



Progress Report 2008 and Application for Continuation in 2009

for research funding under the research programme:

Research in Organic Food and Farming
International Research Co-operation and Organic Integrity
(DARCOF III 2005-2010)

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1. Project title and acronym

*Effective control of perennial weeds and intra-row weeds in organic
cropping through novel technology and new management strategies*

WEEDS

2. Project journal number

J. nr. 3304-FOJO-05-21

3. Project period (month, year)

Start of project:	Jan 2007
End of project:	Dec 2011

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Note that Esmaeil Nadimi and Ivar Lund have both left DAE-DJF because of the geographical mowing of DAE.

7. Midterm description of the project, its results and progress, and application for continuation in 2009

A. Project summary

Currently two major weed problems put severe constraints on organic crop production in Denmark: (i) perennial weeds, most notably *Elymus repens* (L.) Gould, *Cirsium arvense* L. Scop, *Rumex crispus* L. and *Tussilago farfara* L., causing problems in various crops and crop rotations, and (ii) annual intra-row weeds entailing laborious hand-weeding, especially in vegetable rows.

Perennials are traditionally controlled by repeated and prolonged stubble cultivation in late summer and autumn but this strategy conflicts with the objective in organic farming to retain nutrients in the upper soil layer by keeping the soil plant-covered during autumn and winter. In a DARCOF II project just finished, effective control of *C. arvense* was obtained without disturbing the plant cover but treatment intensity was high and not immediately acceptable for organic growers. It was concluded that further research should focus on strategies involving fewer and timelier treatments based on a better understanding of the carbohydrate source/sink dynamics in regenerative roots in response to growth disturbances. In this proposal we will seek to gain a better understanding of the source/sink allocation pattern to optimize tillage and cutting regimes. The work will include both *C. arvense* and *T. farfara* and also provide other essential information, currently missing to plan proper management strategies: (i) vulnerability to intensity and timing of root/rhizome fragmentation, desiccation and subsequent burial; (ii) the effect of treatments on the frag-

mentation and distribution of roots/rhizomes in the soil and proliferation potential. The research will be undertaken under controlled conditions in growth chambers and glasshouses and subsequently validated and further modified under semifield and field conditions to identify the most prospective strategies to control the two species.

The work on perennials also includes *E. repens* and *R. crispus* L. but with an entirely different approach. Owing to the rather superficial placement of rhizomes and rootstocks, research will concentrate on the development of novel technology for effective uprooting, exposing and destroying of rhizomes and rootstocks within a short time span. Such technology will meet the key objective of quick and cost-effective *E. repens* and *R. crispus* control, while having the soil plant covered over most of the year. The work includes an iterative development of appropriate tools followed by field validation of functionality and biological effects. Finally, a prototype implement will be used for validation of the new technology in a wider organic cropping system context.

Methods for controlling intra-row weeds have been studied in previous DARCOF-funded projects. However, finding a solution for effective and selective intra-row weed management, which confidently reduces the need for hand-weeding, remains a challenge in organic farming. Several research institutes have studied different advanced technologies for intra-row weeding, some of which have potential for integration into an intelligent system for arable intra-row weed control. In this project, research will be directed towards an integration of knowledge on the biological environment, cultivation tactics, implements, perception, robotic technology and seeding technology into a system capable of unmanned and selective weeding under field conditions in a given growing system. Technical progress will be evaluated iteratively during the project, in terms of weeding effectiveness and reliability under field conditions.

To gain a better understanding of the perspectives for weed management in organic cropping, the results obtained in the project will be included in an ongoing modelling effort to describe the long-term weed population dynamics in organic and conventional crop rotations. Modelling will be used in the project as a tool to integrate knowledge from literature in combination with new results, as they are generated in the project. The model will serve to organize the work packages into a coherent whole, ensuring a common standard that will make results applicable across the project and also be for the benefit of the end-users by providing an analytical tool to formulate integrated weed management strategies.

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

WP No.	WP title	Responsible scientist	Budget DKK	Start	End	Deliverable No.
1	Effective management strategies for <i>Cirsium arvense</i> and <i>Tussilago farfara</i>	Ilse A. Rasmussen	3,523,636	Jan – 2007	Dec – 2011	D1.1-D1.5
2	Exposure and destruction of <i>Elymus repens</i> rhizomes	Bo Melander	2,144,967	Jan – 2007	Dec – 2011	D2.1-D2.4
3	Field machinery for automatic intra-row weeding in row crops	Michael Nørremark	4,125,439	Jan – 2007	Jun – 2011	D3.1-D3.12
4	Decreasing and delaying weed emergence in row crops	Jesper Rasmussen	1,250,088	Jan – 2007	Dec-2010	D4.1-D4.3
5	Weed population dynamics model	Niels Holst	797,870	Jan – 2007	Dec – 2011	D5.1-D5.3
Co.	Cluster of common tasks	Bo Melander	158,000	Jan - 2007	Dec - 2011	D.Co.1-D.Co.11
Total			12,000,000			

B. Objectives and expected achievements

Long-term objective

Knowledge on how to manage perennial and intra-row weeds effectively by means of novel strategies and technology is available to organic farmers.

Project objectives

1. Effective management strategies for *C. arvense* and *T. farfara*, involving both preventive and direct control measures, have been developed and communicated to organic farmers.
2. Novel technology for exposing and destructing *E. repens* rhizomes and *R. crispus* rootstocks has been developed and for *E. repens* validated in an organic cropping system context.
3. Weeding robot that operates in vegetable crops and physically destroys weeds in the rows has been developed.
4. Punch planting techniques and its strategic use with stale seedbed and physical intra-row weeding has been developed and validated in close collaboration with objective 3.
5. Strategies for the integrated control of two perennial species (*C. arvense*, *T. farfara*) and major annual weed species have been formulated, based on a weed population dynamics model, and communicated to organic farmers.

C. Midterm results and progress

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

WP1 Effective management strategies for *Cirsium arvense* and *Tussilago farfara*

Research activities in task 1: The phenology of above/below-ground source/sink dynamics determined under controlled conditions. PhD project started in October 2007 and milestones 1 and 2 are fulfilled. Some experiments on the early and late growth of both species in controlled conditions have been conducted and others are ongoing. Of the required minimum for the PhD course (30 ECTS), the PhD student has already accumulated 24 ECTS.

Research activities in task 2: The phenology of above/below-ground source/sink dynamics determined under semifield conditions. Preliminary studies indicated that the density of the roots in the experiment of the planted weed species in the growing season (minirhizotrones) and winter (soil cores and digging out) 2007/08 was quite low and variable.

Research activities in task 3: Best-bet control strategies tested in the field. Field experiments on *C. arvense* have been initiated in 2007, and registrations have been carried out in 2008. The experimental treatments are being repeated in 2009. Field experiments on *T. farfara* have been initiated in 2008. Results have not yet been analyzed.

WP2

A. Destruction of *Elymus repens* rhizomes

The methodology and machine design for sorting and crushing rhizomes and rootstocks proposed in Progress Report 2007 has now been provisionally patented but collaboration with a manufacture has not yet been established. An internal DJF patent description has been made, and the patent has provided a spin-off plan for applying DFFE innovation funding for whole machine development. Whole machine development is not compatible with the WP2 deliverables, but parts of the machine are within the scope of D2.1-4.

