countries.

H. Critical reflection on the project

All the experiments on *C. arvense*, except for the descriptive study on the spread and dispersal rates, are conducted in a field with a natural and long-term infestation of *C. arvense*. All the shoot numbers are pre-registered the year before or right before any treatments are performed. This gives a possibility of an exact data analysis from field experiments with a natural *C. arvense* population. Sparser stands of *C. arvense* are most likely more easily to control than denser stands as root densities and distributions in the soil profile increase with the age and become denser, making control more difficult. For that reason, control studies conducted in fields with high densities of *C. arvense* might not reflect normal field situations with more sparse densities.
Also, *C. arvense* subspecies or ecotypes within a subspecies might respond differently to control measures. There has so far been no attempt to document which ecotypes of *C. arvense* that are present in the experimental field. Artificially established ecotypes could have been used for research, but would possibly still not reflect natural conditions within the time frame of this project. The field used for experiments in WP1-2 was considered unique in the sense that the field was heavily infested with *C. arvense* and has been grown organically for at least 10 years without any control in the immediate past by deep tillage operations. Although fields with heavy infestations of *C. arvense* are expected to be harder to control, the preliminary results from both post-harvesting tillage and mowing in the autumn and repeated treatments in grass clover in spring time look very promising.

The descriptive study on the spread and distribution of *C. arvense* in WP3 was planned to give valuable information on the rate of *C. arvense* root encroachment and spread between borders of adjacent plots in the above experiments. These results would not only be interesting for farmers, but also interesting in developing the methodology for conducting long-term control research on *C. arvense* in regards of plot sizes and dimensions. This year, however, results already show that the rate of the root/shoot development in spring barley is higher than expected and the plots size should probably have been larger than they are in WP3. These results are, however, profound and are also valuable in the interpretation of the results in WP1-2.

The success of the integrated control strategy against *E. repens* described in WP4 relies heavily on the growth of the subsequent catch/cover crop. Late harvest of barley leading to a delayed establishment of the catch/cover crop may result in a poor development of the catch/cover crop in the autumn. Suppression of *E. repens* may then be weak, and the disintegration of rhizomes just after harvest may even lead to increased shoot numbers in the subsequent crop if the catch/cover crop provides to little suppression. Also dry weather conditions after barley harvest may result in poor germination of the catch/cover crop seeds and consequently in poor stands.

It was planned to assess the distribution of rhizomes in the soil profile with 5 cm intervals after disintegration in the stubble by the different implements, mentioned in the work package description, had taken place. However, this turned out not to be possible within the time available. It was then decided only to distinguish between rhizomes that remained in the soil and those that were exposed on the soil surface.

8. Budget

A. Account for any change in budgets

B. Budget for the whole project (1.000 DKK)

Total consumption of funds from DARCOF and expected consumption this year and coming years

Year:	Consump-tion before 2000	2000	2001	2002	2003	2004	Total
Man-months							
Scientific personnel		4	10	9	9	10	42
Technical personnel		3	5	6	6	1	21

Year:	Consump-tion before 2000	2000	2001	2002	2003	2004	Total
Salaries							
Scientific personnel		97	273	260	273	334	1.237
Technical personnel		55	96	122	128	23	424
Other operational costs		12	59	73	73	15	232
Equipment		15	50				65
Others (please specify)							
Direct costs							
Indirect costs (20% of direct costs)		36	96	91	95	74	392
Total		215	574	546	569	446	2.350

Comments:

9. Signatures and stamps

Name	Institute	Date	Signature
Head of project			