Danish Research Centre for
Organic Food and Farming

Progress Report 2007 and
Application for Continuation in 2008

for research funding under the research programme:

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

Funded by the Ministry of Food, Agriculture and Fisheries
under the Finance and Appropriation Act, Sections 24.33.02.10

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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

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2. Project journal number

J. nr. 3304-FOJO-05-21

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3. Project period (month, year)

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

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4. Head of project

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Note that Svend Christensen, Henning Tangen Søgaard, and Rasmus N Jørgensen have all left DAE-DJF because of the geographical mowing of DAE. Esmaeil Nadimi, Ivar Lund and Hans Jørgen Olesen are new staff members from DAE.

*Libère Nkurunziza is new staff member for IJV-FLS

7. Midterm description of the project, its results and progress, and application for continuation in 2008

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 inten-

sity 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 fragmentation 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 *Cirsium arvense* and *Tussilago farfara*	Ilse A. Rasmussen	3,523,636	Jan – 2007	Dec – 2011	D1.1-D1.5
2	Exposure and destruction of *Elymus repens* 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

WP 1 Effective management strategies for Cirsium arvense *and* Tussilago farfara
Since the project only started this year (2007), and the experiments have not been harvested or data analyzed yet, there are no results for 2007. As the PhD study first started July first there has been little research activity. However, Libère Nkurunziza has already accumulated more that 10 ECTS of PhD course work (Minimum is 30 ECTS)

WP2 Exposure and destruction of Elymus repens *rhizomes*
During the process of making decisions on tool design and configuration and appropriate methods for rhizome and rootstock destruction (M2.1) and designing the first prototype tools for field investigation and equipment for rhizome and rootstock destruction (M2.2), it was realised that the research have led to the possibility of patenting. Thus, a methodology and machine design for sorting and crushing rhizomes and rootstocks is in the process of patenting. An internal DJF patent description has been made, and the result of the novelty search by a patent agent was that the description was recommended for further issuing of a patent. 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.

The investigation of the lethality of destructing methods assessed and quantified in the laboratory (M2.5) have resulted in methods and trial plans comprising; mechanical crushing and thermal treatment.

WP3 Field machinery for automatic intra-row weeding in row crops
The project has bought a low weight, 13 kW, robotic tool carrier (link: www.hortibot.dk). The robotic tool carrier is in its current state not suitable for row crops. Therefore, modification needs has been identified and initiated. Modifications to both mechanical and software parts are needed. 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. It is planned that a Ph.D. student will

be associated in parallel with the work on software modifications. A Ph.D. project has been advertised on 10th September within the research subject: Intelligent behaviour of a robotic weeding system.

Scenario selected, described and published as conference paper. The paper is based on the intended modifications of the robotic tool carrier equipped with the weeding tools that will be developed via D3.1 and D3.2, and comprised a feasibility study that was carried out to evaluate the viability of this innovative technology. A usage scenario was designed to set the implementation of the robotic system in a row crop of seeded bulb onions considering operational and functional constraints in organic crop production. This usage scenario together with the technical specifications of the implemented system provided the basis for the feasibility analysis, including a comparison with a conventional weeding system. The study showed that robotic inter-row and intra-row weeding systems have the potential becoming more economically viable when compared to conventional tractor operated weeding systems combined with manual weeding. Important determining parameters for the profitability of the autonomous system are the work quality in terms of weeding efficiency, initial investment, and operational costs like maintenance costs. The potential benefits in terms of operational capabilities and economic viability was quantified in the study. Profitability gains ranging from 20 to 50% are achievable through targeted applications. In general, the analyses demonstrated the operational and economic feasibility of using small-automated vehicles and targeted tools in specialized production settings. Further development of the scenario analysis and selection of weeding tool is initiated, with focus on publication of two peer-reviewed papers.

On September 31st, four mechanical engineering students from Vitus Bering will submit their report and mechanical drawings of a light weight toolbar solution for the robotic tool carrier. The toolbar comprises an electrically side shift and enables attachment of various agricultural implements like mechanical weed control units that is supposed to be developed within WP3.

