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VISIT TO AUSTRALIA AND NEW ZEALAND, 7 SEPT. - 12 OCT. 2002

Field day at Colin Gardener's property in Moora (WA)

by

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Introduction

Just after *the 5th Physical and Cultural Weed Control* (PCWC) working group meeting in Pisa, Italy, March 2002, Mike Collins and Frances Hoyle, both from the Department of Agriculture, Centre for Cropping Systems, Northam Western Australia (WA), asked me whether I would like to visit Australia (AUS) and give some talks on results and experiences with non-chemical weed control in arable crops in Denmark and other European countries. Previously, I had been appointed as the new chairman of PCWC (www.ewrs.org/ewrs-pwc.htm) at the Pisa meeting. PCWC is a very active working group with more than 200 members mainly within Europe. The group is connected with the European Weed Research Society (EWRS, www.ewrs.org). Mike Collins also knew me from previous visits to Denmark, and he was quite well informed about the Danish work on non-chemical weed control that has been going on since the mid-80's. Appendix A contains the introduction to our work that I sent to Australia before leaving Denmark, and Appendix B is my CV.

Shortly after the Pisa-meeting, Mike Collins made an enquiry to his contacts round Australia and New Zealand (NZ) to ask whether they were interested in meeting me. Several people responded positively in the weeks to follow and so we ended up with a programme that included visits to Western and South-Eastern Australia, Tasmania, and New Zealand. In the meantime, Andrew Bishop from the Department of Primary Industries, Water and Environment, Tasmania, who had shown a strong interest in my visit, came to visit me at my department in Denmark in May 2002. His visit was part of a long tour round the North European countries.

My visit had three objectives. Firstly, to inform about the European work on physical and cultural weed control. Secondly, to introduce me to agriculture and weed problems in AUS and NZ. Thirdly, to discuss the possibilities of establishing an Australian / New Zealand working group on physical and cultural weed control and how relevant linkages to PCWC can be made. This report is a short summary and selection of people and places that I have seen. It contains my observations, impressions as well as opinions that may differ considerably from an Australian / New Zealand perspective. In some respects, my scientific and cultural background is quite different from what I experienced during my tour, and please excuse me for expressing opinions that may purely be a reflection of poor knowledge and understanding of AUS / NZ agriculture and way of thinking.

Western Australia, 8 -19 Sept.

Excursion to Avondale Research Station, Wednesday 10 Sept.

A major issue at the 13th Australian Weed Control Conference in Perth was problems with herbicide resistance in wild radish and ryegrass populations, and an excursion to Avondale Research Station close to York had been arranged to see some experiments focussing on the resistance issue. (Herbicide resistance is a very small problem in my country). I noticed two approaches to deal with the problem. The one was a lot of small screening plots to look for new effective compounds against resistant weeds. In the short term, such experiments are of course relevant to solve urgent weed problems for the farmers. However in the long run, I find the reliance on new chemicals to turn up regularly and conveniently an endless battle with no happy ending, if cropping practices are not changed as well to disfavour proliferation of the problematic weeds. The other approach actually did include cultural factors to deal with ryegrass problems, and the most effective method appeared to me to be mouldboard ploughing. Mouldboard ploughing simply buries the ryegrass seeds deeply into the soil and thereby prevents germination and emergence. The relatively short living nature of ryegrass seeds will cause many of them to die within a few years, so another

mouldboard ploughing should not create a new weed problem as long as the time interval is long enough. I noticed that mouldboard ploughing is not very known or common in WA and found the discussion on whether farmers would accept such a time consuming method quite amusing. Of course, farm sizes are generally much larger in AUS than in Northern Europe but we do have farms that mould board plough 2000-3000 ha every year. So mouldboard ploughing on land heavily infested with ryegrass, which I would expect to cover only a part of the total farmland, appears manageable to me, particularly as long as this measure only has to take place occasionally.

The Liebe-goup field day, Thursday 12 Sept.

The field day took place in Buntine approx. 200 km northeast of Perth. Different cropping aspects were presented in a very professional way but in very poor crops. Buntine is close to the Australian desert and I got the feeling that cropping is really at the edge in this area. Problems with drought and salinity were very often brought up during my entire stay in AUS. Severe problems that seemed rather insoluble to me but the discussions mostly focussed on ways to solve the problems technically rather than on giving up the land for cropping purposes or other human activity. In Denmark (5.3 mill. people living on an area of 2/3 the size of Tasmania), where human pressure on the land is much higher than in AUS, we have had this debate for several years of areas not being suitable for cropping. This has resulted in areas, where cropping has been given up in favour of nature conservation purposes or just to avoid the negative impact on the environment that agriculture in my country often causes. This development has been heavily subsidised by the government.