Four experiments with destructing *Elymus repens* rhizome pieces of 2-5 cm length, containing one bud per piece, have been conducted in the laboratory during the progress period (M2.5, M2.7):

Experiment a) Destruction by microwaves: Five seconds in the microwave oven (4.0 KJ applied) hardly affected the sprouting ability of rhizome buds. Thirty or more seconds gave a complete bud kill. Thirty seconds corresponds to 24 KJ applied, raising the temperature in the rhizomes to 394°C.

Experiment b) Destruction by hot water: The preliminary results are shown in Table 1. A quick and effective reduction in the sprouting ability of rhizome buds was only achieved for temperatures at 70°C and above. Two different clones – one raised in the glass house and one from a sandy soil (Jyndevad) - were tested at 50°C and 90°C. The glass house clone was slightly more persistent to 50°C treatment than the clone raised under outdoor conditions at Jyndevad.

Table 1. Expt. b) Hot water treatment, 50 rhizome pieces per replication

Temperature (°C)	Time (sec)	% bud sprouting	Deviation (%)
20 (Untreated)	-	80.0	8.2
50	30	64.5	13.0
	60	78.5	8.1
	300	61.0	12.9
	600	25.5	14.3
60	5	79.5	11.5
	30	8.0	10.5
	60	0	0.0
	300	4.5	9.0
70	5	0.5	1.0
	30	0	0
	60	0	0
	300	0	0
90	5	0	0
	15	0	0
	30	0	0
	60	0	0

Experiment c) Destruction by pressure I: Rhizome pieces were pressed at 20 kN and up to 320 kN. All pressures completely killed the buds.

Experiment d) Destruction by pressure II: Based on the results in experiment c), another experiment was made with pressures in the range of 0.5-16 kN using two clones at two lengths (2 and 4 cm, one bud per piece). Increasing pressure reduced the number of sprouted buds in a S-shaped way similar to a dose-response behaviour (Figure 1). A pressure of 16 kN gave an almost complete bud kill irrespective of clone and rhizome length. However, clone and rhizome length affected bud sprouting for pressures below 10 kN.

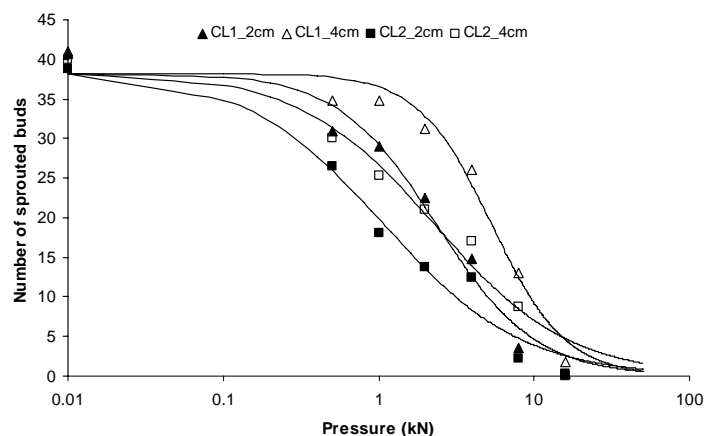


Figure 1. The relationship between number of sprouted buds (50 buds per replicate) and pressure on a log-scale shown for two clones at two lengths.

In addition to experiments a)-d), a crusher developed by Cimbria Videbæk A/S was tested for its ability to crush and comminute rhizomes. However, it did not turn out successfully and the principle seems not relevant for rhizome destruction.

B. Uprooting and exposing *E. repens* rhizomes

Six different implements for uprooting and exposing *Elymus repens* rhizomes were studied in one field experiment at Jyndevad Experimental Station in early September 2008 (<http://www.okologgen.dk/>). The implements were a) tine cultivation (Marsk-Stig Uniflex), b) rotary tiller (Howard/Kongskilde Rotalabor), c) disk tiller (JBT tallerkenharve, developed by DAE), d) tine cultivation + rotary tiller (Kvik-Up harve), e) tine cultivation + rotary tiller (Kvik-Killer) and f) beach cleaner (Beach-Tech (<http://www.beach-tech.com/>)). Preliminary analyses of the results showed that the beach cleaner (f) almost completely remove rhizomes from the soil but the implement still needs some modifications to become functional for field situations. The rotary tiller (b) was the most interesting principles among the other implements studied, especially for its ability to uproot a high proportion of rhizomes by just one pass and for its ability to operate in fields heavily infested with *E. repens*.

Conclusion for WP2

We will focus on mechanical methods for destructing *E. repens* rhizomes in our future work and also include taproots of *Rumex crispus*. For uprooting and exposing rhizomes and taproots we believe that there is a significant potential in the mechanical principles of the rotary tiller (b) and beach cleaner (f). These two principles will have our attention in next years work.

WP3 Field machinery for automatic intra-row weeding in row crops

Modification of the HortiBot in terms of clearance height, robustness of wheel modules and new standardised three point linkage are all completed. The robotic tool carrier is in its current state able to follow a crop row by computer vision, and is able to lift and lower any implement or tool attached to its three point linkage. The new three point linkage enables the HortiBot to be attached to conventional implements.

The faced problems concerning computer vision and real time control of weeding tool(s) based on computer vision will be the most difficult ones to solve in this project. Therefore, cooperation with University of Hohenheim has been initiated with a planned meeting at the end of October 2008 where the details of research and development will be agreed to. DAE has invested in a new camera that has all features necessary for real time computer vision and has so far integrated a segmentation algorithm explained in Rasmussen et al. (2008) that segments the green leaves of plants from ground in images. That is the first step of the image set that is developed within the project milestone M.3.3. The selected image set is a four step procedure: 1) segmentation, 2) plant identification based on leaf morphology, 3) crop plant positioning in the local coordinate system defined by the camera 2-D view, 4) following the path of the same crop plant in subsequent images. The research related to step 4 has been initiated. The step 2 and 3 is where University of Hohenheim has shown interest in cooperation and also has developed some essential algorithms (Weiss & Gerhards, 2007; Sökefeld et al., 2007, see <http://turbo.uni-hohenheim.de/index.de.php>). In addition, an agreement with SDU has been approved by the department leader for sharing a PhD student to assist the programming of the DAE camera for optimizing the real time performance of plant identification.

The selected image set has one serious drawback that no researchers or others have solved. This drawback is occluded leaves, leaf damages and tilted/bended plants and/or leaves at later growth stages. The plant identification based on leaf morphology does not succeed when e.g. occluded leaves occur. Therefore, a cooperation with University of Turku is ongoing which concentrate on using chlorophyll fluorescence as plant species identification, supplementary the before mentioned image set (Tyystjärvi et al., 1999; Keränen et al., 2003). An experiment with two plant species and six weed species has been done. The analysis of data is ongoing and the message from Turku is that our experimental work has revealed promising results. A peer-reviewed paper on this research is planned for submission in 2009.

The publication of the scenario analysis and selection of weed control tools into two peer-reviewed papers is still on-going (D3.3). The selection of weed control tools are based on very accurate positioning of crop plants. Therefore, building the weed control tool for the project is very much depending on the success of the computer vision system for real time plant positioning. That is, having a very accurate plant positioning, a very accurate tool can be build. A CAD drawing of the selected weed control tool for accurate weed control close to crop plants has been produced.

