

Title: I.9 Band-heating for Intra-row weed control

Acronym: IWC (Intra-row Weed Control)

Date: 28.02.00

1. Summary

The project aims at the development of a new integrated machinery system, where the soil in a narrow band around the crop rows is being thermally treated, with which the germination of weeds in between the crops can be effectively limited. Weed control of inter-row weeds is achieved by means of precision hoeing, where the implement is automatically guided by a vision sensor based control system, which 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 research is carried out in close collaboration with the firm ECO-DAN that supports the prototype development and establishment.

2. Research group

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3. Introduction

Although the growers could benefit from growing more row crops, weeds are a major obstacle to increase organic cropping of row crops, such as outdoor vegetables, maize and sugar/fodder beets. Vegetables are considered to be high value crops that might improve the income of the growers, provided that they can manage to cultivate larger areas. Organic sugar is another product demanded by an increasing number of customers, but the supply of organic sugar is currently nearly absent due to the absence of areas of with organic sugar beets. Fodder beets and maize could improve the feeding of milking cows, but as yet, the potential is not by far utilised.

The idea of this proposal is to eliminate the weeding problem by implementing a thermal band treatment system combined with precision sowing. The system approach is new, although many of the elements are known from related implements.

Organic row crops generally have a high demand for weed control. Notably, crops such as seeded onions and leeks require a high degree of weed control throughout most of the growing season, contrary to sugar beets, where weed control is only important from crop emergence until canopy closure in mid-June.

Most of the row crops mentioned require hand-weeding, because highly effective methods for physical weeding are still needed. Generally, Danish and Swedish vegetable growers spend 100-300 h ha⁻¹ to hand-weed onions and carrots (Ascard, 1990; Nielsen and Larsen, 1991), but a time consumption of up to 500 h ha⁻¹ may be necessary under particularly weedy conditions (Melander, unpublished). Time consumptions of up to 150 hours ha⁻¹ for hand-weeding in sugar beets have also been reported (Ascard et al., 1995a). Organic growers will undoubtedly consider this to be financially appreciable, not only in terms of direct labour cost, but also in terms of the amount of time consumed for this single task, considering the amount of other tasks that will be urgent during the growing season. Another major obstacle to increase organic row cropping will be that it may be very difficult to find sufficient local labour to perform the hand-weeding, particularly if many farmers within a small community want to grow organic row crops.

Obviously, rationalisation and mechanisation of weed control in row crops would cause the release of valuable time and manpower, which may help to unburden organic farming.

The process of thermal treatment of the soil as a part of the seedbed preparation is well known, but it is new to perform the treatment in bands. Steaming of the upper 5 cm, or so, of the topsoil will have a clear impact on the weed germination, but the system offers a very high energy consumption, which will cause both environmental and economical problems. One of the reasons will be that the process water and the soil moisture sometimes will be heated to more than 100°C, even though the germination capacity may already be damaged by the time the temperature exceeds approx. 70°C. It is therefore expected to be possible to reduce the energy consumption drastically by treating the soil in narrow bands only and by controlling the heating process carefully.

Band treatment of soil in combination with precision sowing will cause crops to germinate and grow up uniformly in bands of dark soil. The crops will therefore stand out clearly against the background, and the conditions for video-based recognition of the row structure will be very good. The system is therefore highly suitable for precise automatic row guidance of subsequent operations such as hoeing, injection of fertilisers, etc.