Colin Gardener's organic farm in Moora, Friday 13 Sep.

In connection with my visit to WA, Steven McCoy, Department of Agriculture, Government of WA, had arranged a field day on Colin Gardener's organic farm near Moora. It turned out to be a very interesting day. We saw some of his fields and discussed aspects such as crop viability, crop fertilisation, weed pressure, weed control. Some key figures about Colin's farm: 1600 ha (40% organically certified); crop rotation - 3 years' pasture followed by one years' winter wheat and then again 3 years' pasture; winter wheat yields 1.4 - 2 t ha^{-1} (30% less than the conventional yields in the area); stocking rate 7-9 sheep ha^{-1}.

During the day, it became evident to me how difficult organic farming in WA must be as compared with our situation. Farm income was mainly based on the actual organic wool and wheat prices on the export market with very little domestic sale. To me, it appeared to be economically very narrow and uncertain. Other agricultural productions were very difficult because of the low and very restricted water supply. Thus, vegetable production and livestock other than sheep were not possible, we were told. However, Colin and the other organic farmers gathered appeared to be quite happy with their organic choice that was mainly driven by idealism. We had the same situation 20 years ago, where organic farmers were few in numbers but strong believers. This has changed since the introduction of very favourable and almost luxurious subsidies offered by the government since the beginning of the 90's. More 'business-oriented' farmers are now common among the organic producers. Nevertheless, I was quite impressed with the pioneer spirit and courageous attitude of Colin and his colleagues considering their conditions for organic production. Just to mention some of the favourable conditions from which our growers are benefiting: 1) a strong domestic market; 2) an increasing export market nearby (e.g. millions of potential customers in Germany and Britain); 3) publicly funded education and training courses; 4) high subsidies; 5) access to research results governmentally financed; 6) an extensive advisory service throughout the country; 7) strong cooperation among the organic growers, particularly in terms of the exchange of nutrients; 8) last and not least short distances.

During most of the field day, we discussed the prospects for using mechanical weed control in winter wheat. I got the impression that the implements we are using in Europe were not very well known by the growers. Generally, the growers believed that the soils should be cultivated as little as possible mainly to preserve organic matter in the soils. I heard the same statements among the conventional growers and their advisers as well. During my entire stay in AUS, I really never came to any unambiguous conclusion with myself as to whether soil cultivation would be that harmful to the soil as I was told. Sometimes I got the feeling that this understanding of soil conservation was more founded in 'a general opinion/perception' rather than scientific evidence. Weed management in organic cropping systems does require some cultivation operations to take place occasionally, if weed problems are to be solved. Furthermore, most mechanical weed control methods only work the uppermost soil layer, which should have only limited impact on soil organic matter. I have not seen any organic cropping systems yet, where weeds could be controlled without the use of any direct measures, such as flaming, steaming, hand weeding, cutting and especially mechanical control. However, I have to admit that our soils in Northern Europe are geologically much younger and probably also much less fragile than the Australian ones.

The WANTFA Meckering field day, Wednesday 18 Sept.
WANTFA (the Western Australian No-Tillage Farmers Association) arranged the field day, and I was very impressed by the professional set-up of this educational day. Many agronomists presented different aspects of cropping in the wheat belt of WA. I got the impression of a research and advisory staff working hard and determined to provide the farmers with new information to help them improving their cropping systems. However, I also felt that farming is really under pressure in the wheat belt and that both farmers and agronomists are constantly looking for new and better solutions. Again, I felt embarrassed about our situation in Denmark as compared with the conditions in WA with droughts, crop failures, and little governmental support as something you just have to deal with being a farmer in WA. Just to mention some of our advantages: high subsidies, winter wheat yields of 8-11 t ha^{-1} in most areas (that may drop to 6 t ha^{-1} in bad years), plenty of water supply all over the country, and few limitations for livestock and vegetable production. However, we do have many environmentally motivated restrictions on farming.

No-tillage seems to be the big issue not only in WA but also in other parts of AUS that I visited. The benefits are obvious in terms of time and cost savings, and to that Australian farmers and agronomists also add the aspect of soil conservation, which actually is not one of the key factors driving non-inversion tillage in my part of the world. Currently, we have a strong discussion whether or not to shelve the mouldboard plough and lower soil cultivation intensity to a minimum. The major reason for our development is the fact that individual farms are getting larger and larger and so time becomes more critical.