The results of the selection of scenarios for robotic vehicle behaviours (D3.8, M3.9) is pub-

lished within a peer reviewed paper (Jørgensen et al., 2008). The results of this paper will be used for optimising the HortiBot for more robust behaviour in row crops (M3.7, M3.8, M3.13 and D 3.5).

The delivery of a detailed design document for an automated agricultural field machine (D3.4) was done in the form of a paper that will be submitted to a peer reviewed journal ultimo October 2008.

References of relevance for WP3

- Jørgensen, R.N., Nørremark, M., Sørensen, C.G., Andersen, N.A. (2008) Utilising scripting language for unmanned and automated guided vehicles operating within row crops. *Computers and Electronics in Agriculture* 62, 190-203.
- Keränen, M., Aro, E.M., Tyystjärvi, E., Nevalainen, O. (2003) Automatic plant identification with chlorophyll fluorescence fingerprinting. *Precision Agriculture* 4, 53-67.
- Rasmussen, J., Nørremark, M., Bibby, B.M. Assessment of leaf and crop soil cover in weed harrowing research using digital images. *Weed Research* 47, 299-310.
- Sökefeld, M., Gerhards, R., Oebel, H., Therburg, R.-D. (2007) Image acquisition for weed detection and identification by digital image analysis. In: Stafford, J. (Ed.) (2007, June). *Precision agriculture '07, Volume 6, The Netherlands. 6th European Conference on Precision Agriculture (ECPA): Wageningen Academic Publishers*, pp. 523-529.
- Tyystjärvi, E., Koski, A., Keränen, M., Nevalainen, O. (1999) The Kautsky curve is a built-in barcode. *Biophysical Journal* 77, 1159-1167
- Weiss, M., Gerhards, R. (2007) Feature extraction for the identification of weed species in digital images for the purpose of site-specific weed control. In: Stafford, J. (Ed.) (2007, June). *Precision agriculture '07, Volume 6, The Netherlands. 6th European Conference on Precision Agriculture (ECPA): Wageningen Academic Publishers*, pp. 537-544.

WP4 Decreasing and delaying weed emergence in row crops

A total of 8 field experiments were carried out in 2008. Two experiments were designed to investigate the interactions between sowing technique, delayed sowing and crop type (H1, H2 & H3). Normal sowing without flame weeding, normal sowing with pre-emergence flame weeding and punch planting with flame weeding were compared at five different sowing times (from mid April to early May) in sugar beets and onions. Two experiments (H4) were carried out to investigate if punch planting improves the selectivity of mechanical weeding in a fast germinating crop (sugar beet) and a slow germination crop (carrots). Five different intensities of weed harrowing were carried out in an early growth stage of the crops, and the selectivity was analysed as the relationship between weed density and crop density decline. In one experiment, seed bed preparation was either carried out in autumn or in spring, to investigate weed emergence in a row crop (carrots) if tillage in spring was totally excluded (H5). The selectivity of the cycloid hoe, a mechanical intra-row tool that utilizes information about the position of the crop plants, was tested against a weed harrow and treatments with the cycloid hoe, when it had no information about crop plant positions (sugar beets) (H6). A range of intensities was created with the cycloid hoe (with and without intelligence) and the weed harrow, and the decline of weed density and sugar beet density was analysed. The punch planter was compared with the spade seeder in spinach and sugar beets to evaluate weed emergence and the establishment of the crops (H7).

Table 2. Results summarized according to the tested hypotheses.

Hypothesis	Crops	Results
H1 Punch planting with pre-emergence flame weeding reduces weed germination in comparison with normal sowing with flame weeding	Sugar beets Onions	Experiments partly supported the hypothesis but the effect of punch planting was highly influenced by crop and sowing date. In onions, there was a 50% weed density decline compared with normal sowing with flame weeding. However, in sugar beets, there was a small average increase in weed density in punch planted plots. Flame weeding was highly efficient in onions (about 75% weed control), whereas the efficacy in sugar beets was lower and influenced by sowing date.
H2 Punch planting with flame weeding takes advantage of delayed sowing in terms of reduced weed germina-	Sugar beets Onions	Experiments did not support the hypothesis. In neither sugar beets nor onions, late sowing favoured punch planting. Late sowing

	tion in comparison with normal sowing with flame weeding		reduced weed germination in general and flame weeding was only effective in sugar beets when seeding (normal and punch) was delayed.
H3	The potential of reducing weed germination with punch planting is higher in slow germinating crops	Sugar beets Onions	The experiments supported the hypothesis.
H4	Punch planting improves the selectivity of mechanical weeding compared with normal sowing.	Sugar beet Carrot	Experiments did not support the hypothesis. In neither of the crops, the selectivity of weed harrowing was influenced by sowing technique, and the selectivity was low in both crops.
H5	The potential of reducing weed germination with punch planting is higher when the seed bed is prepared in autumn	Carrots	An experiment supported the hypothesis. Punch planting in a seed bed prepared in autumn reduced weed germination compared with normal sowing in a seed bed prepared in spring. Effects of sowing technique, however, were small.
H6	Intelligent weeding with the cycloid hoe improves selectivity of mechanical weeding compared with a cycloid hoe that does not utilize plant position information	Sugar beet	An experiment did not support the hypothesis. The cycloid hoe, which was supposed only to cultivate the intra-row spaces, did not improve the selectivity, when it was compared with a cycloid hoe without information about the crop plants and an ordinary weed harrow.
H7	A spade seeder stimulates more weeds to germinate than the punch planter	Spinach Sugar beet	Data not analysed.

The spring in 2008 was dry and the germination of crop and weeds was influenced by lack of soil moisture when sowing was delayed. Crop establishment was not optimal when sowing was delayed. Especially, the punch planter showed poor crop establishment when the soil dried out in the plots that were assigned for delayed sowing. Also, the punch planter showed limited ability to punch the seeds into the soil, when the soil dried out. In general, the punch planted plots showed less decline in weed emergence than expected. This was most likely due to the dry soil conditions. Tillage only stimulates weed germination if the soil is moist. The experiments will be repeated in 2009.

WP5 Weed population dynamics model

The simulation models of *C. arvensis* and *T. farfara* are being re-formulated in WeedML, a new language for weed modelling that holds promise to become an international standard (<http://www.weedml.org/>, headed by Niels Holst). This will make the models more widely available and easier to access for students and researchers. Niels Holst will take part in two WeedML workshops later this year at which the *C. arvensis* and *T. farfara* models will be presented and discussed. This will heighten the quality of the models.