The faced problems concerning computer vision and control of weeding tool(s) based on computer vision will be the most difficult ones to solve in this project. Therefore, the conclusion is to make contact to the researchers or companies with highest recommendation for crop identification via computer vision, i.e. University of Hohenheim, which currently is the lead within this subject. Contact to the Danish company, FP Engineering, has been made. However, the result is that their computer vision is not satisfactory for providing a solution to fulfill the M3.3.

WP4 Decreasing and delaying weed emergence in row crops

A punch planter prototype was purchased from our collaboration partner at Cranfield University, UK. The machine was set up for testing in the lab. An electric DC motor powered the seeding mechanism and a stationary compressor provided the necessary air pressure. The system will be attached to an automatic tractor existing at KU-LIFE. Software for an electronic controller system based on RTK-GPS will be developed to control the planter motor speed.

A second punch planter based on a different seeding mechanism will be provided by Bonn University, Germany.

The machine modifications and lab testing will be finished during autumn and winter 2007. Both machines will be ready for the planned field experiments in spring 2008.

WP5 Weed population dynamics model

Work on the model of *C. arvense* undisturbed growth is still in progress and continues throughout October-November to reach the deadline 1 December, when that project ends. Formally, the work on the *C. arvense* model is then taken over by this project.

A scientific paper describing the model of annual weed species has been under preparation (*A generic model of annual weed development and reproduction*) to be submitted in 2008.

C.2 Fulfilment of deliverables and milestones

(To be completed for each work package)

Deliverables list (from application)

Workpackage 1						
Delive-rable No	**Deliverable title**	**Lead scien-tist**	**Delivery date**	**Allocated scientific person moths**	**Type of de-liver-able**	**Fulfilled (ok) or devia-tions (d)***
D1.1	Three scientific papers on *C. arvense* and *T. farfara* source-sink dynamics under controlled conditions.	JCS	Jun-10	18	S	d
D1.2	Ph.D. thesis on *C. arvense* and *T. farfara* source-sink dynamics under controlled conditions.	JCS	Jun-10	18	S	d
D1.3	Scientific paper on *C. arvense* and *T. farfara* source-sink dynamics under field conditions.	IAR	Dec-10	5	S	d
D1.4.	Scientific paper on *C. arvense* preventive control: catch crop and stubble cultivation.	IAR	Jul-10	5.5	S	
D1.5	Scientific paper on *C. arvense* and *T. farfara* direct control between-crops	IAR	Nov-11	5.5	S	

** Deviations are to be further discussed in D*

Milestones list (from application)

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

** Deviations are to be further discussed in D*

Deliverables list (from application)

Workpackage 2						
Delive-rable	**Deliverable title**	**Lead scien-**	**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 tech- nology for rhizome and rootstock expo- sure and destruction including compari- sons with common implements for *E. repens* control.	EFK	Sep-11	3	O	
D2.4	Scientific paper on *E. repens* control using new technology for rhizome expo- sure and destruction in organic crop- ping.	BME	Nov-11	6.9	S	

** Deviations are to be further discussed in D*

Milestones list (from application)

Workpackage 2			
Mileston No	**Milestone title**	**Delivery date**	**Fulfilled (ok) or devia- tions (d)***
M2.1	Decisions made on tool design and configuration and appropriate meth- ods for rhizome and rootstock destruction for further studies.	Mar-07	d
M2.2	First prototype tools for field investigation and equipment for rhizome and rootstock destruction are ready.	Aug-07	d
M2.3	Modification and improvements of the technology for rhizome and root- stock exposure and destruction ended.	Jul-08	
M2.4	Exposing ability assessed under field conditions; first series.	Sep-07	d
M2.5	Lethality of destructing methods assessed and quantified in the labora- tory; first series.	Nov-07	
M2.6	Exposing ability assessed under field conditions; second series.	Sep-08	
M2.7	Lethality of destructing methods assessed and quantified in the labora- tory; 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*

Deliverables list (from application)

Workpackage 3						
Delive- rable No	**Deliverable title**	**Lead scien- tist**	**Delivery date**	**Allocated scientific person moths**	**Type of de- liver- able**	**Fulfilled (ok) or devia- tions (d)***
D3.1	Detailed design document - intelligent closed loop weed management imple- ment	MINO	Aug-08	5.5	R	
D3.2	Demonstration of mechanism for intelli- gent intra-row weeding	MINO	Jun-09	3.5	O	
D3.3	Scientific paper on scenarios, selection of technology and feasibility	MINO	Dec-09	5.0	S	