Southeastern Australia, 19-29 Sept.

Agricultural engineers in the Adelaide area, 19 and 20 Sept.
I met with Jack Desbiolles (University of South Australia), John Matthew, and Chris Penfold (both University of Adelaide, Roseworthy Campus). All very dynamic people looking at all sorts of engineering aspects in agriculture. As Chris commented, 'the dynamic behaviour is not just an expression of interests and desire but it has also got an element of prostitution in order to meet the sometimes horrible and uncertain financial conditions that agricultural research are facing nowadays. I can only add: 'Apparently, our situation for funding research is not just a European phenomenon but seems to be present worldwide'. Particularly, the work with heating ryegrass seeds

in connection with the combining (harvesting) operation caught my interest. Lowering or even stopping the annual ryegrass seed input would certainly help a lot to diminish ryegrass populations. We know that very well from numerous population dynamic studies and modelling work.

At Roseworthy campus, I had a long talk with Sam Kleemann about problems with ryegrass and wild radish, the two most troublesome weed species in AUS I reckon. During my stay in WA, I also noticed the many discussions on spraying strategies in minimum tillage systems. The herbicide input for cropping a winter wheat crop appears to me to be almost enormous as compared with our input. The double knockdown strategy contains a heavy herbicide input, which would never be accepted in my country. (Here I have to add that we do not have severe resistance problems). But also the fact that many compounds, which we prohibited many years ago, are still allowed in AUS. Notably the permission to use the very toxic herbicide, paraquat, astonished me. We have had a policy for almost 20 years trying to encourage, and sometimes forcing, agriculture to reduce pesticide consumption in order to meet an increasing environmental concern in the public. This policy has now spread to most other EU-countries and it seems that future subsidies from the EU will have a strong motivation in environmental schemes. To me, this discussion on herbicide consumption appeared to be weak in AUS except for Tasmania.

Institute of Agricultural and Horticultural Research in Mildura, Saturday 21 Sept.
Mike Collins and I met with Kristiane Jaeger, who runs a new project on organic vegetable cropping. We saw her field experiments and discussed some of the challenges that she was facing when starting up such new work. Kristiane worked very enthusiastically on the project, but it seemed to me that she was the only person working on organic aspects at the Institute. The importance of having strong networks struck me during my visit in Mildura. Research in organic cropping involves a lot of difficulties both in terms of design and conduction of field experiments as well as the more "intellectual part" with identifying relevant research themes, formulating a hypothesis, collecting relevant literature, publishing, etc. Exchange of information, experiences and "know-how" is essential, but sometimes I got the feeling that researchers might easily become isolated in AUS, partly because of the geography but probably also partly because of tradition. In this context, I have to say that I can travel back and forth by car to any corner of my country within one long day and still have time enough for a meeting lasting several hours. Nevertheless, networks are extremely important and I know that Mike Collins and Andrew Bishop have already taken action in this context.

Rutherglen Research Institute, Monday 23 Sept.
Viv Burnett at Rutherglen covers a wide range of activities regarding organic farming, notably research, dissemination of information, and advisory tasks. She showed us some of her ongoing research with weed management in organic crop and pasture systems. Particularly her approach to improve the management of pastures before going into annual cropping with winter wheat, canola or pulses was very interesting. Controlling ryegrass is the big issue, and we saw different tactics to deal with this problematic weed: e.g. effects of different grazing and hay/fodder cutting strategies in the late pasture phase before entering annual cropping and the competitive ability of different winter wheat varieties under the influence of different seed rates to suppress weed growth were studied. Somehow I felt quite pleased with this work because it really included cultural and preventive control measures very actively.

Rosnay farm in Canowindra, New South Wales, Tuesday 24 Sept.
Sam Statham runs Rosnay Farm together with his father, and Sam is very active in promoting organic farming not only locally but also countrywide. He regularly disseminates newsletters

electronically to a wide range of people, letters dealing with both technical and political aspects. We also visited other organic growers in the area, and I had the pleasure of staying overnight in Sam's organic bale house.

The WeedFix weeder for vegetable crops at the Institute in Mildura. Kristiane Jaeger in the middle and Mike Collins on the right.

