Danish Research Centre
for Organic Farming

Midterm Status Report 2002 and Application for Continuation in 2003

For research projects financed by grants from
The Directorate for Food, Fisheries and Agro Business
under the Danish Ministry of Food, Agriculture and Fisheries

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1. Research program

Research in organic farming 2000-2005 (DARCOF II)

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2. Project title and number

I.9 Band heating for intra-row weed control

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3. Head of project

Martin Heide Jørgensen
Head of research unit
Danish Institute of Agricultural Sciences
Dept. of Agricultural Engineering

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4. Participating institutes

Danish Institute of Agricultural Sciences (DIAS)
The Royal Veterinary and Agricultural University (RVAU)

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5. Other project staff

Erik Fløjgaard Kristensen, DIAS, Dept. of Agricultural Engineering.
Bo Melander, DIAS, Dept. of Crop Protection
Hans-Werner Griepentrog, RVAU, Agrotechnology

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6. Project period (month, year)

Start of project:	04-2000
End of project:	12-2004

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

A. Project Summary

The project aims at developing a new integrated machinery system for thermal soil treatment in a narrow band around the crop rows, with which the germination of weeds in between the crops can be limited effectively. Weed control of inter-row weeds can be achieved by means of precision hoeing, where a control system with an integrated vision sensor guides the implement automatically. The control system is basically developed by the applicant and commercialised by “ECO-DAN”. The possibility of combining the implement for thermal treatment with a system for precision sowing will be analysed.

In combination with the automatic hoeing system, the proposed system for thermal row treatment will provide effective elimination of the need for manual weeding in row cultivated crops, such as beets and vegetables. The recommended system will enable the farmers and the agricultural industry to meet the customers’ demand for growing organic products.

The energy consumption of the system is considerable, but in relation to the effect of in-row weed removal, it is acceptable. In the evaluation of the energy consumption it is important to have in mind, that many growers makes use of surface flaming in weed control. There are big variations in the energy consumption for this operation but a use corresponding to app 75 l oil per ha is quite normal. The flaming affects the weed such that the weeding activities are reduced by app 30%. Many growers spend app 100 manual hours per ha on weed control. The evaluation of the thermal band heating has to bee seen in this perspective.

The initial laboratory results have shown that in order to obtain an effective weed effect, the soil would have to be heated to a temperature higher than 70°C. The lab tests showed, the system are able to give a close to 100% weed control by a energy input of 170 l oil per ha. The first field trials carried out in 2002 have shown that the maximum temperature would have to be increased to about 85-90°C to obtain an effective weed effect. This is mainly due to energy losses and poor seed-bed preparation. At 90^{o}C, the energy consumption will be about 300 l of oil/ha at a soil water content of 20%. If the system can be improved, so that the max temperature can be lowered to about 70^{o}C, then the energy consumption can be lowered to approx. the 170 l of oil/ha measured under lab conditions. The great deviation in fuel requirement is due to the fact that the losses will increase dependently at increasing temperatures, even if a temperature of 100^{o}C is not reached in any spot of the cross section witch would imply a dramatic energy loss due to evaporation of soil water.

The activities are organised in the following five work packages (WP):
1. Technical process analysis
2. Basic biological analysis (lab. test)
3. Establishment of prototype and technical field validation
4. Biological field validation
5. Precision sowing in treated bands and determination of seed positions

The timing of the activities is as follows: WP 1 & 2 are carried out in close connection, and likewise are WP 3 & 4. The activities in WP 5 follow their own plan. This WP aims at developing a system for precision seeding within the treated bands. WP 5 also involves a system for geo-positioning of each individual seed in order to control the following operations very precisely. The results of this package can be used independently, but the WP also involves a potential future improvement of the steam system, where the band treatment could be developed into a spot treatment. In the following, the technical, the biological and the seeding activities are described individually.