C.2 Fulfilment of deliverables and milestones
(To be completed for each work package)

Deliverables list (from application)

Workpackage 1						
Deliverable No	Deliverable title	Lead scientist	Delivery date	Allocated scientific person moths	Type of deliverable	Fulfilled (ok) or deviations (d)*
D1.1	Three scientific papers on <i>C. arvensis</i> and <i>T. farfara</i> source-sink dynamics under controlled conditions.	JCS	Jun-10	18	S	d
D1.2	Ph.D. thesis on <i>C. arvensis</i> and <i>T. farfara</i> source-sink dynamics under controlled conditions.	JCS	Jun-10	18	S	d
D1.3	Scientific paper on <i>C. arvensis</i> and <i>T. farfara</i> source-sink dynamics under field conditions.	IAR	Dec-10	5	S	d
D1.4.	Scientific paper on <i>C. arvensis</i> preventive control: catch crop and stubble cultivation.	IAR	Jul-10	5.5	S	
D1.5	Scientific paper on <i>C. arvensis</i> and <i>T. farfara</i> direct control between-crops	IAR	Nov-11	5.5	S	

* Deviations are to be further discussed in D

Milestones list (from application)

Workpackage 1			
Milestone No	Milestone title	Delivery date	Fulfilled (ok) or deviations (d)*
M1.1	Sampling programme and protocol for controlled experiments defined.	Nov-07	ok
M1.2	Analytical method for determination of carbohydrate reserves identified.	Feb-08	ok
M1.3	The phenology of above/below-ground source/sink dynamics of carbohydrates under controlled conditions determined for <i>C. arvensis</i> and <i>T. farfara</i> , replicate 1.	Nov-09	d
M1.4	The timing of physical disturbances to pursue in task 2 identified.	Feb-09	d
M1.5	The phenology of above/below-ground source/sink dynamics of carbohydrates under controlled conditions determined for <i>C. arvensis</i> and <i>T. farfara</i> , replicate 2.	Jun-09	d
M1.6	Sampling programme and protocol for semifield experiments on source/sink dynamics defined.	Mar-09	d
M1.7	The phenology of above/below-ground source/sink dynamics of carbohydrates under semifield conditions determined for <i>C. arvensis</i> and <i>T. farfara</i> .	Mar-11	d
M1.8	Sampling programme and protocol for field test of best-bet strategies defined.	Mar-07	ok
M1.9	Effect of \pm catch crops combined with \pm stubble cultivation determined for <i>C. arvensis</i> .	Dec-09	
M1.10	Effect of best-bet between-crops control determined for <i>C. arvensis</i> and <i>T. farfara</i> and communicated to organic farmers	Nov-11	

* Deviations are to be further discussed in D

Deliverables list (from application)

Workpackage 2						
Deliverable	Deliverable title	Lead scientist	Delivery date	Allocated scientific	Type of de-	Fulfilled (ok) or

No		tist		person moths	liver-able	devia-tions (d)*
D2.1	Report on technology for exposing and destroying rhizomes and rootstocks.	BME	Jan-09	3	R	
D2.2	Conference paper on the technology for exposing and destroying rhizomes and rootstocks, and its effects on rhizome and rootstock viability and growth.	EFK	Jun-09	4	P	
D2.3	Public demonstration of the new technology for rhizome and rootstock exposure and destruction including comparisons with common implements for <i>E. repens</i> control.	EFK	Sep-11	3	O	
D2.4	Scientific paper on <i>E. repens</i> control using new technology for rhizome exposure and destruction in organic cropping.	BME	Nov-11	6.9	S	

* Deviations are to be further discussed in D

Milestones list (from application)

Workpackage 2			
Milestone No	Milestone title	Delivery date	Fulfilled (ok) or deviations (d)*
M2.1	Decisions made on tool design and configuration and appropriate methods for rhizome and rootstock destruction for further studies.	Mar-07/Mar08	OK
M2.2	First prototype tools for field investigation and equipment for rhizome and rootstock destruction are ready.	Aug-07/Sep08	OK
M2.3	Modification and improvements of the technology for rhizome and rootstock exposure and destruction ended.	Jul-08	d
M2.4	Exposing ability assessed under field conditions; first series.	Sep-07/	OK
M2.5	Lethality of destructing methods assessed and quantified in the laboratory; first series.	Nov-07/Mar08	OK
M2.6	Exposing ability assessed under field conditions; second series.	Sep-08	d
M2.7	Lethality of destructing methods assessed and quantified in the laboratory; second series.	Nov-08	
M2.8	Technology for rhizome exposure and destruction implemented in a cropping system context.	Aug-09	
M2.9	Weeding effectiveness assessed under the influence of burial and catch crop growing assessed.	Aug-11	
M2.10	Strategies taking the new technology into account formulated and communicated to organic farmers.	Oct-11	

* Deviations are to be further discussed in D

Workpackage 3						
Deliverable No	Deliverable title	Lead scientist	Delivery date	Allocated scientific person moths	Type of deliverable	Fulfilled (ok) or deviations (d)*
D3.1	Detailed design document - intelligent closed loop weed management implement	MINO	Feb-09	5.5	R	D
D3.2	Demonstration of mechanism for intelligent intra-row weeding	MINO	Dec-09	3.5	O	
D3.3	Scientific paper on scenarios, selec-	MINO	Jun-10	5.0	S	

	tion of technology and feasibility					
D3.4	Detailed design document - augmented machine	MINO	May-08	4.5	R	OK
D3.5	Demonstration of augmented implement carrier – in-field controlled operation	MINO	Jan-10	4.5	O	
D3.6	Scientific paper on automatic machinery for autonomous row operation	MINO	Jun-10	4.5	S	
D3.7	Requirements specification for implementation of the technology in future organic farming	MINO	Sep-10	4.5	R	
D3.8	Model of relevant operational control strategies and machinery implemented	MINO	May-08	3.5	O	OK
D3.9	Detailed design document - software components supporting selected control strategies	MINO	Jan-10	4.5	R	
D3.10	Demonstration of integrated automatic intra-row weeding machinery	MINO	Apr-10	3.5	O	
D3.11	Scientific paper on software components, control algorithm and simulations	MINO	Sep-10	5.5	S	
D3.12	Scientific paper on weeding effectiveness and reliability of automatic intra-row weed management	MINO	Aug-11	5.5	S	

* Deviations are to be further discussed in D

Milestones list (from application)

Workpackage 3			
Milestone No	Milestone title	Delivery date	Fulfilled (ok) or deviations (d)*
M3.1	Scenarios for intra-row weeding selected	Jul-07	OK
M3.2	Decisions made on technology base for implement research	Sep-07	OK
M3.3	Image set and mathematical foundation for computer vision established	Dec-08	D
M3.4	Mechanism for intelligent intra-row weeding demonstrated in laboratory – in field operation	Oct-09	
M3.5	Scenarios for automatic machine use in row crops selected	Jul-07	OK
M3.6	Decision made on technical modifications required for commercial machine	Sep-07	OK
M3.7	Augmented implement carrier demonstration under controlled conditions	Feb-09	D
M3.8	Augmented implement carrier demonstration - in-field operation	Aug-09	
M3.9	Scenarios for robotic vehicle behaviours selected	Jul-07	OK
M3.10	Modelling, validation, simulation and testing of software control strategies and algorithms completed for selected scenarios	Jun-09	
M3.11	Assemble of a controller for vehicle and implement completed	Nov-09	
M3.12	Software framework, computers and electronics selected	Jan-10	
M3.13	Implementation of controller and validation completed on vehicle	Mar-10	
M3.14	Experiments with weeding effectiveness and reliability of automatic intra-row weed management completed	Mar-11	
M3.15	Optimal crop planting patterns to suit yield optimisation and space requirements to make automatic intra-row weeding operational identified.	Jun-11	

Deliverables list (from application)