The group of Deidre Lemerle at Wagga Wagga Agricultural Institute, Wednesday 25 Sept.
Formerly, the group has been working on crop/weed competition and in particular on ways to improve the competitiveness of cereal varieties. Some of this work is now transformed into the development of new openers for direct drilling or minimum tillage systems. David Gregor has taken up the challenge of developing an opener that is capable of drilling cereals at narrow row spacing under high residue conditions to improve crop competitiveness. It will be interesting to follow his achievements. I was also introduced to some field experiments looking at different cutting regimes of hay to reduce ryegrass seed shedding, which of course is expected to lower ryegrass infestations in subsequent crops.

Kerry Andersson's farm near Wagga Wagga, Thursday 26 Sept.
Kerry Andersson showed us his controlled traffic systems on his farm. An obvious measure to avoid overlapping of pesticides and fertilisers and to limit soil compaction.

The Australian Conference on Engineering in Agriculture, Charles Sturt University, 27 and 28 Sept.
The conference covered a wide range of engineering issues in agriculture. I will not go into further details about the programme but rather comment on the frustrations that the attendees were expressing in relation to the lack of interest in agricultural engineering research that seemed to be present among politicians and probably the manufacturing industry as well. One of the explanations that came up was the poor ability of engineers to explain the relevance of their work and to act as lobbyists. I think that you may find similar traits among European engineers but our politicians' attitude towards agricultural engineering has become more positive in recent years. They have realised that engineering research is necessary for solving the environmental problems that follow agricultural activity. In my area of expertise, weed research, we really need new technical solutions to be able to replace or at least reduce reliance on herbicides.

Tasmania, 30 Sept. – 4 Oct.

Andrew Bishop and John McPhee from the Department of Primary Industries, Water and Environment, Devonport Tasmania, had arranged my stay in Tasmania. The Tasmanians had expressed a strong interest in our pesticide policy in Denmark, and particularly which actions we have taken to reduce reliance on pesticides and to promote organic farming. Andrew and John had arranged seminars at three places, Devonport, Launceston, and Hobart, where I gave talks on these issues to broad audiences. Besides that, I visited several farms and field trials, where we discussed the prospects of using less herbicide.

Among the places that I visited in AUS, Tasmania was probably the state showing the strongest interest in farming systems with as little detrimental impact on the environment and nature as possible. Not so much among the farmers but more on the part of research, advisory service, and authorities. Regarding the farmers, it was quite amusing for me to experience that farmers are farmers whatever it is Denmark or Tasmania. Their scepticism towards new initiatives and way of responding are not very different in spite of being more than 15.000 km apart.

Generally, I found many similarities between Danish and Tasmanian agriculture, although the Tasmanian climate is slightly warmer and cropping is more dependent on irrigation. The increasingly critical view on pesticide consumption in Tasmania appear to be similar to the one we had 15-20 years ago, and still have. However, I did not get the impression that this environmental concern had changed practices much as pesticide legislation was still quite liberal and the number of organic farms or organic area was very small. That may change considerably in years to come, particularly if the demand for organic products and/or products produced according to certain environmental schemes increases on the overseas markets. The home market in Tasmania seems not large enough to really drive such a development.

Visit at Forthside Vegetable Research Station, Devonport Tasmania, Andrew Bishop first from the right and John McPhee second from the right.

New Zealand, 5 – 12 Oct.

John-Paul Praat, Lincoln University, Hamilton, had arranged my stay in New Zealand and made all the contacts to people who had shown interest in my visit. He also managed to get a grant to support my tour round NZ.

Heritage farm Hamilton, Monday 7 Oct.
I visited Richard Prew, Heritage Farm near Hamilton, and saw some of his organic production of kiwi, apples, and asparagus. He is a strong believer in compost tee to improve crop growth. I was particularly interested in his experiences with the Vaporjet system for weed control in asparagus. The asparagus had a remarkable re-growth capacity after treatment. The Vaporjet system kills aboveground vegetation through heating from a mixture of hot air and vapour. In principle, the method is very similar to flame weeding or weeding by hot water and may have similar applications. However, fire risks using Vaporjet or hot water are almost absent and Vaporjet weeding uses less energy than hot water.