WP 1 & 3
A laboratory processing rig capable of producing batches of heat treated soil has been established. The test rig is designed as a rotating plate with a furrow, in which the soil is placed manually before the treatment is started. The process conditions are analysed to ensure a uniform temperature profile in the cross section of the soil string. The system is documented by determining the heat distribution and the cooling characteristics for the cross section of the soil profile. A temperature deviation of less than 20°C within the cross section can be achieved with the tine design and distribution used in the test rig. Under laboratory conditions, a cooling by 10°C from the maximum temperature will take approx. 10 min. A couple of series of heat-treated soil batches for biological analysis, as described in WP 2, have been produced.

The analysis concerning requirements for the design of injection tines has shown that soil adhesion can be a serious problem, especially if the water content and the temperature increase due to steaming. One way to avoid this could to design tines that will allow the surface temperature to become sufficiently high for the soil to dry. The capacity of single tines is likewise analysed. Here, the main restriction is that for flow rates that exceed a given value, some of the steam will penetrate the soil layer without condensing, and thereby, the energy loss will become unacceptably high. It seems possible to control the flow direction in order to obtain a uniform temperature profile in the soil cross section, although it has been experienced that large soil clods have not been penetrated effectively during the process. This means that in order to obtain a safe effect of the treatment, it is a precondition is that a sufficient seedbed preparation has been carried out prior to the operation.

A one-row equipment has been build up on the basis of a commercial 200 kW steam boiler. The universal frame of the equipment permits rearrangement of the tines. In the spring 2001, the first version of the system was tested in the field. The technical design was iteratively improved, and a second functional version was established during the winter 2001/02. In the spring 2002, a series of systematic field trials was established. The biological results are described in WP 4. The technical analysis has shown the maximum temperature and the tillage intensity of the seed-bed. The results can be manipulated by using an inter-row rotary tiller. The field experiments are carried out with 12 tines mounted on the frame, so that the soil temperature is gradually increased as the implement passes the soil. The row of tines is about

1,5 m long, which involves some restrictions with regard to keeping an even driving direction. In principle, the system functions reasonably well. To eliminate problems with rapid cooling of the surface layer, a rubber cloth can be mounted around the tines, and a section can be drawn behind the implement. As it appears from the results from WP 2 & 4, the biological results are promising.

The next phase will be to establish a more practically focused test version of the implement. One major question is whether it is possible to attract a commercial company to join the project activities with the goal of establishing the next version for field trials in the spring 2003, or whether it has to be done by the partners. To evaluate the commercial perspective for the system a consultant has been attached to the project with the purpose of making a market analysis for use of the system under European conditions. The analysis results show that the system may be of interest for organic growers of carrots, onions and other vegetables, whereas it does not meet the demands for organic beets. The calculation shows a break-even balance with an area of approx. 4 ha with carrots or onions. The calculation is based on a 5-year pay-off period. During the next month, contact will be taken to a few selected manufactures with the goal of discussing collaboration and knowledge transfer.

The following design parameters will be analysed in the next version:

- Integration of a rotary cultivator in front of the row of steam tines
- Better steam integration and distribution with the goal of minimising the required maximum temperature
- Possible process speed
- Compaction of the tines to minimise the length of the implement

In addition to the specific parameters the whole system will be redesigned to obtain a system that is more field applicable. The focus on this part depends on whether it is possible to attract a commercial partner.

WP 2 & 4

S preliminary structure of the basic biological model, including preliminary definitions of technical requirements for band-heating has been established.

The basic model has been defined as a non-linear and an S-shaped dose-response curve with a maximum level of *PLANTS* in untreated plots (*D*). The parameter ED_{50} describes the level of *MAXIMUM TEMPERATURE* where *D* is reduced to 50%. The exponent *B* describes the slope and the positioning of the dose-response curve around ED_{50}:

$$PLANTS = \frac{D}{1+\left(\frac{TEMPERATURE}{ED_{50}}\right)^{B}} + Error$$

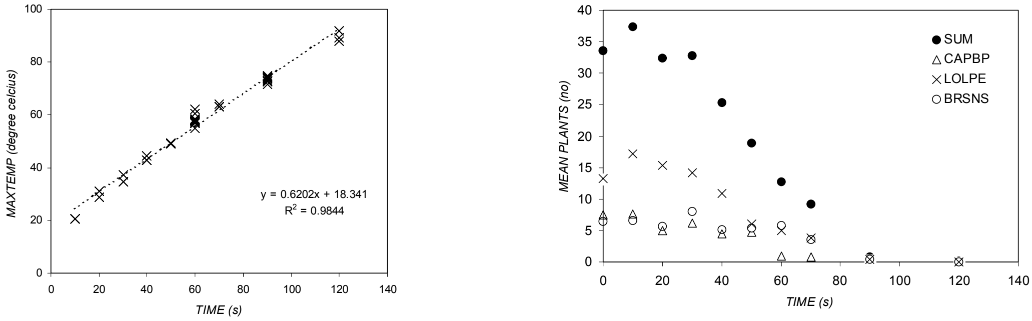

Figure 1. Relation between treatment time in the steaming table (s) and the maximum soil temperature (left). Mean number of recorded weed plants (No.) versus steaming time in table (s) (right). SUM is all weeds together, CAPBP is *Capsella bursa-pastoris* L., LOLPE is *Lolium perenne* L. and BRSNS is *Brassica napus* L.

Preliminary definition of the technical requirements to equipment for band heating. There are some slight indications of a minor positive effect of soil heating in the low temperature areas (approx. 20ºC) – see Fig. 1. This effect might be of importance for the development of the technical equipment, since a minor weed germination increase must be expected in soil fractions that are heated to only approx. 20ºC. However, this effect has no significant influence for the description of the lethal effects of agronomic importance when modelling the complete curve. The lethal effects of agronomic significance (at least 95% elimination of weed seeds) have been found to occur when the maximum soil temperature increases to approx. 75ºC.

The soil type and the moisture content of the soil samples did not affect the lethal effect of steaming, as long as the maximum soil temperature increased to 70°C or more. This was evident for both natural weed seeds in the samples and those added prior to steaming. However, the experimental study into the influence of different soil aggregates sizes failed due to a low content of natural weed seeds in the soil samples. The experiment will be repeated the coming spring with soil samples containing a larger number of weed seeds.

The germination of seeds of onion, maize, sugar beet and partly carrots that had been added to the heated soil immediately after steaming was generally not hampered by any of the investigated temperatures.

The results obtained in WP2 clearly indicate that steaming of the soil to a maximum temperature of preferably 80°C or more will reduce the number of emerged weed seedlings by 95-100%, irrespective of soil type and moisture content of the seedbed. It furthermore seems likely to sow the crop seeds directly into the heated soil by means of sowing equipment that is rear-mounted on the band-steamer. This will make retrieval of the steamed band much easier, and then, a separate pass for sowing can be avoided.

The first tests of the prototype band-steamer in the field showed that a high weed control level can be achieved; however, only at maximum temperature that is approx. 10°C higher than the temperature leading to the same effect in the laboratory. Distribution of the steam in the band and maintenance of the heat in the topsoil layers appear to be crucial factors for the success of band-steaming in the field. The importance of the seedbed structure in terms of soil aggregate size remains to be seen. It is expected that medium to large sized aggregates will protect contained weed seeds from the lethal effect of steaming and that if the aggregates collapse due to e.g. rain, they may later germinate.

WP 5

The application of Real Time Kinematic GPS (RTK-GPS) has permitted site-specifications within an accuracy of 1 cm. The RTK-GPS method will therefore form the basis of the entire concept for the positioning of individual cultivated plants within a field by way of electronic field maps with geographical co-ordinates for each individually sowed seed.

A six-row precision seed drill (Monopill, Kverneland) was used as a basis for the production of electronic field maps with geographic co-ordinates for each individually sowed seed. Seeds from the *Beta vulgaris*, cv. Magnum were sowed at a row interval of 50 cm. Each individual seeding unit was equipped with optical sensors for registration of the sowed seeds. The seed drill was furthermore equipped with an RTK-GPS, a DaqBook 120 datalogger and a portable PC. The GPS-antenna was placed on the seed drill rather than on the tractor, in order to eliminate any potential shear variations that might be caused by the movements generated by the tractor and the seed drill.