Workpackage 4						
Deliverable No	Deliverable title	Lead scientist	Delivery date	Allocated scientific person moths	Type of deliverable	Fulfilled (ok) or deviations (d)*
D4.1	Punch planter adjusted and ready for field experiments	JER	Jan-08	5	O	d
D4.2	Peer-reviewed article: punch planting in row crops	JER	Jun-10	5	S	
D4.3	Peer-reviewed article: interactions between sowing and weed control methods.	JER	Sep-10	5	S	

* Deviations are to be further discussed in D

Milestones list (from application)

Workpackage 4			
Milestone No	Milestone title	Delivery date	Fulfilled (ok) or deviations (d)*
M4.1	Punch planter adjusted to ready for field experiments	Jan-08	OK
M4.2	Punch planting studied in field experiments ended	Oct-09	
M4.3	Investigations on the interactions between punch planting, physical weed control and stale seedbed strategies finalised	Oct-09	

* Deviations are to be further discussed in D

Deliverables list (from application)

Workpackage 5						
Deliverable No	Deliverable title	Lead scientist	Delivery date	Allocated scientific person moths	Type of deliverable	Fulfilled (ok) or deviations (d)*
D5.1	Scientific paper on partly validated simulation model of <i>C. arvensis</i> and <i>T. farfara</i> growth and population dynamics.	NHO	May-09	3.5	S	
D5.2	Scientific paper on field-validated simulation model of <i>C. arvensis</i> and <i>T. farfara</i> growth	NHO	Jul-11	3.5	S	
D5.3	Best-bet control strategies communicated to organic farmers.	NHO	Nov-11	1	P,C	

* Deviations are to be further discussed in D

Milestones list (from application)

Workpackage 5			
Milestone No	Milestone title	Delivery date	Fulfilled (ok) or deviations (d)*
M5.1	Model of <i>C. arvensis</i> undisturbed growth validated against literature (from other project).	May-07	OK
M5.2	Model of <i>C. arvensis</i> disturbed growth developed from controlled experiment.	Dec-07	OK
M5.3	Model of <i>T. farfara</i> growth developed from controlled experiment.	Feb-08	d (Jan-

			09)
M5.4	Models above validated against literature.	Oct-08	d (Feb-09)
M5.5	Best-bet strategies formulated by way of model.	Mar-08	Cancelled
M5.6	Model validated against field experiments.	Jun-10	
M5.7	Model of major annual weed species validated	May-07	OK
M5.8	Best-bet strategies fine-tuned.	Nov-09	
M5.9	Strategies taking the new technology of WP3 and WP4 into account formulated by way of simulated scenarios.	Oct-10	

* Deviations are to be further discussed in D

Deliverables list (from application)

Workpackage Co						
Deliverable No	Deliverable title	Lead scientist	Delivery date	Allocated scientific person moths	Type of deliverable	Fulfilled (ok) or deviations (d)*
D.Co.1	Project home page implemented	NHO	Jan-07	1	O	OK
D.Co.2	Annual report 2007 submitted.	BME	Sep-07	0.4	R	OK
D.Co.3	Annual report 2008 submitted.	BME	Sep-08	0.4	R	OK
D.Co.4	Annual report 2009 submitted.	BME	Sep-09	0.4	R	
D.Co.5	Annual report 2010 submitted.	BME	Sep-10	0.4	R	
D.Co.6	Annual report 2011 submitted.	BME	Sep-11	0.4	R	
D.Co.7	Communication to farmers: plan for 2008 specified.	IBE	Jan-08	0.6	R,P,C	OK
D.Co.8	Communication to farmers: plan for 2009 specified.	IBE	Jan-09	0.6	R,P,C	
D.Co.9	Communication to farmers: plan for 2010 specified.	IBE	Jan-10	0.6	R,P,C	
D.Co.10	Communication to farmers: plan for 2011 specified.	IBE	Jan-11	0.6	R,P,C	
D.Co.11	Final report submitted.	BME	Dec-11	0.5	R	

* Deviations are to be further discussed in D

(The nature of the deliverables must be indicated by S = publication in scientific journal with peer review; P = publication in journals without peer review; R = reports; C = presentation at meetings and congresses or O = other types of deliverables, e.g., prototypes, models, websites, etc.).

D. Description of deviations and subsequent adjustments of plans

WP1

Task 1. The start of the PhD. Project was delayed 7 months in 2007 and the first experiments were conducted at the probable time of dormancy for *Cirsium arvense* (autumn). This dormancy problem has been discussed with our Swedish Colleagues during a workshop in March 2008. They did not find it, so we are eagerly awaiting this year autumn growth in the greenhouse to see if the "dormancy" last year was an artifact. Early growth experiments were properly conducted in spring 2008 and sampled and now the samples are being analyzed for carbohydrate and the hydrolysis products of fructans. It means that the PhD project dealing with WP 1 and Task1.1 [M1.3 and M1.4] will be delayed because the identified quantification method of special carbohydrates and particularly fructans is currently ongoing. We decided to use a simple acid hydrolysis of fructans instead of a very detailed analysis that is too time consuming. This stems from the fact that we wish to keep handling time of a samples down so we could get more individual measurements instead of few but detailed measurement of fructan species. Currently, we are investigating the possibilities of using $^{14}\text{CO}_2$ to study translocation pattern in the plants in relation to phenology.

Task 2. The experiments on phenology of above/below-ground source/sink dynamics determined under semifield conditions have been post-poned due to the missing input from task 1. Due to the results from preliminary studies on root density, it was judged, that a postponement would give better results and also give the possibility to include the results from task 1 as originally planned. The experiments will be carried out 2009. The preliminary studies on roots using mini-rhizotrones, soil cores and digging are being repeated in 2008. If the results from the mini-rhizotrones are not improved, this part of the experiment may be given up.

Task 3. At the project meeting in June 2008 there was agreement that it would be beneficial with more than 6 treatments in the experiment with *T. farfara* at Jyndevad. In order to carry out 3 more treatments, money originally allocated for experimental equipment, which turned out to be cheaper than expected (mini-rhizotrones), was transferred to this task. It would be very beneficial if additional money for these extra treatments could be transferred from somewhere else in the project for the 2009 running of the experiment.

WP2

The patent has now been approved but no manufacturer has yet accepted to collaborate on developing the machinery. In the meantime we have developed another machine for uprooting *Elymus repens* rhizomes and this was tested in comparison with 5 other implements in early September. We will further modify and develop the technology for uprooting and exposing *E. repens* rhizomes and rootstocks of *Rumex crispus* in the coming year. Thus M2.3 and M2.6 will be slightly delayed.

WP3

Revision of budget for DAE was done in September 2008. DAE consumed less than the budget due to reduced staff since last yearly status report. The timetable for both the delayed and the coming milestones and deliverables has all been postponed with half a year in order to meet the new staff composition at DAE.

A PhD student is employed from November 1st 2008 who will be associated in parallel with the work on software modifications in terms of adding more intelligent behaviour and robustness to the HortiBot. The PhD student will assist the process of fulfilling the D 3.11, 3.6, 3.8, and M 3.7, 3.8, 3.10-13.