4. State of the art

It is intra-row weeds, i.e. weeds that grow in the rows between the crop plants rather than those growing between the rows, that will create a demand for hand-weeding, (Mattsson et al., 1990). Usually, the first flushes of seedlings emerging within 2-3 weeks after sowing will be the most numerous ones, and thus the most time-consuming ones to remove, but later weed emergence may also cause considerable problems in slow developing crops. Several non-chemical methods to improve the control of annual intra-row weeds have been introduced in recent years. Some of the methods are based on new principles, such as vertical brush weeding and soil cultivation in darkness (e.g. Jensen, 1992; Melander, 1997; Fogelberg, 1998), while others are based on old principles that have been subjected to new research (e.g. Ascard, 1995; Ascard & Bellinder, 1996; Melander & Hartvig, 1995, 1997). Direct control methods to conduct post-emergence, e.g. weed harrowing, vertical brush weeding, torsion weeding, ridging and finger weeding, have shown to operate at relatively low selectivity. This may indicate that high weed control might be associated with unacceptable crop damage (e.g. Ascard & Bellinder, 1996; Melander, 1997; Melander & Hartvig, 1995; Ascard *et al.*, 1995b). However, more strategic approaches, where two or more methods have been combined into a specific control strategy adapted to the actual weed problem, have provided some promising results (Baumann, 1992; Melander, 1998a).

In spite of the fact that it would be desirable to become less dependent of mechanical post-emergence control, because it may cause damage to the crop, as well as of the costs involved will be fairly high at the present moment (Melander, 1998b). However, in order to avoid mechanical post-emergence treatment, strong efforts to prevent weeds from emerging in the rows will be needed. Apparently, this will not be possible with the current methods, and new approaches will have to be considered.

Thermal treatment of the soil appears to be a perspective approach in that context, because it may help to render manual weeding in organic row crops completely unnecessary. Previous investigations on soil steaming have shown that very effective and extended weed control can be obtained, because the heat will kill the weed seeds in the upper soil layers. Weed species such as *Senecio vulgaris*, *Stellaria media* and *Poa annua* were almost completely controlled, and the effect persisted for several months, provided that firstly the temperature was raised to more than 70°C at soil depths down to 2.5 cm and that this temperature was maintained for 6-9 minutes (Bødker & Noyé, 1994). The effect of heating on the germinating ability of weed seeds is also known from composting and mulching. Most viable weed seeds will lose their germination capacity at temperatures of about 60°C and persist for a long duration of time when covered by mulch and when in compost (Davies et al., 1993; Grundy et al., 1998). Experiments with solarisation by use of plastic sheeting have revealed soil temperatures as high as 57°C at a depth of 5 cm with large reductions in 46 weed species out of an initial group of 57 species (Linke, 1994). Thompson et al. (1997) have tested the viability of imbibed weed seeds in soil exposed to a range of different air temperatures in an oven. They used seeds of common arable weed species and found that germination of all the species could be prevented at 75°C (or higher) when exposed to heat for periods of 0.5 days or more. The maximum temperature required to prevent germination varied among species and was of greater importance than the duration of heating. However, the use of very high temperatures (262°C) did not result in a rapid devitalisation of the weed seeds, because the seeds were greatly shielded from the air temperature by soil throughout the reduced duration of heating. Bloemhard et al. (1992) found that heating with steam permitted better penetration of soil, as this method was much more effective than heating at the same temperature as in the oven.

Besides solarisation, steaming is the only applied technique for soil heating. With this method both the energy and the time consumption involved will be very high, primarily because the soil will be treated down to depths of 15-20 cm, and consequently, a large soil volume will be heated. Future development of soil heating methods should therefore focus on localising the heat to a certain soil layer in order to save energy and time.

As mentioned, thermal soil treatment is a known technique for pest control and seed manipulation. One type of commercial systems uses the principle of applying steam pressure on the soil surface. Steam will infiltrate well into the soil and be an effective energy conducting medium. Anyhow, there has to be a significant time process to ensure that also weeds covered with compact soil and aggregated at a given depth will be affected by the treatment. This is the reason why this type of implement is moved in steps or continuously at a relatively slow speed. With this system it will be difficult to control the depth of a treatment, and in part of the soil underneath the effective tilled layer, some of the energy may be consumed without exceeding the temperature, at which a weed killing effect may take place. Thereby, the energy will be lost. Another system will lift the upper soil layer and carry the soil on a conveyor belt through a thermal processing chamber. After the processing, the soil will be put back on the ground. The energy source in this system is that of a set of gas burners. Here, very accurate control of the working depth can be made. The next steps to be taken will be to control the tilled soil volume in precise bands and to control the thermal process, so that the energy efficiency can be optimised in relation to the biological effect obtained.

Weed seeds predominantly germinate from the upper 0-5 cm soil layer, and most seedlings emerge from the upper 0-2 cm soil layer, because small-seeded weed species are usually most frequent in the seedbank (Chancellor 1964; Roberts & Chancellor, 1986; Andreassen, 1991). Small seeded species, especially *Veronica persica*, *Viola arvensis*, *Stellaria media*, and *Papaver rhoeas*, only emerge from the upper 0-2 cm soil layer, due to the limited food reserves in the seeds. Species with larger seeds containing more food reserves may emerge from deeper soil layers, although a considerable number may emerge from the upper 0-2 soil cm layer (Chancellor 1964; Froud-Williams *et al.*, 1984). Examples include *Avena fatua*, *Sinapis arvensis*, *Alopecurus myosuroides*, and *Galium aparine*. Since the size of the viable seedbank in the upper 0-5 cm soil layer will determine the number of weed seedlings emerging in a crop, heating of the soil – also known as *band-heating* – should be targeted at minimising or even eliminating the content of viable weed seeds in that particular layer. In addition, the range of band-heating should be no more than approx. 5-7 cm, because remaining weeds can be controlled by common cultivation methods conducted close to the crop row (Ascard & Mattsson, 1994; Melander & Hartvig, 1997).

However, technical development of thermal band application would require identification of a number of biological parameters governing the inactivation of weed seed germinability, particularly when short periods of heating at very high temperatures are considered. This will clarify and specify the need of ability of technical devices that are developed with the purpose of developing commercial equipment with a reasonable working capacity. Obviously, temperature, duration of treatment and amount of soil to be treated are expected to have major impact, because they will all be decisive as the amount of heat that the seeds will receive. For example, biological investigations can reveal whether a short period at high temperatures will provide a better weeding effect than a long duration at lower temperatures. Also, soil type and water content of the soil appear to have a significant effect in that context, because both factors will govern the transmission of heat in the soil (Brady, 1974). The characteristics of the weed seeds in terms of thickness and hardness of the seed coat appear also to have significant influence on the effect of heating (Thomson *et al.*, 1997).

None of the mentioned factors have been systematically investigated in relation to the development of an operational weeding machine for band-heating.

Precision sowing instead of bulk drilling is currently the most common seeding procedure for sugar beets, maize and vegetables. Precision seeders have a high accuracy of seed placement, and consequently they will offer better conditions for development of crop plants by which a high yield may be obtained. Especially because of the uniformity in seeding depth and seed spacings in the row a high field emergence and homogenous plant development can be obtained.

The principle of singling the seeds is dependent on the seed properties, e.g. seed size and shape. For small seeds, e.g. vegetables, pneumatic systems are the most common ones, whereas for beets and maize mechanical systems are more common. Different types of removers, coulters, rollers, etc. are available today, so that the best way to adapt to soil type, operation condition and production strategy (conservation tillage) can be found. The aim is to obtain well-prepared local soil conditions, optimal seed placements and finally, suitable methods for seed covering and recompaction of the soil.

Due to the non-avoidable soil treatment during the seeding progress, weed seeds have to be stimulated to germinate (Rasmussen, 1996, Eriksen, 1999). The seeding operation will therefore contribute to a higher emergence of weeds.

Hoeing along crop rows is commonly used to remove weeds between the rows (inter-row weeding).

The combination of seeding methods and positioning systems utilising RTK GPS has not been used so far, although results from investigations for other agricultural applications have

been published (Larsen et al. 1994, Dijksterhuis et al. 1998, Van Zuydam et al. 1999, Gebbers/Schmidt 1999). The achieved accuracy was in the range from 1 to 2 cm.

5. Objectives and expected achievements

The aim 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 highly demanded 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 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).

6. Description of work packages including methods

Table 1. Work package list

Work package No.	Work package title	Responsible participant	Budget DKK	Starting date	Closing date	Deliverable No.
1	Technical process analysis	MHJ	949	4/00	12/02	1a,1b,,,
2	Basic biological analysis (<i>lab. Test</i>)	BM	990	4/00	12/04	2a,2b,,,
3	Establishment of prototype and technical field validation	MHJ	1.216	1/01	12/04	3a,3b,,,
4	Biological field validation	BM	810	4/02	12/04	4a,4b,,,
5	Precision sowing in treated bands and determination of seed positions	HWG	735	4/00	3/02	5a,5b,,,

WP1: Technical process analysis

Work package number:	1
Starting date or starting event:	04/00
Responsible person:	MHJ
Contributing persons:	EFK JKK
Man-months:	21

Objectives

The objective of the work is to establish specific knowledge concerning possible thermal processes that is expected to be suitable for the implementation of the treatment explained in WP 2. The most important parameters to be analysed is the energy consumption, the degree of mechanical soil interaction and the possibility of developing a commercial system with a low degree of complexity.

Description of work

Task 1: Basic process analysis.

There is a need for having the opportunity of producing thermally treated batches of soil that have well documented process history. The aim of this task is to build up a process rig for this purpose. The idea is to build a system consisting of a rotating pipe with some internal width drawing equipment to ensure a constant flow of the soil through the pipe. A thermal treatment of the soil will be ensured by a flow of heated air through the pipe in the opposite direction of the soil. The system is used to produce batches of soil with a well defined history of treatment for analysis in the biological tests (WP 2). The treatment history is described by the temperature gradients, including max. temperature and process time at this temperature.

Task 2: Investigation of possible process methodology

In general, the process methodology can be divided into two characteristic different system approaches, providing the soil band is lifted from the ground during the treatment or the heat is infiltrated in the upper soil layer without lifting the soil band. Perhaps the soil surface in the band is opened by elastic tines or some rotary implement during the process. In this WP different possible systems are analysed. The process rig from Task 1 fits the idea of lifting the soil band. In this task, the rig will be used for analysing the possibility of heat generating by burning gas or by heating air by means of oil burning. The tests will be carried out in laboratory by feeding the system with a controlled flow of soil, or by outdoor one-row tests, where the band geometry and the forward velocity will be strictly controlled to obtain comparable results. Included in the outdoor tests is the design of a soil handling system. A special pilot system for analysis of the approach without lifting the soil band has to be developed. The idea is to build a tunnel-like system to be heated with gas burners. This system has to be analysed in outdoor one-row tests. One of the major things to be analysed is the heat infiltration in the soil under different soil conditions and depending on the tilling intensity. The analyses also cover the possibility of controlling the thermal treatment to take place only in the predescribed band. Naturally, steam injected into the soil also have to be analysed, due to the fact that this method is already being used in commercial full-width systems. Steam will infiltrate easily into the soil and apply effective heat transfer to the soil with a low mechanical soil interaction. The question is, however, if the energy consumption is too high. As an alternative, the possibility of using microwaves as heating source will also be analysed under lab conditions. If this shows promising results, a quite different process rig will have to be built.

The results from this task gives the basic knowledge needed to start WP 3 concerning the technical product type.

Task 3: Publication

The basic knowledge established in this WP will be published in an international reviewed journal.

Task 4: Supplementary studies

During the work in WP 3 it is expected that some additional problems or possibilities will arise and have to be analysed.

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 include heating source, temperature of transfer medium (heated air). The tillage/handling system interacting with the soil. (06/01)

1.c. The theoretical energy consumption for different technical systems analysed under laboratory conditions. (12/01)

Milestones

Medio 2000: Establishment of laboratory processing rig, capable of producing batches of heat treated soil.

Autumn 2000: Ready to carry out methodology test.

Medio 2001: 1 Phase of methodology investigations to be completed

Medio 2001: Supplementary investigations and publication to be finished

WP2: Basic biological analysis

Work package number:	2
Starting date or starting event:	April-00
Responsible person:	BM
Contributing persons:	TH
Man-months:	25

Objectives

- 1) to establish a basic model describing the relationship between germination capacity of weed seeds in the soil as influenced by soil temperature and short heating periods provided by band-heating techniques
- 2) to extend the model to describe the influence of the following key-factors: soil volume, soil moisture content, soil type, and weed seed characteristics, such as size and seed coat structure
- 3) to investigate seed germination and plant establishment of crop seeds sown in pre-heated soil

Description of work:

Overall work plan :

The work will be arranged according to the following scheme:

- Task 1) Theoretical considerations and data capture for building the basic biological model (Objective 1), period: Apr-00 to Dec-00 and Feb-01 to Oct-01.
- Task 2) Model extension to include the effects of major key factors (Objective 2), period: Apr-01 to Dec-01 and Feb-02 to Oct-02
- Task 3) Publication of the results achieved in Task 1), period: 2002
- Task 4) Crop establishment in heated soil (Objective 3). Period: Apr-02 to Dec-02
- Task 5) Publication of results from Tasks 2) and 4). Period: 2003 and 2004

Work content of Tasks 1)-5):

- Task 1) Firstly, the literature will be reviewed followed by planning a phase for the experiments for model building. The planning phase will also include more theoretical considerations about the mathematical structure of the basic model, and consequently the amount of data required for verification. From mid-summer 2000, the first series of experiments with soil containing large amount of weed seeds of different species is planned to be started. The soil will be heated to a range of temperatures and heating periods specifically focusing on short periods of high temperatures. Temperatures ranging from e.g. 50°C to 500°C and periods of heating ranging from e.g. 1 sec. To 10 min. are considered. However, this will going to be defined more precisely during the planning phase. Technical equipment and devises for heating the soil will be delivered by the Department of Agricultural Engineering. The soil heating will take place in laboratory, and different heating sources, e.g. microwaves or steam, will be considered. The heated soil will be placed in trays which will be placed in a glass house for 30 days for germination, after which the number of emerged weed seedlings can be recorded. Non-heated soil samples will also be germinated for 30 days for comparison. It will also be considered to use soil samples with known weed seed contents where seeds of individual weed species will be incorporated into sterile soil samples prior to heating.
- Task 2) The work involved with Task 2) is an extension of that involved with Task 1). The basic model is going to act as a basic tool to understand and describe the impact of the key factors mentioned in Objective 2. The experiments will likewise take place in the laboratory, and the germination will take place in the glass house. Levels of each key factor will be chosen according to the variation that will be found in the field, e.g. sandy soils versus loamy soils, soil water contents at field capacity versus at saturation, and thick and hard coated weed seeds versus thin and soft coated seeds.
- Task 3) It is expected that the results achieved in Task 1) will provide sufficient information to submit a journal paper or at least a conference paper.
- Task 4) Samples of different soil types will be heated in laboratory and thereafter placed outdoors in the field in a band structure similar to the one created by the prototype band-heater. Crop germination, emergence and establishment will be monitored and compared to crop development in untreated soil. Crop species representing different demands for sowing depth and germination time will be used. It is also planned to collect small soil samples for the assessment of microbial activity in the heated soil in order to study the re-entrance of biological activity in the heated soil.
- Task 5) This part includes the final publication of results with special emphasis on the results obtained in Tasks 2) and 4). All categories of publications will be considered.

Deliverables

- Man (year 00-04): Annual progress reports completed by a final report
- 2.a. (year 02): Draft paper for international publication on the basic model
- 2.b. (year 04): Draft papers on 1) model extension and 2) crop establishment in pre-heated soil for international publication
- 2.c.(year 02-04): National publication, as required

Milestones

- M1 (autumn 01): Preliminary structure of the basic biological model including preliminary definitions of technical requirements for band-heating
- M2 (autumn 02): Completion of model extension to explain the impact of major factors affecting the biological effect of band-heating on weed seed germination
- M3 (spring 03): Final results on crop establishment in pre-heated soil and statements on the agronomic consequences

WP3: Establishment of prototype and technical field validation

Work package number:	3
Starting date or starting event:	2001 – 2004
Responsible person:	MHJ
Contributing persons:	MHJ EFK JKK
Man-months:	30

Objectives

Based on knowledge from WP1 and WP2 to design operative systems for iterative improvements and field validation.

Description of work

Task 1: The system approach

The WP will be started when the basic knowledge is elaborated to a degree where it becomes possible to design a documented first prototype for operative field investigations. A major element is the heating source that must be capable of producing the predescribed heating conditions, but here the capacity will also be important, and this is expected to be a bottleneck for the capacity of the full system. One possibility of manipulating the capacity could be to build separate treating systems for each row or building system that will treat several rows at a time. This has to be analysed together with the consequences for the soil handling systems, and also An overall estimate of the costs and the complexity of the system have to be analysed.

The idea will be to combine the implement for thermal band treatment with a directly mounted precision drill. It therefore is important to analyse the cooling gradient for the treated soil in the operative systems. Possibilities to improve the cooling gradient could be to perform local irrigation in the

treated bands and or to combine the system with a heat exchanging system, where cold air passes the hot soil before an additional heating takes place. The reason for doing so would be to decrease the energy consumption, and as such, the cooling effect should be regarded as an additional effect.

Task 2: Establishment of prototype 1

The design of the improved prototype should allow for adjustments of the max temperature and the process time at this temperature. Moreover, the band width and the depth has to be adjusted in order to be able to carry out the biological field tests described in WP 4. The technical validation covers the energy consumption obtained under field conditions As to the reliability of the system, an important part here will be the soil handling system, which will have to be analysed on soil areas with different clay contents and moisture contents. The analysis furthermore covers the effect on the aggregate stability of the soil under these different conditions.

The result is expected to be a well-documented system, built from commercial parts, if possible. The project therefore lacks a commercialisation and a simplification of the system.

Task 3: Field test and evaluation

Task 4: Publication

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

Spring 2001: Prototype 1 ready for field test.

WP4: Biological field validation

Work package number:	4
Starting date or starting event:	Apr-02
Responsible person:	BM
Contributing persons:	TH
Man-months:	20

Objectives

1) to validate intra-row weeding effects and crop responses by means of a prototype for band-

heating in row crops

- 2) to investigate the actual need for heating intensity in row crops showing different weed control requirements
- 3) to outline the agronomic aspects of a weed control system based on band-heating for intra-row weed control and automatically row-guided hoes for inter-row weeding

Description of work

The agronomic and biological validation of the prototype for band-heating contain the following tasks:

- Task 1) Planning of the biological and agronomic validation of the prototype band-heater (Objectives 1 and 2). The implementation of band-heating is temporarily planned to take place over two years (02 and 03), each year on a sandy and loamy soil, respectively. A two-factorial randomized block experiment will be laid out on each soil type. One factor will be heating intensity and the other one is considered to be crop types representing different demands for weed control.
- Task 2) Conduction of biological field assessments in years 02 and 03 (Objective 1 and 2). Firstly, weed emergence in the band-treated area will be followed over time. Secondly, the growth of weeds that may eventually have escaped band-heating will be recorded and the impact of the weeds on crop growth and subsequent weed population will be assessed. Thirdly, crop emergence and development will be described by regular assessment of the number of established crop plants, the vegetative crop growth above as well as below the ground (to follow root growth from heated soil to unheated soil) and finally the yield and quality of the crops. Fourthly, assessments on weed control effect achieved by supplementary inter-row weeding by automatically row-guided hoes.
- Task 3) Public demonstration of the band-heater, arrangement of seminars, and publication of results, nationally as well as internationally (Objective 3) to take place in 2003 and 2004.

Deliverables

- Man (years 02-04): Annual progress reports
- 4.a. (years 03-04): 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
- 4.b. (years 03-04): Arrangement of demonstrations and seminars

Milestones

- M1 (spring 02): Final plans for field experimentation
- M2 (autumn 03): Finalising field experimentation with band-heating including validation of the performance of the band-heater prototype
- M3 (year 04): 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.

WP5: Precision sowing in treated bands and determination of seed positions

Work package number:	5	
Starting date or starting event:	04/00	
Responsible person:	HWG	
Contributing persons:	HWG	1 new temp. post
Man-months:	24	

Objectives

The adaptation of precision sowing equipment to special band treatment demands shall be realised. Particular seeding tools will have to be modified and investigated to achieve good seed placements and adequate covering in treated bands. Furthermore the position of each placed seed shall be determined by means of a high precision DGPS. The position data will then be utilised to optimise the energy input of thermal soil treatment (spot treatment) and to allow guidance of weeding tools for inter and intra-row weeding.

Description of work

Depending on the design of the soil treatment equipment used and the performance of the implement the seeder specifications will be determined. Particular seeder components will have to be modified to achieve good seed placements and adequate covering in treated bands. Different types of cleaners, coulters, rollers, etc., will have to be investigated to find the best way to adapt them to the current soil type and operation conditions.

During the seeding operation, the GPS system attached to a seeder will log the positions and thereby the moving path of the operating implement. Furthermore, each seeding device – e.g. 6 per implement – will be equipped with optical sensors to monitor the dropped seeds.

(A six-row seeder with attached optical sensors will be delivered by the project supporting company Kverneland Accord, Soest, Germany.)

The time data that regard dropped seeds will be combined with those from the GPS receiver. The computer system of the seeding vehicle will store the data of the driving path and the position of seeds for each row. By knowing the machine dimensions it will be possible to calculate the absolute geographical position of the rows and the seeds. The accuracy of plant position determined by this method is within a range from 1 to 2 cm.

A map will be created to give information about the position of each dropped seed and the moving path of the seeding vehicle for the complete field. The field map with the position of each plant will serve as input data for a weeding implement. The logged data of row positions can be used for inter-row hoeing, while the single crop plant positions can be used for intra-row weeding.

(The RTK DGPS equipment is available at The Royal Veterinary and Agricultural University, Dept. of Agricultural Sciences. Specially developed and optimised GPS equipment for the described task will cost between DKK 20.000 to 25.000, providing a production of 10 devices is made. The devices will therefore be suitable for today's agricultural applications [Borre 1999].)

Deliverables

Man Annual progress reports WP5

5.a Conference paper about RTK GPS and precision sowing (10/01)

5.b. Good adaptation of precision seeder to equipment of band treatment (12/01)

5.c. Optimised seed placement tools of precision seeder with regard to special soil properties of treated bands

5.d. Draft paper about determination accuracy of row and seed positions for international publishing (4/02)

5.e. Information of placed seed positions for inter-row hoeing and intra-row weeding

5.f. Final report (4/02)

Milestones

8/00: Seeder ready for first field trials

11/00: First field trials finished

3/01: Results from first field trials available (accuracy of crop row and seed/plant position determination)

8/01: Seeder ready for second field trials

11/01: Second field trials finished

3/02: Results from second field trials available (accuracy of crop row and seed/plant position determination in treated soil bands)