After the seeding and the data retrieval, data from the optical sensors and from the RTK-GPS were synchronised chronologically. On the basis of the synchronised data, an estimated geographical position for each individual seed was calculated by way of interpolation and geometrical calculations of the vector dislocation of the seeding units in relation to the GPS-antenna. The seed drill direction was determined by making a linear regression of the GPS co-ordinates.

The significance of the effect of the soil type and the seed bed quality on the average deviation between the sowed seed and the plant in question was studied with the purpose of estimating the influence of the biological factors of the concept on the overall deviation in cm between the estimated and the actual geographic position of the beet plants. The analysis was done by use of digital image analysis of the local area around the location of the seed. The localisation of the beet plant was measured, and the deviation relative to the placement of the seed was calculated. To find the actual placement of the seed, it was uncovered from the soil. The deviation between horizontal positions of beet plants and the beet seeds increased when the size of the soil aggregates in the seedbed increased (Table 1).

Table 1. Mean deviation between horizontal positions of beet plants and beet seeds

Soil	Seed bed quality	Mean deviation (mm)
Heavy clay	Coarse	17.4
Heavy clay	Fine	14.9
Sandy clay	Coarse	11.7
Sandy clay	Fine	11.2
	LSD (5%)	0.39

The digital image analysis system was also used for analysis of the general deviation between the geographic position of the seed placement and the beet germination point. This was done by placing a geographic reference point in the image area. The deviation between the estimated geographic co-ordinates for seeds and the actual co-ordinates for beets will be reduced when the forward speed of the sowing machine is reduced and when the relative speed of the seed disc is increased (Table 2).

Table 2. Average general deviation between estimated and actual geographic positions for beet plants.

Distance between seeds in the rows (mm)	Forward speed (km/h)	Average deviation (mm)
202	7.0	59.2
125	7.0	52.6
202	3.5	50.3
125	3.5	31.8
	LSD (5%)	5.4

During 2002, the system has been optimised. The seed drill has been equipped with an additional optical sensor for recording of the position of sticks in the soil. The sticks are placed in a row at a known geographical position. By means of this system the data retrieval and data management can be optimised by repeatedly passing and recording the positions. In addition, the seed drill has been equipped with a digital tilt sensor for measurement of the inclination of the seed drill forwards, backwards and sidewise.

The resulting electronic field map with estimated geographic positions for each single plant can be used for guidance of tractor, hoe, application of nutrients, fungicides, etc., for each individual plant. This provides the possibility of significant optimisation of the use of plant care.

Table A1. Work package list (from application)

No.	Work package title	Partici-pants*	Budget (1.000 DKK)	Start	End	Deliverables No(s):
1	Technical process analysis	MHJ, EFK	978	4/00	12/02	1a,1b
2	Basic biological analysis (lab. test)	BM, TH	990	4/00	12/04	2a,2b
3	Establishment of prototype and technical field validation	MHJ, EFK	1.246	1/01	12/04	3a,3b
4	Biological field validation	BM, TH	810	4/02	12/04	4a,4b
5	Precision sowing in treated bands and determination of seed positions	HWG	976	4/00	3/02	5a,5b

* Responsible participants are underlined

B. Objectives and expected achievements

The aim of the project is to develop a system for thermal soil treatment in close bands covering the crop rows. The system has to be optimised for minimum energy consumption and effective weed control in the intra-row area. In relation to the development of the system it is a high demand to respect the structure of the soil and its positive biological activity.