Furthermore, a new researcher with engineering background is found and employed from December 1st 2008, who will be associated with the development of the implement for weed control in 2009. The design of the implement is done, but sensors, actuators and end effectors have not been selected yet. Building the implement needs more engineering support, which the new employment will provide, and consequently, the process of developing the weed control tool within the project, i.e. D 3.5, 3.9, and M 3.4, 3.10-13 will be able to proceed, but with delays. The construction of the implement requires fine mechanical skills. It is decided to outsource the construction work. Manufacturing of electronics is planned to be done at new facilities at the Foulum campus, where an electronic technician is available.

WP4

Proceed as planned except that there will be no field experiments with a robotic weeder delivered from WP3 in 2009. Therefore, experiments will continue with the cycloid hoe in 2009, which at present is the only intra-row weeding tool in the project that operates with intelligence.

WP5

Due to the delay of the controlled experiments with disturbed growth, the models describing disturbed growth have been delayed (M5.3 and M5.4) but not more than the completed models can be presented at the WSSA Annual Meeting.

Another consequence of the delay of the controlled experiments was that the models could not be used to formulate best-bet strategies for weed control as planned (M5.5). Consequently the best-bet strategies, that are now being tested in the field, were formulated based on current knowledge only. However, the models will still be a valuable analytical tool to understand the response of the weeds to the different strategies.

E. Project publications and other products

1. Products from Organic Eprints archive

Ascard, J; Melander, B and et al., (2007) [Thermal Weed Control](#), in Upadhyaya, M.K. and Blackshaw, R.E., Eds. *CAB International 2007. Non-chemical Weed Management*, chapter 10, page pp. 155-175. CAB International.**

Holst, N.; Rasmussen, I.A. and Bastiaans, L. (2007) [Field weed population dynamics: a review of model approaches and applications](#). *Weed Research* 47(1):pp. 1-14.**

Melander, B. (2007) [Status on physical and cultural weed control methods for field crops in Europe](#). Paper presented at Novel and Sustainable Weed Management in Arid and Semi-Arid Ecosystems, Rehovet, Israel, October.**

Melander, Bo (2008) [Ukrudt i økologiske marker skal bekæmpes på nye måder](#). In *Landbrugsavisen*, 4. April. Landbrugsavisen.

Rasmussen, I.A.; Bastiaans, L.; Holst, N.; Grundy, A. and Melander, B. (2007) ['All models are wrong - but some are useful' - a report from an EWRS workshop on modelling weed population dynamics](#). Paper presented at 14th EWRS Symposium, Hamar, Norway, 17-21 June 2007; Published in Bårberi, P.; Bastiaans, L.; Bohren, C.; Christensen, S.; Gerowitt, B.; Grundy, A.; Hatcher, P.; Kudsk, P.; Melander, B.; Rubin, B.; Streibig, J.; Tei, F.; Thompson, A. and Vurro, M., Eds. *14th EWRS Symposium 17-21 June 2007 Hamar Norway*, page 116.**

Rasmussen, I.A.; Bastiaans, L.; Holst, N.; Grundy, A. and Melander, B. (2007) [Report from an EWRS workshop on modelling weed population dynamics](#). Paper presented at 7th EWRS workshop on Physical and Cultural Weed Control, Salem, Germany, 11-14 March 2007; Published in Melander, B.; Cloutier, D. and Gerowitt, B., Eds. *Proceedings 7th EWRS workshop on Physical and Cultural Weed Control*, page 174.**

Rasmussen, Jesper (2008) [Mindre ukrudt med punktsåning](#) [Less weeds with punch planting]. In *Maskinbladet*, 29.. August, Volume 28, No 447, page 13.

Sørensen, Claus G.; Nørremark, Michael; Jørgensen, Rasmus N.; Jensen, Kjeld; Maagaard, Jørgen and Jensen, Lars Aa. (2007) [Hortibot: Feasibility study of a plant nursing robot performing weeding operations – part IV](#). Paper presented at 2007 ASABE Annual International Meeting, Minneapolis, Minnesota, US, 17 - 20 June 2007(Paper Number: 077019), page pp. 1-12.

Thomsen, Henning C. and Rasmussen, Ilse A. (2008) [Anlægelse af forsøg på Jyndevad Forsøgsstation](#) [Treatment of experiments at Jyndevad Experimental Station]. Online at <http://www.okologgen.dk/index.php?page_id=62>. Accessed 24. September 2008

van der Weide, R.Y.; Bleeker, P.O.; Achten, V.T.J.M.; Plotz, L.A.; Fogelberg, F. and Melander, B. (2008) [Innovation in mechanical weed control in crop rows](#) [Nye mekaniske metoder til bekæmpelse af ukrudt i rækken i rækkeafgrøder]. *Weed Research* 48:pp. 215-224.*

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

* 25-75% financed by DARCOF

Melander B. chaired and was main scientific organiser of the 7th workshop of the Physical and Cultural Weed Control working group under EWRS (European Weed Research Society). The meeting was held 12-14 March 2007. An extensive proceeding can be downloaded (http://www.ewrs.org/pwc/pdf/2007_Salem.pdf).

Melander B chaired and organised session 3: *Crop-weed interactions and non-chemical methods* at the 14th EWRS Symposium 17-21 June 2007 at Hamar Norway.

Melander B. (2007). Oral presentation. Results and experiences with the control of perennial weeds in organic farming in Denmark. Information day organised by Bioforsk in Norway on the 27 Nov. 2007 in Rygge, Norway.

Nørremark, M. (2008). Oral presentation. Automation technology for leaf scale precision agri- and horticulture. Seminar at Turku University, 1st February 2008, Turku, FIN.

** 5-25% financed by DARCOF

F. Scientific education

WP1

PhD-student Libéré Nkurunziza has participated in the following courses:

1. SOAR summer school: Scales and cross-scales in ecosystem services in agriculture and organic farming 4 ECTS (see attached)
2. Nova Analysis of Biological assays in Agriculture, PhD course 6 ECTS (See Attached)
3. Mixed linear methods, PhD course 6 ECTS (see attachement)
4. Non-linear regression with R, PhD course 2 ECTS (see attached)
5. Introductory course for PhD student at the Faculty of Life Sciences, 2 ECTS (see attached)
6. Water – plant relation methods, PhD course 6 ECTS (see attached)
7. 2 SOAR seminars

A course in Isotope technique that should have begun in August has been postponed but hopefully in November 2008 it will start

WP2

1 VIP and 1 TAP from DJF/DAE passed a C# programming course at Aalborg Technical College, November 28th-30th 2007 and March 5th-8th 2008.

G. National and international cooperation

1. The PhD project has been presented at a workshop at the Swedish Agricultural University. The objective of the workshop was to discuss future joint research on perennial weeds, including the observed "dormancy" of *C. arvense*.
2. An abstract for the workshop on perennial weeds at Wageningen University (10-12 November 2008) and a poster presentation on: "Induced adventitious bud sprouting and carbohydrate reserves remobilization in Canada thistle [*Cirsium arvense* (L.) Scop.]"
3. Ilse A Rasmussen is co-organiser of the EWRS workshop on perennial weeds at Wageningen University (10-12 November 2008).
4. Bo Melander is main scientific organiser of the 8th workshop of the Physical and Cultural Weed Control working group under EWRS (European Weed Research Society) to be held 9-11 March 2009 (<http://www.ewrs.org/pwc/8thworkshop.asp>).
5. Niels Holst has been invited to present WeedML at a the Annual Meeting of the Weed Science Society of America (WSSA) in February 2009 (<http://www.wssa.net>). The models of *C. arvense* and *T. farfara* will be presented there as examples of WeedML in use, and at the same time the models will be made publicly available on Internet.