Havelock North, Tuesday 8 Oct.
I took part in the LandWISE meeting at Havelock North, and later I visited Scott Lawson in Hastings who runs an organic farm of 173 ha primarily with vegetables and fruits. At the end of the day, I visited Jonathan Brownrigg, Brownrigg Agriculture Hastings, who wanted to discuss different options to lower time consumption for hand weeding intra-row weeds in squash, as there are no effective herbicides available. Scott Lawson also complained about the time consumption for hand weeding in vegetables, particularly in onions. We have the same experience in Europe and we are working hard to find better solutions than the current ones, although we have been able to lower time consumption considerably by optimising the tactical use of current mechanical and thermal methods. Jonathan Brownrigg had recently visited Europe and bought some equipment for mechanical intra-row weed control including the newly developed automatic steering system for steerage hoes developed by Nick Tillett, Silsoe Research Institute in the UK, and commercialised by Garford Farm in England. Jonathan Brownrigg mentioned that he uses the Vaporjet system and that energy consumption may reach 250 l diesel per ha when used against large weeds. Normally we use 50-60 kg gas per ha, which approximates 45-55 l diesel per ha, for pre-emergence flaming in vegetables but weeds are also very small (cotelydon stage and up to two-three true leave stage) at the time of treatment.

Napier, Wednesday 9 Oct.
Visit at the place where the Vaporjet systems is manufactured, and in the afternoon I went to see Scott Lawson again and later Mike Glazebrook, Hawkes Bay near Hastings, who runs a mixed conventional and organic property.

John Baker, Palmerston North, Thursday 10 Oct.
During the planning phase of my tour, I expressed a strong interest in seeing people and places with expertise in non-inversion tillage systems. So I was quite happy to visit world famous John Baker and see his Cross-Slot opener. I spent most of the day with Bill Ritchie, and we discussed a wide range of issues related to minimum tillage systems.

Kowhai Farm, Christchurch, Friday 11 Oct.
Lincoln University, Canberra, and Heinz Waittie's ltd. run Kowhai Farm. There are several organic experiments taking place and an interesting project looking at different ways to improve biological

diversity on the farm and in particular biological control of pests. After having seen the farm, we had a seminar for the rest of the day. I found the environment around Kowhai Farm and Lincoln University very stimulating with a strong interest and willingness in trying to move agriculture in a more environment-friendly direction.

John-Paul Praat (on the left) and the author visiting some volcanic activities near Rotorura (NZ)

Final remarks

On Saturday 12 Oct., I flew back to Denmark from Christchurch over Auckland, Hong Kong, and London after what has been a fantastic experience for me. It took me 38 hours to reach Copenhagen, so I realised how far away NZ is from Denmark. I think that Christchurch is probably the furthest you can go from Denmark when travelling from one country to another. I will never forget this tour that brought me to many places and people 'down under'. I was very happy with the hospitality and warmth that I met throughout my stay. It certainly lived up to the reputation that people from AUS and NZ have in Denmark.

Generally, I was quite astonished at the fact that we, in Denmark, have so much in common with Australians and New Zealanders (or vice versa) in terms of mentality, society, and way of thinking. Actually more than we have with other European countries that are much closer to us geographically.

Acknowledgements

First of all, I want to acknowledge Mike Collins for being the primary force in making this tour possible. He made all the contacts prior to my visit and planned the major logistics of my route. He also managed to get some funding and last but not least, he and his wife housed me for more than a week at his wonderful place at Klackline just outside Northam in WA. Also many thanks to Andrew Bishop and John McPhee for arranging the Tasmanian part and to John-Paul Praat for the New Zealand part of my journey. I also had the privilege to stay at John-Paul's house for two nights. Special thanks also to the Australian Society of Engineers and the Department of Primary Industries, Water and Environment, Tasmania, for considerable financial support.

Appendix A

A summary of the major results and experiences with non-chemical weed control in Denmark

by

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Background

The research into non-chemical weed control began in 1986 as a consequence of public concern about pesticide consumption in Danish agriculture. Pesticide usage increased perceptibly from 1981 to 1985, mainly because more effective compounds became available to the farmers. The public became increasingly aware of the risks of groundwater pollution and impoverishment of the flora and fauna in the agricultural landscape. Every square metre of Denmark is somehow under the influence of man, and arable cropping covers approx. 2/3 of the total area of the country.

Consequently, the Danish parliament decided to encourage Danish agriculture to reduce its pesticide consumption by offering more money for research, training, education, and dissemination of information. Besides, they decided that pesticide consumption in terms of both amount and treatment frequency per ha should be lowered by 50% within a 10-year period. This pressure to cut pesticide usage is still present in spite of a significant change in pesticide consumption and behaviour among the Danish farmers, although the goal of 50% has not been fully achieved yet. The political pressure was further intensified by an increasing number of cases with pesticides found in the groundwater (drinking water) at levels above the officially accepted levels.

Another circumstance that further pushed research in non-chemical weed control up through the 90's was the steadily increasing number of organic farms that turned up due to favourable subsidies offered by the Danish government. Organic farming is now covering around 7% of the total cropped land, but the strong increase in the late 90's now seems to have levelled off.