The objective will be achieved through the following activities:

- Establishment of a prototype of an implement that will permit the performance of thermal soil treatment in narrow bands covering the crop rows. The prototype will be a result of a detailed analysis of the thermal processes involved
- Establishment of basic biological knowledge for erasing the germination capacity of weed seeds in soil
- Realisation of the adaptation of precision sowing equipment to special demands involved with band treatment. Modification and investigation of particular tools to achieve good seed placements and good covering in treated bands. Determination of the position of each placed seed by means of high precision GPS. Utilisation of the position data to optimise the energy input on thermal soil treatment (spot treatment) and to allow a guidance of weeding tools between crop rows and plants in order to remove unwanted plants (inter and intra-row weeding).

C. Midterm results and progress

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

Results from the laboratory rig and the one-row field equipment prove the technical hypothesis. It is possible to obtain a fairly uniform temperature profile in a cross section of a soil band. The energy consumption is now 300 l oil/ha. A parameter study indicates that it can be lowered to approx. 170 l oil/ha by optimising the system.

Biological results from both the laboratory investigations and the field tests show that the system can imply an effective weed control, although the system for field application has to be optimised due to energy consumption reductions.

A market analysis for the system showing an economic balance for a production area of approx. 4 ha with carrots or onions has been made.

Results from studies of the precision seeder and (RTK) geo-positioning of individual seeds prove that in principle, the system is running. The seeding quality and the accuracy in seed distance are very high, but the statistical error in the positioning is too high to fulfil the aim of being able to use the data for precision hoeing.

C.2 Fulfilment of deliverables and milestones

(To be completed for each work package)

WP number and title **WP1: Technical process analysis**	Time schedule according to application	Deviations, if any*
Deliverables		
1.a: A setup for producing batches of thermally treated soil with a well-defined and documented treatment history.	(08/00)	
1.b: Documentation of the possibility of designing thermal soil treatment systems to give the soil a treatment with a given temperature history. The technical documentation includes heating source, temperature of transfer medium (heated air). The tillage/handling system is interacting with the soil.	(06/01)	
1.c: The theoretical energy consumption for different technical systems analysed under laboratory conditions.	(12/01)	
Milestones		
1.1 Establishment of laboratory processing rig capable of producing batches of heat-treated soil.	(06/00)	
1.2 Ready to carry out methodology test.	(09/00)	
1.3 1 phase of methodology investigations to be completed.	(06/01)	
1.4 Supplementary investigations and publication to be finished.	(08/01)	

** Deviations are to be discussed further in D*

WP number and title **WP2: Basic biological analysis**	Time schedule according to application	Deviations, if any*
Deliverables		
2.a: Draft paper for international publication on the basic model.	(06/02)	
2.b: Draft papers on 1) model extension and 2) crop establishment in pre-heated soil for international publication.	(06/04)	
2.c: National publication, as required.	(year 02-04)	
Milestones		
2.1 Preliminary structure of the basic biological model	(09/01)	
2.2 Completion of model extension to explain the impact of major factors affecting the biological effect of band-heating on weed seed germination	(09/02)	
2.3 Final results on crop establishment in heated soil and statements on the agronomic consequences	(04/03)	

** Deviations are to be discussed further in D*

WP number and title **WP3: Establishment of prototype and technical field validation**	Time schedule according to application	Deviations, if any*
Deliverables		
3.a: Establishment of an operative prototype for field test.	(02/01)	
3.b: Establishment of an optimised prototype for technical field validation and validation of the basic biological knowledge.	(02/02)	
3.c: Documentation of the technical system	(11/04)	
Milestones		
3.1 Prototype 1 ready for field test.	(04/01)	

** Deviations are to be discussed further in D*

WP number and title **WP4: Biological field validation**	Time schedule according to application	Deviations, if any*
Deliverables		
4.a: Draft papers on the perspectives of a weed control system for row crops based on band-heating for intra-row weeding and automatically row-guided hoeing for inter-row weeding.	(Year 03-04)	
4.b: Arrangement of demonstrations and seminars.	(Year 03-04)	
4.c:		
Milestones		
4.1 Final plans for field experimentation.	(02/02)	
4.2 Finalising field experimentation with band-heating including validation of the performance of the band-heater prototype.	(08/03)	
4.3 A final description of the potential and practical implementation of band-heating techniques in organic as well as in conventional row-cropping systems for herbicide saving purposes.	(09/04)	