D3.4	Detailed design document - augmented machine	MINO	May-08	4.5	R	
D3.5	Demonstration of augmented implement carrier – in-field controlled operation	MINO	Jul-09	4.5	O	
D3.6	Scientific paper on automatic machinery for autonomous row operation	MINO	Dec-09	4.5	S	
D3.7	Requirements specification for implementation of the technology in future organic farming	MINO	Mar-10	4.5	R	
D3.8	Model of relevant operational control strategies and machinery implemented	MINO	May-08	3.5	O	
D3.9	Detailed design document - software components supporting selected control strategies	MINO	Jul-09	4.5	R	
D3.10	Demonstration of integrated automatic intra-row weeding machinery	MINO	Nov-09	3.5	O	
D3.11	Scientific paper on software components, control algorithm and simulations	MINO	Mar-10	5.5	S	
D3.12	Scientific paper on weeding effectiveness and reliability of automatic intra-row weed management	MINO	Feb-11	5.5	S	

** Deviations are to be further discussed in D*

Milestones list (from application)

Workpackage 3			
Mileston 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	Jun-08	
M3.4	Mechanism for intelligent intra-row weeding demonstrated in laboratory – in field operation	Apr-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	Aug-08	
M3.8	Augmented implement carrier demonstration - in-field operation	Feb-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	Dec-08	
M3.11	Assemble of a controller for vehicle and implement completed	May-09	
M3.12	Software framework, computers and electronics selected	Jul-09	
M3.13	Implementation of controller and validation completed on vehicle	Sep-09	
M3.14	Experiments with weeding effectiveness and reliability of automatic intra-row weed management completed	Sep-10	
M3.15	Optimal crop planting patterns to suit yield optimisation and space requirements to make automatic intra-row weeding operational identified.	Dec-10	

Deliverables list (from application)

Workpackage 4						
Deliverable No	**Deliverable title**	**Lead scientist**	**Delivery date**	**Allocated scientific person**	**Type of deliver-**	**Fulfilled (ok) or devia-**

				moths	**able**	**tions (d)***
D4.1	Punch planter adjusted and ready for field experiments	JER	Jan-08	5	O	
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			
Mileston No	**Milestone title**	**Delivery date**	**Fulfilled (ok) or deviations (d)***
M4.1	Punch planter adjusted to ready for field experiments	Jan-08	
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 *C. arvense* and *T. farfara* growth and population dynamics.	NHO	May-09	3.5	S	
D5.2	Scientific paper on field-validated simulation model of *C. arvense* and *T. farfara* 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			
Mileston No	**Milestone title**	**Delivery date**	**Fulfilled (ok) or deviations (d)***
M5.1	Model of *C. arvense* undisturbed growth validated against literature (from other project).	May-07	Nov-07
M5.2	Model of *C. arvense* disturbed growth developed from controlled experiment.	Dec-07	Jan-08
M5.3	Model of *T. farfara* growth developed from controlled experiment.	Feb-08	
M5.4	Models above validated against literature.	Oct-08	
M5.5	Best-bet strategies formulated by way of model.	Mar-08	
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	
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	
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
PhD. Project at Life, UC. Among a total of 12 applications for the PhD position, we selected Libère Nkurunziza, a graduate of University of Linköping, Sweden. However, Libere was not, at the time of acceptance for the job, Swedish citizen, so it took half a year to get him a work permit. Consequently, Libere commenced the PhD study at July first. It means that the PhD project dealing with WP 1 and Task1.1 will be delayed half a year. This also has consequences for the milestone (M1.1-M1.5) and delivery (D1.1-D1.2) lists that all will be delayed 6 months. Unfortunately, this may influence the experiments in tasks 1.2 and 1.3, which were meant to be planned according to this year's results in task 1.1.

WP2
Due to patent description and that patenting takes time, the contact to any machine manufacturer is delayed. Free delivery of machines from manufacturer is necessary, but depending on the patent. The patenting process has thus delayed M2.1, M2.2 and M2.4 but is planned to be catched up with during 2008. M2.7 is planned to proceed as planned.