Cereals

Spring barley and winter wheat cover a large area of the cropped land, and investigations with weed harrowing in those crops was one of the first activities that were started back in 1986. Firstly, a more basic understanding of the weeding principles of weed harrowing was achieved by developing a model that could separate the positive effects of harrowing from the negative ones (Rasmussen, 1991). The positive effects mainly come from the control of weeds while the negative ones are mainly associated with the damage that the harrow may cause to the crop by uprooting and soil coverage. In the beginning of the 90's, the principles of pre-emergence, post-emergence and selective weed harrowing were introduced (Rasmussen & Svenningsen, 1995). It was found that problematic weed species with a fast growth habit were most effectively controlled by pre- and post-emergence harrowing, and particularly when the two principles were combined. However, the two principles could also cause severe damage to the crop when used inappropriately. Selective harrowing is used at later crop growth stages than the other two principles, typically from the end of

tillering to early stem elongation. The crop is more tolerant to harrowing at that time, and the treatment can be done at a fairly high driving speed. Selective harrowing only controls weed species that are weakly rooted and have a scrambling or climbing growth habit. Treatments consisting of pre-emergence harrowing followed by post-emergence harrowing and sometimes even selective harrowing gave very good results in spring barley with control levels reaching those common for herbicide treatments (Rasmussen & Rasmussen, 1995).

Soon it became evident that selectivity is a key-factor to the success of mechanical weeding, not only in cereals but also in other crops (Rasmussen, 1992; Melander, 1997). Low selectivity is present when the risk of damaging the crop is very high whereas high selectivity is present when a high weed control level can be achieved without damaging the crop significantly. The ideal situation for mechanical weed control is when the crop is well anchored and the weeds are small, weakly anchored, and thus very susceptible to even light mechanical control. Therefore most of our research in recent years has been focussing on cultural factors, such as fertiliser placement, crop seed vigour, row spacing, seed rate, cultivation tactics, and variety choice, that might improve the selectivity of mechanical weed control in cereals as well as other crops (Rasmussen et al. 1996; Rasmussen & Rasmussen, 2000, Rasmussen 2002; Melander, 1998; Melander & Rasmussen, 2001; Melander et al., 2001; Melander et al., 2002a).

Our results with weed harrowing in winter wheat were not as good as in spring barley because tap-rooted weed species with an erect growth habit were only poorly controlled by spring-applied harrowing. Autumn-applied harrowing is more efficient against such species, but the risk of damaging the crop can be very high. Consequently, we initiated new research with spring-applied row hoeing in winter cereals grown at increased row spacing (Melander et al., 2001; Melander et al., 2002a). This technique has become more promising as new automatic steering systems based on vision technology have been developed lately (Soegaard & Melander, 2000).

Most of our work with mechanical weed control in cereals has given us a valuable basic knowledge from which it has been possible to develop mechanical as well as other non-chemical weed control methods for other crops than cereals.

Legumes

Weed harrowing has been investigated for peas and lupin. Pre-emergence and early post-emergence harrowing are possible in peas until the first true leaves are visible, then the crop becomes very sensitive as opposed to cereals where the sensitivity is highest at the early crop growth stages.

Both old and new genotypes of lupin have shown a remarkably high tolerance to even high intensities of weed harrowing at several early crop growth stages (Jensen & Melander, 2002). Hoeing at increased row spacing is also possible without risking the yield (Jensen et al., 1999). The new genotypes are determining spring-sown lupin characterised by early flowering and ripening, which in contrast to the older genotypes make them more relevant for cropping under Danish conditions. The organic growers in particular have shown a strong interest in lupin cropping as it fixates nitrogen, produces valuable proteins, and provides favourable conditions for effective mechanical weed control.

Maize and potatoes

Weed harrowing in maize has been very promising on sandy soils. Also ridging with potato disk hillers or rolling cultivators are useful tools for maize, but usually combinations with weed harrowing provide the most reliable solutions. Sometimes the weeds escape weed harrowing if the treatments are delayed because of the weather, and thereby become too large for the harrow. Then the disk hillers can be used to bury the weeds provided that the crop is large enough to withstand hilling.

We have achieved very good results with a rolling cultivator in potatoes. However, other solutions might also be useful such as repeated weed harrowing followed by disk hilling.

Vegetables

Mechanical weed control, such as weed harrowing, torsion weeding, brush weeding, and finger weeding, work very well in most transplants: e.g. cabbage, leek, celery, and onion. The selectivity is normally high and only very little subsequent hand-weeding is necessary to achieve an overall satisfactory weed control level.