** Deviations are to be discussed further in D*

WP number and title **WP5: Precision sowing in treated bands and determination of seed positions**	Time schedule according to application	Deviations, if any*
Deliverables		
5.a: Conference paper about RTK GPS and precision sowing.	(10/01)	
5.b: Good adaptation of precision seeder to equipment of band treatment.	(01/02)	
5.c: Optimised seed placement tools of precision seeder with regard to special soil properties of treated bands .	(08/02)	
5.d Draft paper about determination accuracy of row and seed positions for international publishing.	(08/02)	
5.e Information of placed seed positions for inter-row hoeing and intra-row weeding.	(08/02)	* Delayed
5.f Final report.	(08/02)	* Delayed
Milestones		

5.1: Seeder ready for first field trials.	(08/00)	
5.2: First field trials finished.	(11/00)	
5.3: Results from first field trials available (accuracy of crop row and seed/plant position determination).	(03/01)	
5.4: Seeder ready for second field trials.	(08/01)	
5.5: Second field trials finished.	(11/01)	* Delayed
5.6: Results from second field trials available (accuracy of crop row and seed/plant position determination in treated soil bands).	(03/02)	* Delayed

** Deviations are to be discussed further in D*

D. Description of deviations and subsequent adjustments of plans

- Collaboration with ECO-DAN
  In the application there was a signed agreement with the company ECO-DAN, confirming that the company would support the technical innovation in the project, and that they would take over the prototype establishment and commercialisation after finishing the project. Due to internal focusing on the activities, ECO-DAN is not able to complete the activities, and the project group is now free to make collaboration with other industrial partners. For this purpose, a market analysis as described in article 7a, has been established.
- Delay in WP 5
  Due to problems in attracting a research assistant and to unforeseen technical problems, a delay in the activities in the spring 2001 was realised. The plan and the budget was then remade, and since then, the activities have followed the revised plans. The activities in this WP will be finished by the end of 2002.

E. Project publications and other products

1. Articles in international, scientific journals with review procedures

Griepentrog, H.-W., Nørremark, M. (2003). High accurate seed position mapping by using RTK-GPS. Precision Agriculture (peer reviewed journal, planned).

2. Papers presented at congresses, symposiums, etc.

Blackmore,S., Griepentrog, H.W. (2002). A future view of precision farming: 131-145. In: Proceedings 'Precision Agriculture', Bonn, 13-15 March 2002. KTBL, Darmstadt.

Griepentrog, H.-W., Nørremark, M. (2003). The use of RTK-GPS for single plant care cropping systems. In: Proceedings of the 4th European Conference on Precision Agriculture, July 15-18, 2003, Berlin (planned).

Griepentrog, H.W., Nørremark, M. (2001). Bestandesführung mittels kartierter Pflanzenpositionen: 285-290. In: Proceedings VDI-Tagung Landtechnik, Hannover. VDI Verlag, Düsseldorf.

Jørgensen, M.H. & Melander, B. (2002). Band heating for intra-row control. Power and Machinery. Proc. AgEng 2002, Budapest. ISBN 963 9058 12 2ö, ISBN 963 9058 14 9, Abstracts Part 2: 130-131. CD Paper: http://www.gte.mtesz.hu.

Melander, B., Heisel, T. & Jørgensen, M.H. (2002). Stribedampning og andre teknologiske nyheder til bekæmpelse af ukrudt i økologiske grønsager (Band-steaming and other technological novelties for weed control in organic vegetables). Den nasjonale kongress for økologisk landbruk 2002, Høgskolen i Hedmark Report No. 3 – 2002, 9-16.

Melander, B., Heisel, T. & Jørgensen, M.H. (2002). Band-steaming for intra-row weed control. 5th EWRS Workshop on Physical Weed Control. Pisa, Italy, 11-13 March 2002, (CD-paper).