WP3
Real time computer vision for plant identification is not developed anywhere. Due to personal reductions at DAE, the computer vision part is postponed. Therefore, the conclusion is to make contact to the researchers or companies with highest recommendation for crop identification via computer vision, i.e. University of Hohenheim, which currently is the lead within this subject. An adjustment of budget and project plans was necessary. Revision of budget was done in June 2007. Milestones and deliverables have generally been modified to meet the new staff composition at DAE.

WP4
Proceed as planned

WP5
Milestones M5.1 and M5.2 have been postponed due to delays in a preceding project. The postponement is not critical. The inclusion of growth disturbances in the *C. arvense* model cannot be based on results from the work of the PhD student (WP1) due to the delay in his engagement. Growth disturbances will instead be modelled based on literature data, as far as possible.

WPCo
Proceed as planned

E. Project publications and other products

1. Products from Organic Eprints archive

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.**

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 Bàrberi, 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.**

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.

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

5-25% 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.

*   25-75% financed by DARCOF

F. Scientific education

PhD-student Libére Nkurunziza has participated in the following courses:
Soar Scales and cross-scales in ecosystem services in agriculture and organic farming ¤ ECTS (see attached)

Nova Analysis of Biological assays in Agriculture, PhD course 6 ECTS (See Attached)

National cooperation with SDU/Technical Faculty/Robocluster about robotic tool carrier ("Plant Nursing" research project)

G. National and international cooperation

H. Critical reflection on the project

The project has just started this year, so not much can be reported regarding the experiments and preliminary results.

However, we have realised how difficult it was to fill the PhD position in WP1 mainly because of difficulties for foreigners to get a working permit in Denmark. It has delayed the PhD-project by 6 month and changed the planning of some of the other activities in WP1. The planning of some of the field experiments should have been based on the first results in the PhD project but the duration of the whole project does not allow for a delay of the field experiments. Thus it has been decided to commence these experiments independently of the PhD work but still in close collaboration with the achievements in the PhD project.

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, after some adjustments of the working package, we believe that we have brought WP3 back on the track and are able to deliver the deliverables listed.

8. Budget

A. Account for any change in budgets

B. Budget for the whole project

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

Year:	Original budget	Expected consump-tion 2007	2008	2009	2010	2011	Total
Man-months	201.45	37.89	66.96	67.55	25.58	14.05	212.03
Scientific personnel	149.75	25.11	48.46	52.55	18.38	12.05	156.55
Technical personnel	51.7	12.78	18.5	15	7.2	2	55.48

Year:	Original budget	Expected consump-tion 2007	2008	2009	2010	2011	Total
Salaries							
Scientific personnel	6,381,284	1,019,081	1,890,447	2,147,333	863,604	704,636	6,625,101
Technical personnel	1,431,754	286,226	383,820	342,320	171,400	46,000	1,229,766
Other operational costs	2,047,087	371,599	832,860	507,356	201,918	96,000	2,009,733
Equipment	71,200	40,400	25,000		1,000		66,400
Others (please specify)	68,675	11,000	22,000	24,000	12,000		69,000
Direct costs	10,000,000	1,728,306	3,154,127	3,021,009	1,249,922	846,636	10,000,000
Indirect costs (20% of direct costs)	2,000,000	345,661	630,827	604,201	249,984	169,327	2,000,000
Total	12,000,000	2,073,967	3,784.954	3,625,210	1,499,906	1,015,963	12,000,000

Comments:

9. Signatures and stamps

Name	Institute	Date	Signature
Head of project Bo Melander	Aarhus University, Faculty of Agricultural Sciences, Integrated Pest Management	1 October 2007	

Appendix I. Detailed budget

A. Budget for each participating institute

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

Year:	Original budget	Expected consump-tion 2007	2008	2009	2010	2011	Total
Man-months	74.9	9.9	17.65	18.15	15.38	13.65	74.73
Scientific personnel	40.4	5.4	6.65	8.15	8.38	11.65	40.23
Technical personnel	34.5	4.5	11	10	7	2	34.5

Year:	Original budget	Expected consump-tion 2007	2008	2009	2010	Total	
Salaries							
Scientific personnel	2,258,322	290,546	365,162	454,887	467,621	678,676	2,256,892
Technical personnel	716,000	122,00	182,000	202,000	164,000	46,000	716,00
Other operational costs	766,000	115,00	193,000	211,215	153,000	95,000	767,215
Equipment	25,000		25,000				25,000
Others (please specify)							
Direct costs	3,765,322	527,546	765,162	868,102	784,621	819,676	3,765,107
Indirect costs (20% of direct costs)	753,064	105,509	153,032	173,620	156,924	163,935	753,021
Total	4,518,386	633,055	918,194	1,041,722	941,545	983,611	4,518,128

Comments:
1.5 scientific months has been moved to 2010, and 10,000 DKK operational costs to 2008 compared to the original budget

B. Budget for each participating department

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

Year:	Original budget	Expected consump-tion 2007	2008	2009	2010	2011	Total
Man-months	75.5	16.5	27.5	28	2		74
Scientific personnel	54	13	22	25	2		62
Technical personnel	21.5	5.5	5.5	3	0		14

Year:	Original budget	Expected consump-tion 2007	2008	2009	2010		Total
Salaries	2,846,369	606,461	1,044,585	1,144,896	88,373		2,884,315
Scientific personnel	2,278,015	517,235	898,765	1,062,176	88,373		2,566,549
Technical personnel	568,354	89,226	145,820	82,720	0		317,766
Other operational costs	771,965	180,099	444,761	96,831	12,328		734,019
Equipment							
Others (please specify)							
Direct costs	3,618,334	786,560	1,489,346	1,241,727	100,701		3,618,334
Indirect costs (20% of direct costs)	723,666	157,312	297,869	248,345	20,140		723,666
Total	4,342,000	943,872	1,787,215	1,490,072	120,841		4,342,000

Comments:
Expected consumption in 2007 is reduced due to researchers leaving their positions at DAE. Consequently, it was necessary to adjust the budget for 2008, 2009 and 2010 according to the changed dates for milestones and deliverables as outlined above.

C. Budget for each participating department

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

Year:	Original budget	Expected consump-tion 2007	2008	2009	2010	2011	Total
Man-months	1.94	0.41	0.51		1		1.92
Scientific personnel	1.94	0.41	0.51		1		1.92
Technical personnel	0	0	0		0		0

Year:	Original budget	Expected consump-tion 2007	2008	2009	2010		Total
Salaries	102,600	20,000	26,000		56,600		102,600
Scientific personnel	102,600	20,000	26,000		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	20,000	27,000		57,600		104,600
Indirect costs (20% of direct costs)	20,920	4,000	5,400		11,520		20,920
Total	125,520	24,000	32,400		69,120		125,520

Comments:
0.51 scientific month has been moved to 2008 due to delays in the plans.

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	Expected consump-tion 2007	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	Expected consump-tion 2007	2008	2009	2010	2011	Total
Salaries	1,086,000						
Scientific personnel	1,086,000	174,000	355,000	369,000	188,000		1,086,000
Technical personnel							
Other operational costs	190,000	30,000	62,000	65,000	33,000		190,000
Equipment							
Others (please specify)	69,000	11,000	22,000	24,000	12,000		69,000
Direct costs							
Indirect costs (20% of direct costs)	269,000	43,000	88,000	91,000	47,000		269,000
Total	1,614,000	258,000	527,000	548,000	281,000		1,614,000

Comments:
Note the PhD project has been delayed 0.5 year because the student was first hired July first due to prolonged work permit issues.

E. Budget for each participating department

Name of Institute and department: WP4, **Department of Agricultural Sciences**, Life, UC

Year:	Original budget	Expected consump-tion 2007	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	Expected consump-tion 2007	2008	2009	2010	2011	Total
Salaries	647,900	75,000	283,700	294,400			653,100
Scientific personnel	507,900	0	227,700	236,800			464,500
Technical personnel	140,000	75,000	56,000	57,600			188,600
Other operational costs	307,900	45,000	130,400	131,100			306,500
Equipment	44,200	40,400					40,400
Others (please specify)							
Direct costs	1,000,000	160,400	414,100	425,500			1,000,000
Indirect costs (20% of direct costs)	200,000	32,080	82,820	85,100			200,000
Total	1,200,000	192,480	496,920	510,600			1,200,000

Comments:

One scientific month has been converted into technical time in 2007

F. Budget for each participating department

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

Year:	Original budget	Expected consumption 2007	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	Expected consumption 2007	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