Specific for WP3

As a consequence of the previous reduction of staff at DAE the only short term solution to fulfil deliverables and milestones in the project was arranging national and international cooperation. DAE contacted the leading research group on plant identification using computer vision at the University of Hohenheim. There is arranged a meeting with researchers from University of Hohenheim at the end of October 2008. There will from January 2009 be three DAE researchers spending time on the computer vision part. In addition, and also in 2009, a PhD student from SDU will assist the project regarding computer vision and the agreement is that the student spends a full year work on the assistance.

As mentioned previously, the selected computer vision approach has some drawbacks that were identified from the research related to M3.3. Therefore cooperation with University of Turku was established to measure chlorophyll fluorescence of crop and weed species in order to investigate whether this could add more robustness to the plant identification by computer vision. A Finnish student help was employed to conduct the experimental work. This cooperation has been going on since March 2008 and ends in the beginning of 2009 with a scientific paper on this novel approach to robust plant identification for individual plant care.

H. Critical reflection on the project

WP1

task 1, we have experienced problems with putative dormancy in *C. arvensis* and consequently we have not been able to initiate the experiments before this dormancy was broken. We are still looking into the matter because the literature is somewhat vague about it. Another thing we have encountered is that detailed analysis of fructans will be too expensive and tedious and therefore we are trying to develop a method that makes us able to process more analysis of carbohydrate and if possible only a rough estimate of fructans.

In this project the experiments in task 2 are dependent on the results obtained from experiments in task 1. This has been a problem since the results from task 1 were not yet available at the planned time for establishment of the experiment in task 2, but we hope to have the results from task 1 before next spring. Also in task 2, we had planned to use minirhizotrones to be able to evaluate the root biomass in deeper soil layers. This method has been successfully used with catch crops, but preliminary results indicate that the root system of *C. arvensis* is so much different, that the minirhizotrones may not be relevant to use for this weed.

WP2

The studies on physical destruction of *E. repens* rhizomes has shown that mechanical destruction through pressure is useful. However, whether such a method can become operational in a field situation with stones and other unwanted objects still needs further consideration. It might be that simple removal of rhizomes through collection in a tank appears to be the most economical and rational solution.

Uprooting and exposing *E. repens* rhizomes showed remarkable promise using the Beach-Tech implement. We foresee a significant contribution to the control of perennial weeds in organic agriculture, if this mechanical principle can become operational in the field situation. However, in its current state more work need to be done to modify and improve that implement.

WP3

DAE at Bygholm has suffered from a loss of expertises, which clearly shows the vulnerability of a work package when it relies on very special expertises. However, with the adjustments and postponing of parts of the WP3, the new employments, and the international cooperation, it is believed that DAE will be able to deliver the deliverables listed in WP3.

DAE facilities are under construction at the Foulum campus, but the project will not suffer from this intermediate period, as the fine mechanical part will be outsourced and an agreement is reached to use an electronic technician from another department at the Foulum campus. For the construction of the weed control implement, more or less complete instrumentation, which is also easy to apply to the construction work, is intended to be utilised, such that time and requirements for facilities and competences are reduced to a minimum.

WP4

All experimental plans will be repeated unchanged in 2009 in order to investigate how environmental

factors (year) influence the effects of punch planting and delayed sowing. Several details about the practical implementation of the experimental plans, however, will be adjusted. In 2008, we learned that we need to be more careful with flame weeding in order to attain effective control of weeds in late growth stages. Re-growth of weeds in late growth stages is a problem that we need to take into consideration. Higher gas doses or higher number of treatments have to be considered. We also realized that the intensity of tillage associated with seed-bed preparation may be crucial. From the literature, we know that there exists a positive correlation between the intensity tillage and the weed germination. In 2008, we prepared the seedbed in plots that were allocated late sowing with a weed harrow, which only gives a low intensity of tillage. In 2009, we will attempt to make the seedbed with an ordinary seedbed harrow. Seeding techniques will not be studied together with the robotic weeder under development in WP3 in the 2009 growing season due to the delays described under WP3. However, we will continue with our fairly comprehensive experimental set up for test of the cycloid hoe, which gave astonishing results in 2008. From our experiments in 2008, we learned that even if high tech implements like the cycloid hoe carry conviction in lab conditions, the results under field condition in growing crops does not have to be promising. This finding, underlines the necessity that technical innovation goes hand in hand with field trails. Hopefully, the work in WP3 can provide room for an integration of seeding techniques and robotic weeding later in the project.

WP5

The modelling of disturbed weed growth was delayed, as a side effect of the delay in the employment of the PhD student. However, this delay has been put to good use, as the time has been spent to reformulate the models in the WeedML modelling language. We see this as a benefit because WeedML models will likely reach a broad audience of students and researchers.

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:	Original budget	Consumption 2007	Expected consumption 2008	2009	2010	2011	Total
Man-months	201.45	36.12	51.74	64.05	39.00	20.55	211.46
Scientific personnel	149.75	25.84	36.74	48.05	28.55	17.05	156.23
Technical personnel	51.70	10.28	15.00	16.00	10.45	3.50	55.23

Year:	Original budget	Consumption 2007	Expected consumption 2008	2009	2010	2011	Total
Salaries							
Scientific personnel	6,381,284	1,041,833	1,321,995	1,981,044	1,274,259	900,770	6,519,901
Technical personnel	1,431,754	273,625	330,000	326,795	269,400	91,000	1,290,820
Other operational costs	2,047,087	323,414	527,852	721,224	299,590	196,000	2,068,080
Equipment	71,200	40,021	7,000	4,179	1,000		52,200
Others (please specify)	68,675	13,000	22,000	17,000	18,000		70,000
Direct costs	10,000,000	1,691,893	2,208,847	3,050,242	1,862,249	1,187,770	10,000,000
Indirect costs (20% of direct costs)	2,000,000	337,979	441,369	609,648	372,449	237,554	2,000,000
Total	12,000,000	2,029,872	2,650,216	3,659,890	2,234,698	1,425,324	12,000,000

Comments:

9. Signatures and stamps

Name	Institute	Date	Signature
Head of project Bo Melander	University of Aarhus, Faculty of Agricultural Sciences, Integrated Pest Management	8 October 2008	

Appendix I. Detailed budget

A. Budget for each participating institute (1.000 DKr)

Name of Institute and department: University of Aarhus, Faculty of Agricultural Sciences, **Department of Integrated Pest Management**

Year:	Original budget	Consumption 2007	Expected consumption 2008	2009	2010	2011	Total
Man-months	74.9	9.9	14.65	18.15	18.3	13.65	74.73
Scientific personnel	40.4	5.4	5.15	8.15	9.55	11.65	40.23
Technical personnel	34.5	4.5	9.5	10	8.75	2	34.5

Year:	Original budget	Consumption 2007	Expected consumption 2008	2009	2010	Total	
Salaries							
Scientific personnel	2,258,322	290,546	288,162	454,887	532,621	678,676	2,256,892
Technical personnel	716,000	122,00	140,000	202,000	217,000	46,000	716,00
Other operational costs	766,000	115,00	206,000	217,215	153,000	95,000	767,215
Equipment	25,000		7,000				25,000
Others (please specify)							
Direct costs	3,765,322	527,546	641,162	874,102	902,621	819,676	3,765,107
Indirect costs (20% of direct costs)	753,064	105,509	128,232	174,821	180,524	163,935	753,021
Total	4,518,386	633,055	769,394	1,048,923	1,083,145	983,611	4,518,128

Comments:

B. Budget for each participating department (1.000 DKK)

Name of Institute and department: University of Aarhus, Faculty of Agricultural Sciences, **Department of Agricultural Engineering**

Year:	Original budget	Consumption 2007	Expected consumption 2008	Expected consumption 2009	2010	2011	Total
Man-months	75.5	16,5	15.5	24,5	12,5	6,5	75,5
Scientific personnel	54	13,5	12	20.5	11	5	62
Technical personnel	21.5	3	3.5	4	1,5	1,5	13,5

Year:	Original budget	Consumption 2007	Expected consumption 2008	Expected consumption 2009	2010	2011	Total
Salaries	2,846,369	606,500	544,000	976,707	478,028	241,134	2,846,369
Scientific personnel	2,278,015	530,000	441,000	873,987	433,028	196,134	2,474,149
Technical personnel	568,354	76,500	103,000	102,720	45,000	45,000	372,220
Other operational costs	771,965	175,100	140,000	256,865	100,000	100,000	771,965
Equipment							
Others (please specify)							
Direct costs	3,618,334	781,600	684,000	1,233,572	578,028	341,134	3,618,334
Indirect costs (20% of direct costs)	723,666	156,320	136,800	246,714	115,605	68,227	723,666
Total	4,342,000	937,920	820,800	1,480,286	693,633	409,361	4,342,000

Comments: Consumption in 2007 is based on registered expenses in the DAE account manager system. The budget for 2008 is reduced due to unforeseen reduction of DAE staff. Consequently, it was necessary to adjust the budget for 2009, 2010 and 2011 according to the changed dates for milestones, deliverables and new employments as outlined above. In the budget made in 2007 the salary and other operational costs for 2008 was D.kr. 1.044.585 and D.kr. 444.761 respectively. It is therefore necessary to apply for transfer of D.kr. 500.585 and D.kr. 3047.61 to the remaining project years for salary and other operational costs respectively.

C. Budget for co-financing from each participating institute (1.000 DKK)

Name of Institute and department: University of Aarhus, Faculty of Agricultural Sciences, **Department of Genetics and Biotechnology**

Year:	Original budget	Consumption 2007	Expected consumption 2008	2009	2010	2011	Total
Man-months	1.93	0.64	0.29		1		1.93
Scientific personnel	1.93	0.64	0.29		1		1.93
Technical personnel	0	0	0		0		0

Year:	Original budget	Consumption 2007	Expected consumption 2008	2009	2010		Total
Salaries	102,600	30,987	15,013		56,600		102,600
Scientific personnel	102,600	30,987	15,013		56,600		102,600
Technical personnel	0	0	0		0		0
Other operational costs	2,000	0	1,000		1,000		2,000
Equipment							
Others (please specify)							
Direct costs	104,600	30,987	16,013		57,600		104,600
Indirect costs (20% of direct costs)	20,920	6,197	3,203		11,520		20,920
Total	125,520	37,184	19,216		69,120		125,520

Comments: In 2008, the budget includes an additional amount of 11,800 kr "From place of work" to cover "Other operational costs", (mentioned in the application). It suggested that this money can be most efficient used if part of this is used to buy a new PC for Kristian Kristensen, as his work uses PC's very intensively. Therefore, it is suggested that 5,500 of this 11,800 kr "From place of work" is used for "Other operational costs" and 6,300 for "Equipment".

D. Budget for co-financing from each participating institute

Name of Institute and department: WP1, PhD-project at **Department of Agricultural Sciences, Life, UC**

Year:	Original budget	Consumption 2007	Expected consumption 2008	2009	2010	2011	Total
Man-months	36	6	12	12	6		36
Scientific personnel	36	6	12	12	6		36
Technical personnel							

Year:	Original budget	Consumption 2007	Expected consumption 2008	2009	2010	2011	Total
Salaries	1,086,000						
Scientific personnel	1,086,000	173,000	355,000	369,000	189,000		1,086,000
Technical personnel							
Other operational costs	190,000	6,000	65,000	76,000	43,000		190,000
Equipment							
Others (please specify)*	70,000	13,000	22,000	17,000	18,000		70,000
Direct costs		192,000	442,000	462,000	250,000		1,346,000
Indirect costs (20% of direct costs)	268,000	38,000	88,000	92,000	50,000		268,000
Total	1,614,000	230,000	530,000	554,000	300,000		1,614,000

Comments: *PhD course and supervision

E. Budget for each participating departmentName of Institute and department: WP4, **Department of Agricultural Sciences**, Life, UC

Year:	Original budget	Consumption 2007	Expected consumption 2008	2009	2010	2011	Total
Man-months	20	2.78	9	9	2		74
Scientific personnel	15	0	7	7	2		62
Technical personnel	5	2.78	2	2	0		14

Year:	Original budget	Consumption 2007	Expected consumption 2008	2009	2010	2011	Total
Salaries	647,900	75,125	292,000	280,775			647,900
Scientific personnel	507,900	0	205,000	258,700			463,700
Technical personnel	140,000	75,125	87,000	22,075			184,200
Other operational costs	307,900	25,814	114,152	167,934			307,900
Equipment	44,200	40,021		4,179			44,200
Others (please specify)							
Direct costs	1,000,000	140,960	406,152	452,888			1,000,000
Indirect costs (20% of direct costs)	200,000	28,192	81,230	90,578			200,000
Total	1,200,000	169,152	487,382	543,466			1,200,000

Comments:

F. Budget for each participating department

Name of Institute and department: Danish Agricultural Advisory Service, **National Centre Crop Production**

Year:	Original budget	Consumption 2007	Expected consumption 2008	2009	2010	2011	Total
Man-months	2.6	0.3	0.3	0.4	1.2	0.4	2.6
Scientific personnel	2.4	0.3	0.3	0.4	1	0.4	2.4
Technical personnel	0.2	0	0	0	0.2	0	0.2

Year:	Original budget	Consumption 2007	Expected consumption 2008	2009	2010	2011	Total
Salaries	155,960	17,300	17,820	24,470	70,410	25,960	155,960
Scientific personnel	148,560	17,300	17,820	24,470	63,010	25,960	148,560
Technical personnel	7,400	0	0	0	7,400	0	7,400
Other operational costs	11,000	1,500	1,700	3,210	3,590	1,000	11,000
Equipment							
Others (please specify)							
Direct costs	166,960	18,800	19,520	27,680	74,000	26,960	166,960
Indirect costs (20% of direct costs)	33,392	3,760	3,904	5,536	14,800	5,392	33,392
Total	200,352	22,560	23,424	33,216	88,800	32,352	200,352

Comments:

No changes in the budget