However, sown vegetables that germinate slowly and have a slow initial growth rate, such as carrots, direct-sown leek, and onion, are much more difficult to manage by non-chemical means. So far, it has been possible to reduce up to 80-90% of the number of intra-row weeds in onion and leek, but 50-80 hours of hand-weeding still remained to obtain full control (Melander & Rasmussen, 2001). A strategic use of pre-emergence flaming followed by either brush weeding or hoeing close to the row (Melander & Hartvig, 1997) made it possible to achieve such effects.

Realising that common thermal and mechanical control methods would not bring us any further, we have started a new project with band-steaming for highly valuable row crops with the goal of completely eliminating the need for manual weeding (Melander et al., 2002b).

Farmers reception of non-chemical weed control methods

Our results and recommendations are widely used among the organic farmers. Generally, they follow our work with great interest.

A significant barrier among the conventional farmers to adopt to non-chemical weed control is, of course, tradition and a general scepticism. They use some of the methods occasionally and then only if there are no effective herbicides available or if non-chemical weed control is more cost-effective. Only very few conventional farmers use weed harrowing in cereals, firstly because most broad-spectrum herbicides are rather cheap, and secondly because the weather conditions might disfavour mechanical weed control. Frequent rainfall at the early crop growth stages may lead to periods where the field is not passable, and thus one or more treatments are easily lost. This is especially a problem on the more heavy soils. In contrast, dry weather conditions and light soils promote both the effect and the accuracy of the timing of harrowing.

Row hoeing in winter oil seed rape grown at 50 cm row spacing has become quite common among conventional farmers as an alternative to herbicides. Some of the abundant weed species in oil seed rape cannot be controlled chemically, and hoeing has proved to be as cost-effective as herbicides. A steadily increasing number of potato growers have shifted to mechanical weed control by means of rolling cultivators that have proved to be almost as rational and effective as chemical control. Inter-row hoeing in vegetables and sugar beets are quite common. In transplanted cabbage, most growers now rely entirely on mechanical weed control as very few herbicides, not covering the needs, are approved for cabbage. Non-chemical control methods are also introduced in other row crops in those situations where a lack of herbicides forces the farmers to think of other ways to control the weeds.

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Appendix B

CURRICULUM VITAE
{PRIVATE }
Bo Melander (age 41)

Department of Crop Protection, Danish Institute of Agricultural Sciences (DIAS), Research Centre Flakkebjerg (http://www.agrsci.dk/plb/index_uk.shtml), DK-4200 Slagelse, Denmark
Tel: +45 5811 3393, Fax: +45 5811 3301, e-mail: Bo.Melander@agrsci.dk

Education:	October 1987, M.Sc. Agr. at the Royal Veterinary and Agricultural University, Copenhagen
Date of Employment at DIAS:	March 1988
Previous and Present Employment and Position:	1988-94: Research assistant 1994-98: Researcher 1998-00: Senior scientist 2000 - 2002: Head of Research Unit, *Weed Ecology*, and Senior scientist
Key Qualifications:	1) Physical weed control in conventional and organic cropping. 2) Basic knowledge of the fundamental principles of mechanical and thermal weed control methods. 3) Strategic research with physical, preventive, and cultural control methods to define the most appropriate weed control strategy for the crop. 4) Extensive work on crop/weed interactions, weed population dynamics**,** and economic aspects in order to judge the agronomic consequences of weed control. 5) Botanical surveys of the vegetation on set-aside land
Membership of Professional Associations:	a) European Weed Research Society (EWRS). EWRS working groups: 1) *Physical and Cultural Weed Control*, Chairman 2) *Weed Management Systems in Vegetables* 3) *Site specific weed control* Member of the Scientific Committee (SciCom) of EWRS b) Weed Science Society of America (WSSA) c) International Weed Science society (IWSS)

Participation in EU-Concerted Action (No AIR 3 – CT 93-1464) – No Tillage. Four meetings from 1994 to 1998 discussing the agronomic prospects for reduced tillage in European agriculture.

Reviewer for the journals *Journal of Agricultural Engineering Research*, *Weed Research*, and *Biological Agriculture and Horticulture*

Weed specialist consultant on a Danida-financed project in Eritrea. Subject: mechanical weed control in maize and sorghum.

Invited keynote speaker (co-author) at the 12th EWRS Symposium, Wageningen (NL). Session-organiser at the 12th EWRS Symposium, Wageningen (NL). Scientific organiser of the 4th workshop of the EWRS working group Physical and Cultural Weed Control, held at Elspeet (NL) in 2000.

Ninety papers in Danish journals, proceedings and magazines. Numerous presentations and talks at international and national events including farmers meetings.

List of papers in English

Reviewed international journals

Melander B. (1994). Modelling the effects of *Elymus repens* (L.) Gould competition on yield of cereals, peas and oilseed rape. *Weed Research, 34, 99-108.*

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Melander B. & Hartvig P. (1997). Yield responses of weed-free seeded onions [*Allium cepa* (L.)] to hoeing close to the row. *Crop Protection, 16 (7), 687-691.*

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Melander B., Cirujeda A. & Jørgensen M.H. (2002). Row hoeing and fertiliser placement for weed control in winter wheat. *Weed Research (submitted 5th April 2002)*.

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International conferences, symposia, workshops, and meetings

Melander B. (1993). Population dynamics of *Apera spica-venti* as influenced by cultural methods. *Brighton Crop Protection Conference, Weeds 1993, 1, 107-112.*

Melander B. (1994). Impact of non-inversion tillage on weeds in temperate regions. *Proceedings EU-Concerted Action - No-Tillage - Workshop I, 49-58.*

Melander B. (1996). Preliminary experiences with a 2-year growing system using non-inversion tillage for in-row weed control in row crops. *Proceedings EU-Concerted Action - No-Tillage – Workshop III, 61-67.*

Melander B. (1998). A review of the major experiences with weeds in non-inversion tillage systems within the European Economic Community (EEC). *Proceedings EU-Concerted Action - No-Tillage -Workshop IV, Final Report, 63-68.*

Melander B. (1998). Economic Aspects of Physical Intra-Row Weed Control in Seeded Onions. *Proceedings of the 12th International IFOAM Scientific Conference, Mar del Plata, 180-185.*

Melander B. (1999). A 2-year cropping system for intra-row weed control in row crops. Abstract. *11th EWRS Symposium Basel 1999, 101.*

Melander B. (2000). Mechanical weed control in sorghum and maize – a review. *DANIDA-report, published by The Danish Institute of Agricultural Sciences, Research Centre Flakkebjerg DK-4200 Slagelse, 16 pages.*

Melander B. (2000). Mechanical weed control in transplanted sugar beet. *Proceedings of the 4th EWRS Workshop on Physical Weed Control. Elspeet, NL, 20-22 March, 2000, p. 24. (http://www.ewrs.org/physical–control/meeting.htm).*

Melander B. & Hartvig P. (1995). Weed harrowing in seeded onions. *9th EWRS Symposium Budapest 1995: Challenges for Weed Science in a Changing Europe, 543-549.*

Melander B. & Jacobsen O.H. (1994). Weed problems and nitrogen uptake associated with unsown

rotational set-aside in Denmark. *Aspects of Applied Biology, 40, 1994 Arable farming under CAP reform, 547-552.*

Melander B. & Jensen R.K. (1998). Perspectives and reality about physical weed control in row crops. Abstract. *3rd EWRS Workshop on Physical Weed Control,* Wye College, UK, 23-25 March, 1998

Melander B., Tebrügge F., Carvalho M., Viaux P. & Lescar L. (1998). Group III: agronomic (yields, crop rotation, weeds, …..) and economic aspects. *Proceedings EU-Concerted Action - No-Tillage - Workshop IV, Final Report, 75-77.*

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Clarke J.H., Melander B. & Orlando D. (1995). Comparison of the effect of weed control strategies for rotational set-aside in United Kingdom, Denmark and France. *Brighton Crop Protection Conference - Weeds 1995, 1, 329-338.*

Graglia E., Heisel T., Walter A.M. & Melander B. (2002). Adjusting crop competitiveness to site-specific weed pressure: Preliminary results. *12th EWRS* Symposium 2002, Wageningen (NL), 406-407.

Hatcher P.E. & Melander B. (2002). Combining physical, biological and cultural methods: Prospects for an integrated non-chemical weed mangement strategy. *12th EWRS Symposium 2002, Wageningen (NL), 226-227*.

Jensen R.K., Melander B. & Jørnsgård B. (1998). Tolerance of Lupin to Mechanical Weed Control. Abstract. 3rd European Conference on Grain Legumes – 1998 – Valladolid, 479.

Jensen R.K., & Melander B. (1999). Mechanical weed control in spring barley with under sown grass clover ley. Abstract. *11th EWRS Symposium Basel 1999, 121.*

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