Melander, B., Heisel, T. & Jørgensen, M.H. (2002). Aspects of steaming the soil to reduce weed seedling emergence. 12th EWRS Symposia 2002, Wageningen (NL), 236-237.

Nørremark, M.; Griepentrog, H.-W. (2003). The use of RTK-GPS for high accurate georeferencing of field data. In: Proceedings of the 4th European Conference on Precision Agriculture, July 15-18, 2003, Berlin (planned).

Tei, F., Baumann, D.T., Bleeker, P.O., Dobrzanski, A., Economou, G., Fogelberg, F., Froud-Williams, R.J., Hoek, H., Melander, B., Rocha, F., Ruuttunen, P., Rzozi, S.B., Sanseovic, T., Simoncic, A., Torma, M., Uygur, F.N., van der Weide, R.Y., Verschwele, A., Villeneuve, F. & Zaragoza, C. (2002). Weeds and weed management in carrots: A review. 12th EWRS Symposium 2002, Wageningen (NL), 14-15.

3. Reports, articles in agricultural journals, etc.

Melander, B., Heisel, T. & Jørgensen, M.H. (2001). Stribedampning mod ukrudt i højværdiafgrøder (Band-steaming for weed control in high-value crops). Forskningsnytt om økologisk landbruk i Norden, No. 6. November.

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

Griepentrog, H.W., Nørremark, M. (2002). Positionering af frø og afgrøderækker med RTK-GPS (Positioning of seeds and crop rows by means of RTK-GPS). In: Proceedings 'Teknik i Landbruget 2002', 21.05.2002, Aarhus (DK).

Melander, B. Two lectures at the Agricultural University in Copenhagen on 21 and 23 November

Melander, B. Oral presentation at the EWRS working group meeting, Weed Management Systems in Vegetables, at Zaragosa, Spain, 4 June, 2001.

F Scientific education

None

G. National and international cooperation

- Kai Borre, Professor

University of Aalborg (AaU)

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- Kverneland Accord GmbH, Coesterweg 42, D-59494 Soest, Germany

- Trimble Navigation Europe Ltd, Meridian Office Park,
Osborn Way, Hook, Hampshire, RG27 9HX, England

Critical reflection on the project

The present status is that the functionality of the system is being demonstrated under field conditions, and that the further activities are concerned with documentation and improvement of the system.

As mentioned, the thermal band heating system eliminates the need for an extensive manual weeding, and therefore, it is considered an attractive system. In spite of that – especially in the organic perspective – there are two negative side effects that require special focus, namely the influence on the microbiology in the treated soil and the energy consumption.

As mentioned, the required energy input under laboratory conditions is 170 l of oil per ha. Under field conditions by use of the first test implement, the consumption has been approximately 300 l oil per ha. This fact is the driving reason why the future research plans are aimed at reducing the input to the same level as that seen under laboratory conditions. In the energy input analysis it is important to bear in mind that the use of the system will eliminate the normal requirement for one perhaps two flaming operations and a manual weeding activity, which will often require more than 100 hours per ha. In this perspective, a consumption of 170 l/ha seems to be reasonable.

The project planning has involved many concerns about the influence on the microbiology in the soil. The subject has been discussed with a number of national experts, who believe that it is an advantage if the operation is very precisely controlled, so that it can performed exclusively in bands. This means that the main soil volume will remain undisturbed, – in the upper layer, as well. The effect of this might be a rapid regeneration of the soil. A literature study has shown very few references on this topic. However, it seems that a regeneration period of about four weeks may be expected.

When analysing the negative side effects, one should also pay attention to the positive elements. When the microbiology is repealed, the disease carrying fungi will also be eliminated. This could be expected to have a positive effect on some germination problems. Another fact is that thermal band heating has proved to be an almost 100% effective weed control method, the result being that weeding damage on the crop will not occur and that the row crops may again be the crucial element in a rotation where weeds can be removed effectively.