7. Implementation and time schedule**Table 3. Deliverables list**

Deliverable No.	Deliverable title (this is filled out according to the descriptions)	Delivery date	Meeting	Nature
1.a	A setup for producing batches of thermally treated soil with a well defined and documented treatment history	Aug. 2000		O*
5.a.	Conference paper about RTK GPS and precision sowing	Okt. 2001		Pu
Man. A	1. Annual progress report 2000	Nov. 2000		Re
3.a	Establishment of an operative prototype for field test	Feb. 2001		O*
1.b	Documentation of the basic technical process analysis	Jun.2001		Re
5.b.	Good adaptation of precision seeder to equipment of band treatment	Dec. 2001		O*
5c	Optimised seed placement tools of preci-	Dec. 2001		O*

Deliverable No.	Deliverable title (this is filled out according to the descriptions)	Delivery date	Meeting	Nature
	sion seeder with regard to special soil properties of treated bands			
Man. B	2. Annual progress report 2001	Nov 2001		Re
3b	Establishment of an optimised prototype for technical field validation and validation of the basic biological knowledge	Feb. 2002		O*
5.e.	Draft paper on placed seed positions for inter-row hoeing and intra-row weeding	Apr. 2002		Pu
5.f.	Information of placed seed positions for inter-row hoeing and intra-row weeding	Apr. 2002		O*
2.a	Draft paper for publication on the basic biological model	Nov 2002		Pu
Man. C	3. Annual progress report 2002	Nov 2002		Re
1.c	Documentation of the supplementary technical process analysis	Dec. 2002		Pu
4.a.	Draft papers on the perspective 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.	May. 2003		Pu
4.b	Demonstration on the perspective of the system	May. 2003		Re
Man. D	4. Annual progress report 2003	Nov 2003		Re
4.b	Demonstration on the perspective of the system	May 2003		Re
2.b	Draft paper for publication on the model extension	Jun 2004		Pu
2. c	Draft paper for publication on crop establishment in pre-heated soil for international publication	Nov. 2004		Pu
3.c	Draft paper for publication of the technical documentation	Nov. 2004		Pu
Man. E	5. Annual progress report 2004	Nov 2004		Re

O*: Equipment established as an integrated part of the research.

Table 4: Task and Time table

Acro- IWC	Year Mont	200												2001												2002												2003												2004																										
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10																	
Tasks																																																																												
Project Management: Annual reportation Coordination meetings			X						X			X		X						X				X		X									X			X		X									X			X		X												X						X				
WP1: Basic technical lab studies Supplementary lab studies				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																				
WP2: Theoretical consideration and model extension Publication and results from the above Crop establishment in heated soil Publication			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
WP3: One row field studies Field trials (six rows equipment)													X	X	X	X	X	X	X	X	X	X	X	X	X	X												X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
WP4: Conduction of biological field assessments Publication and demonstration																									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									
WP5: Establishment of seeder and first field trial Modification and second field trial			X	X	X	X	X	X	X	X	X	X	X	X	X										X	X	X																																																	

8. Collaborative partners

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- Trimble Navigation Europe Ltd, Meridian Office Park,
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9. Budget (details after 21.02)

Institution DJF, JBT	2000	2001	2002	2003	2004
Salary (scientific)	140.000	175.000	140.000	140.000	210.000
Salary (technical)	100.000	200.000	175.000	125.000	100.000
Operation	75.000	125.000	60.000	44.000	44.000
Overhead	63.000	100.000	75.000	62.000	71.000
Total	378.000	600.000	450.000	371.000	425.000
Institution DJF, PLB					
Salary (scientific)	68.000	71.000	224.000	235.000	329.000
Salary (technical)	73.000	96.000	141.000	106.000	0
Operation	25.000	25.000	40.000	40.000	28.000
Overhead	33.000	38.000	81.000	76.000	71.000
Total	199.000	230.000	486.000	457.000	428.000
Institution KVL					
Salary (scientific)	243.000	324.000	81.000		
Salary (technical)	30.000	60.000	0		
Operation	30.000	40.000	5.000		
Overhead	61.000	85.000	17.000		
Total	364.000	509.000	103.000		
Total	941.000	1.339.000	1.039	828.000	853.000

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