In the project planning it was decided to focus on the weeding process in order to establish a well-documented system. In this perspective, the analysis of especially the influence of the microbiology in the soil was left out, even it is very interesting. Now that the system seems to have a promising functionality, it would be of great benefit for the project if it were possible to establish some supplementary funding in order to link such analyses to the project.

8. Budget

A. Account for any change in budgets

B. Budget for the whole project (1.000 DKK)

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

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	25	14	11	14		68
Technical personnel	20	13	9	4		47

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	208.000	537.000	375.000	490.000		2.180.00 0
Technical personnel	499.000	346.000	231.000	100.000		1.176.00 0
Other operational costs	300.000	105.000	84.000	72.000		561.000
Equipment						
Others (please specify)						
Direct costs	1.577.000	988.000	690.000	662.000		3.917.00 0
Indirect costs (20% of direct costs)	315.000	198.000	138.000	132.000		783.000
Total	1.892.000	1.186.000	828.000	794.000		4.700.00 0

Comments:

9. Signatures and stamps

Name	Institute	Date	Signature
Head of project			

Appendix I. Detailed budget

A. Budget for each participating institute (1.000 DKK)

Name of Institute: Danish Institute of Agricultural Sciences

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	13	11	11	14		49
Technical personnel	19	13	9	4		45

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	454.000	364.000	375.000	490.000		1.683.000
Technical personnel	469.000	316.000	231.000	100.000		1.116.000
Other operational costs	250.000	100.000	84.000	72.000		506.000
Equipment						
Others (please specify)						
Direct costs	1.173.000	780.000	690.000	662.000		3.305.00
Indirect costs (20% of direct costs)	234.000	156.000	138.000	132.000		660.000
Total	**1.416.000**	**936.000**	**828.000**	**794.000**		**3.965.00**

Comments:

Name of Institute: **The Royal Veterinary and Agricultural University**

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	12	7				19
Technical personnel	1	1				2

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	324.000	173.000				497.000
Technical personnel	30.000	30.000				60.000
Other operational costs	50.000	5.000				55.000
Equipment						
Others (please specify)						
Direct costs	404.000	208.000				612.000
Indirect costs (20% of direct costs)	81.000	42.000				123.000
Total	**485.000**	**250.000**				**735.000**

Comments:

B. Budget for each participating department (1.000 DKK)

Name of Institute and department: DIAS, Department of Agricultural Engineering

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	9	4	4	6		23
Technical personnel	12	7	5	4		28

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	315.000	140.000	140.000	210.000		805.000
Technical personnel	300.000	175.000	125.000	100.000		700.000
Other operational costs	200.000	60.000	44.000	44.000		348.000
Equipment						
Others (please specify)						
Direct costs	815.000	375.000	309.000	354.000		1.853.000
Indirect costs (20% of direct costs)	163.000	75.000	62.000	71.000		371.000
Total	**987.000**	**450.000**	**371.000**	**425.000**		**2.224.00**

Comments:

Name of Institute: DIAS, Department of Crop Protection

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	4	7	7	8		26
Technical personnel	7	6	4	0		17

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	139.000	224.000	235.000	280.000		878.000
Technical personnel	169.000	141.000	106.000	0		416.000
Other operational costs	50.000	40.000	40.000	28.000		158.000
Equipment						
Others (please specify)						
Direct costs	358.000	405.000	381.000	308.000		1.452.000
Indirect costs (20% of direct costs)	71.000	81.000	76.000	61.000		289.000
Total	**429.000**	**486.000**	**457.000**	**369.000**		**1.741.00**

Comments:

Name of Institute and department: **RVAU, Agrotechnology**

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	12	7				19
Technical personnel	1	1				2

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	324.000	173.000				497.000
Technical personnel	30.000	30.000				60.000
Other operational costs	50.000	5.000				55.000
Equipment						
Others (please specify)						
Direct costs	404.000	208.000				612.000
Indirect costs (20% of direct costs)	81.000	42.000				123.000
Total	**485.000**	**250.000**				**735.000**

Comments: