IAMFE Denmark 2008

The 13th International Conference and exhibition on mechanization of field experiments

Conference Center Koldkærgaard
1st - 3rd July 2008
IAMFE Denmark 2008

Proceedings from

The 13th International Conference and exhibition on mechanization of field experiments

Editors:

Lars Byrdal Kjær
Torbjörn Leuchovius
John Stevens

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Preface to IAMFE 2008

It is an honour to be asked to write this preface to IAMFE 2008, the 13th IAMFE International Conference and Exhibition on Mechanisation of Field Experiments. Professor Egil Oyjord will present a bound copy of his life’s work, spanning almost 50 years. There will be displays of the most modern equipment and devices available. Invaluable and informative papers and posters will be presented and preserved within well prepared proceedings. Old friendships and collegial acquaintances and relations will be renewed in old fashioned face to face ways. New ones will be made, to be kept alive and “grown” after the conference, over the internet. The proceedings of this Conference will be available on DVD and on-line including many useful links to contributors and exhibitors, proving IAMFE commitment to modernization.

The objective of IAMFE is to assist agronomists, plant breeders and others carrying out field experiments, to increase the accuracy and capacity of their research work by mechanization. An important pillar in the foundation of IAMFE is to assist agronomists and plant breeders in developing countries get suitable high quality research equipment to speed up the development of new and better varieties of crops, and to improve the agronomic practices of the farmers.

I have known and worked with Egil toward these objectives since the beginning of IAMFE, and before. I am now 85 year of age, and as I look back over the proceedings from the first IAMFE International Conference in Norway (1964) and compare it with this conference, I marvel at the improvements in technology. I note with interest, reference to the continued use and application of some of our earliest versions of the Oyjord - Schou planters, cell wheels and distributors still in use. It is rewarding to see how these simple technologies have lasted long enough to serve the needs of three generations of scientists. I am also interested to see reported, how these old basic technologies have been re-engineered and up-dated using modern products, methodologies and technologies. That these basic concepts have stood the test of time as a metering and distribution technology, demonstrates the lasting value of field testing and networking through IAMFE. It also emphasises a continuing need by many of our end users for basic equipment, components and modules that are simple, reliable and affordable.

In the early days, we had to manufacture and assemble all our parts in one place due to communication and logistical constraints. Today it is possible to have components engineered all over the world and brought together at various end points for assembly. As a result of globalization and the internet, it has now become routine to source components globally and integrate them into research equipment from a very wide range of “off the shelf” sources throughout many sectors of industry. This is to be encouraged and promoted I feel, by IAMFE. At the same time it emphasises the continuing need for and useful role of IAMFE in helping to identify, establish, up-date and maintain standards for equipment used in the mechanization of field experiments. Without the internet, this would not be possible. We must not, however loose site of the continued value of face-to-face contact, as at this conference, or in future at agricultural shows and trade fairs as proposed in the General Assembly report.

The manufacture of research equipment remains specialised and seldom includes volume runs. The invaluable role played by small operators continues including those where one or two people are manufacturing / machining specialized components, not solely for research but as part of a much broader range of products using very sophisticated components, to be sent all over the world. Globalization and the internet, rather than forcing these people out of production, has made it possible for them to develop and extend their markets in simple and affordable ways. This is to be encouraged, particularly since many of us are now getting older and for many years have found it increasingly difficult to involve, train and then retain skilled young staff so that our hard earned knowledge, still in use 50 years later, was not lost. “Our work is not over”; you as the younger generation must now face up to the reality of dealing with the energy crisis, economic food crisis and impact of climate change, all of which seem to have come to a head over the past months.

An exceptionally good job has been done in preparing for this conference. Congratulations! I look forward to meeting you at the Exhibition.

Mr Bengt Hallerström
Founding Member, IAMFE, Sweden
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Reflections on the value of IAMFE conferences

Author
- Founder and Honorary President of IAMFE, Egil Oyjord, Norway
  E-mail: eg-oey@online.no

Summary
This paper gives a short history about IAMFE and my reflections on the value of the International and Regional IAMFE Conferences as well as the National IAMFE Branches.

Short History
It is 50 years since 1958 when I made a study tour to five European countries. During this tour I conceived the idea that agronomists and plant breeders should have a place to write to in order to get up to date information about machinery, equipment and instruments for the mechanization of field experiments. It took me six years before this idea was realized. IAMFE was founded at the "NATO Advanced Study Institute on Mechanization of Field Experiments" arranged in Norway in 1964. Seventy-one participants from 17 countries took part in this event. This was the world’s first international conference and exhibition on mechanization of field experiments. The NATO conference in Norway was later named IAMFE / NORWAY ’64. Since then I was President of IAMFE for 36 years until I stepped down in the year 2000. Because of lack of funds I also served as Executive Secretary of IAMFE for almost 28 years, except for 14 months in 1972-73, when Dr. Graeme R. Quick, Australia / USA was employed as Acting Executive Secretary of IAMFE.

In 1993 Torbjorn Leuchovius, the Swedish University of Agricultural Sciences, without salaries from IAMFE, took over as Executive Secretary of IAMFE and became Director of our International IAMFE Centre which was moved from Norway to Uppsala, Sweden. (www.iamfe.org) After IAMFE / RUSSIA 2004, Dr. Vladislav Minin, St.Petersburg, Russia, without salaries from IAMFE, took over these positions. Since 2001 Torbjorn Leuchovius has been Director of our Global Institute and Agricultural University Internet HUB (www.iau-hub.org)


Reflections on the value of IAMFE / NORWAY ’64 can be summarized as follows.

Our first conference was a great success and it became a model for all the later IAMFE Conferences. The main content of the programme was: Presentations of papers, discussions and an exhibition of machinery, equipment and instruments for mechanization of field experiments. The most important value of IAMFE ’64 is that IAMFE / NORWAY made a foundation for organizing 11 International and six Regional IAMFE conferences. These conferences have resulted in the establishment of 12 national IAMFE Branches. The IAMFE conferences have created a meeting place for manufacturers, agronomists and plant breeders. Standardization of working widths of plot seeders and plot combines was an important result of IAMFE ’64. Agronomists, plant breeders as well as manufacturers of plot research equipment have followed our 1964 recommendations.

The participants reflections on the value of IAMFE / NORWAY ’64

On June 23, the participants of IAMFE / NORWAY ’64 adopted a Resolution which among several flattering statements about the success of the NATO conference, singled out Egil Oyjord as "one deserving our highest praise for his farsightedness and motivation that made this meeting possible."

Additional reflections on the value of IAMFE / NORWAY ’64 were expressed in letters from the participants upon their return home after the con-
Reflections on the value of our International IAMFE Conferences since 1964:

Our International IAMFE Conferences and the Proceedings have given the participants up-to-date information on machinery, equipment and instruments for the mechanization of field experiments. Mechanization has multiplied the capacity of field experiments since IAMFE was founded 44 years ago. This has been possible through a close cooperation between the agricultural scientists and the manufacturers. The International IAMFE Conferences have given inspirations to the arrangements of Regional and National IAMFE Conferences and to the foundation of National IAMFE Branches. IAMFE by its conferences has created a basis for the publication of The IAMFE Handbook, The ASAE/IAMFE Directory, The IAMFE / IAU Directory, The IAMFE News, The Chinese Textbook on Mechanization of Plant Breeding and Seed Processing and The Global Institute and Agricultural University Internet Hub.

“Efficiency and precision in research” has been our guideline for the operation of IAMFE:

Regional IAMFE Conferences and Exhibitions

So far the following 6 Regional IAMFE Conferences have been arranged: Sweden 1977, India 1985, Syria 1987, Lithuania 1995, Argentina 1998 and Russia 2006. The numbers of participating countries have been up to 20 and the numbers of participants have been up to 130.

Reflections on the value of our Regional IAMFE Conferences

The Regional IAMFE Conferences and Exhibitions have served its purpose by spreading important information to agricultural scientists who have not had the possibility to participate in the International IAMFE Conferences and Exhibitions.

National IAMFE Branches

Reflections on the value of our National IAMFE Branches:

The National IAMFE Branches have organized National IAMFE Conferences and Expositions and are very important for the promotion of mechanization of field experiments in their countries. The IAMFE Branches have also been very useful for IAMFE in the arrangement of International and Regional IAMFE Conferences and Expositions. Our experiences from Europe are that most countries with National IAMFE Branches are able to handle their own problems in mechanization of field experiments.

Reflections on the value of the exhibitions and demonstrations arranged at the IAMFE Conferences:

The exhibitions and demonstrations of machinery, equipment and instruments carried out by the manufacturers at the IAMFE conferences, have been extremely important to the participants as well as to the manufacturers.

In a statement of 23.10.07, Dr. Hans-Ulrich Hege, a German plant breeder, founder and manufacturer of the famous Hege plot research machinery wrote to me:

“I would like to confirm that the foundation of IAMFE has been very important for the progress in the world plant production. IAMFE is of essential assistance in keeping the climate in balance and to feed a growing population in the world. Plants are the natural sources for minimizing the CO₂ emissions to avoid a warmer climate. With a warmer climate the diseases become more aggressive and the lifetime of varieties becomes shorter. Therefore development of new varieties and efficient field experiments are of increasing importance in the future. IAMFE with its international and regional conferences helps in an effective way to distribute modern experiences between countries and regions. I rely on further plant breeding for adaptation of plant varieties for meeting the challenges of tomorrow.”

Main Conclusions regarding the value of the IAMFE Conferences

The IAMFE Conferences, the Proceedings and the Exhibitions and Demonstrations have transferred technology and knowledge to agronomists, plant breeders and agricultural engineers all over the world. Further information about IAMFE and its activities can be found by writing www.iamfe on Google and clicking.

I regret very much that in spite of all efforts made, I was not able to secure a financial basis for operation of our International IAMFE Centre. IAMFE and the IAMFE Conferences have survived because I and others have worked without salaries from IAMFE. We strongly believe that mechanization of field experiments is extremely important for increasing the efficiency of plant breeding and agronomic trials in order to meet the need for food in the world. Others shall judge the value of our efforts.

In a letter of November 13, 1970, the Nobel Peace Prize winner 1970, Dr. Norman E. Borlaug, wrote to me:

“... It will be a pleasure to work with you and IAMFE in the furtherance of the green revolution.”

I have contributed to this aim in two ways:

1. Started production of the Oyjord batch type plot seeders in Jens A. Schou Mek. Verksted in 1960. Until Wintersteiger, Austria took over the production in 1974-76, I designed, developed, organized and directed the production and export of the Oyjord plot seeders from Norway to agronomists and plant breeders in 57 countries all over the world. Increased capacities in sowing of plots per man-hour between 10 to 400 times as well as reduced experimental errors have been reported.

2. By founding and developing IAMFE with its International and Regional Conferences and National Branches together with others. (See Google: egil oyjord)

I believe the IAMFE contributions to efficient plant breeding research have been very important for the increase in the world food production. I hope the “Green Revolution” also can become a reality in Africa as it as been in China, India and other countries.

My main reflections are that the ideas I conceived 50 years ago and have worked on realizing, have had a significant impact on food production in the world. I am very grateful to all who have helped me to try to fulfill my visions and I would especially like to extend my thanks to Torbjorn Leuchovius and my wife Malfrid.
Introduction

On behalf of IAMFE and IAU, it is both an honour and a privilege to welcome delegates and exhibitors to IAMFE Denmark 2008 (our 13th international conference). And, to be able to thank in person over the coming days, all those who have contributed so much over the past four years to make this conference and exhibition the success I know it will be. We have approximately 100 participants / delegates here from 25 countries. This is truly a global event.

To quote from the excellent web site prepared for this conference.

The objective of the conference is to provide insight, knowledge, motivation and inspiration to organize and carry out field experiments at a high professional level. Believing field experimentation is the key to modern and sustainable agriculture, we – as field experimenters – are obliged to engage in the objective of this conference. The conference will be a mixture of oral presentations on new developments in field experiment methods and technology and exhibition of machinery and equipment.

It is very special to us that Professor Egil Oyjord our Patron and Mr Bengt Hallerström our most esteemed founding member of IAMFE are in good enough health and to be able to attend. Bengt and Ms Rut will be here on Wednesday at the exhibition. Björn Andersson has very kindly agreed to stand in for Bengt at the GA to read the “Auditors report” written and signed by Bengt. Thank you, Björn. We extend our sincere thoughts and best wishes to Ms Målfrid Oyjord and Ms Anita Leuchovius whom are unable to attend, as in the past. Their family involvement and support has always impressed me. Things will not be the same without them.

Acknowledgements

For many years I, as I expect many other delegates have, wished for the opportunity to visit and get to know first hand, the facilities and workings of AgroTech A/S. As stated on their web site, Agro Tech combines knowledge in technology and biology-based natural sciences in a new potential growth sector. AgroTech A/S is a non-profit organisation owned by the Danish Agriculture Advisory Service, National Centre. AgroTech co-operates widely with knowledge based institutes and provides services to a broad field of private companies, and other organisations and parties within the primary focus areas of:

- Agricultural technology;

The overview of Prof’s life work just presented is astounding, made possible through a combination of his own efforts and those of his family and the team he brought together around him. No wonder we all admire and respect him so much. It remains a quandary to me, why this basic work used by plant breeders and agronomist the world over for more than 40 years was never taken onboard by the CGIAR (including developed and developing world members), formalized and promoted under their own initiatives. Instead, it seems to have been taken for granted.

Perhaps this will be re-visited over the coming months as the world enters a new crisis era of economic food shortages exacerbated by rapidly escalating energy prices, climate change and falling contributions in real terms to research and development. It is inevitable that reduced and zero cultivation will receive more attention including technologies suited to small- and medium-sized tractors covering research as well as production, encompassing the developing and developed world.
• Biomass processing technology, e.g. for energy production, pharmaceuticals;
• Sensor technology;
• Information and communication technology;
• Environmental and energy technology;
• Rural development;
• Horticultural technology;
• Testing and documentation of new technologies.

Such forward looking applied attitudes impress me greatly, including the potential as a role model. Thank you Director, Mr Rene L. Damkier for extending to us this opportunity which is now going to be turned into reality, built on the day-to-day, hour-by-hour (and as deadlines approached minute-by-minute) inputs of Lars Byrdal Kjaer, (Head of Field Trials and Statistics, AgroTech) and his staff, Søren Haastrup and Lotte Hornbek. Thank you for your combined inputs together with the ever-present backstopping provided by Torbjorn Leuchovius, Executive Secretary IAMFE, 2004 / Chairperson IAU and Vladislav Minin, Executive Secretary IAMFE, 2004-2007. May we never think this for granted!

We are very grateful that Dr Carl Åge Pedersen, Director, Plant Production, Danish Agricultural Advisory Service could spare the time to prepare and present his keynote address.

Who can listen and learn without eating and feeling comfortable? I can’t! I am confident that Koldkærgaard Conference Center will take very good care of us using their modern facilities including a renowned kitchen. I am looking forward to the Danish cuisine. Thank you in advance. Lunch on Wednesday will be a large barbecue event sponsored by Haldrup. I am also looking forward to that. Thank you. Yes I alread know, my wife and family tell me often, that I like food!

It is most appreciated that the Experimental Station Koldkærgaard has made its fields available, in which exhibitions will take place. We very much appreciate these facilities being extended to us. No amount of words, video and static display can replace a good old fashioned hands-on display. Thank you.

We would not be here today, had China via our IAMFE Vice President, Prof. Shang Shuqi and the India Branch of IAMFE not graciously agreed to allow the venue to be changed. After having made offers at IAMFE 2004 which were accepted at the time and then modified later to give more people in Europe the opportunity to participate in a local venue. Thank you for this. You were most understanding.

Key Notes / Points
IAMFE continues to adjust to the rapidly changing times. Over the coming three days, an excellent series of papers will be presented. Additional posters / technical notes will be displayed and field exhibitions and demonstrations made as outlined in the Conference Proceedings. This can be found along with other additional information so kindly and efficiently provided in your Welcome Pack, backed up on-line.

After this conference it is our hope that the IAMFE 2008 web area can be kept open and further developed to include details of conference presentations, posters and exhibits, including links to other relevant areas. Indeed we would like to see it grow to the scientists / agronomists / plant breeders equipment version of www.agmachine.com to include and meet a wide range of end-user needs including component suppliers. To this end, I would like to propose that all of you here register (contribute) and pay for at least one link before you leave. That way, you will also be recorded as Foundation Members. Afterwards, the price will need to go up.

It would be fantastic if our exhibitors and our presenters could start the ball rolling by becoming founding members, including those exhibitors confirmed as present here to show us their products:

1. Haldrup, Denmark (www.haldrup.dk)
2. Baumann, Germany (www.baumann-saatzuchtbedarf.de)
3. Edor Skoglund AB, Sweden (www.edor.se)
4. Doriane, France (www.doriane.com)
5. Norddeutsche Pflanzenzucht, H.G. Lembke KG, Germany(www.biomatnet.org)
6. GTA Sensorik GmbH, Germany (www.gta-sensorik.com)
7. Zuern, Germany (www.zuern.de)
8. F. Poulsen Engineering ApS, Denmark (www.visionweeding.com)
10. Mapro Systems AB, Sweden (www.mactrac.se)
11. Swedish University of Agricultural Sciences, Sweden (http://www.ffe.slu.se) including the Flexiseeder project (www.flexiseeder.com)
12. Wintersteiger, Austria (www.wintersteiger.com)

Conclusions
It is not an easy time for IAMFE. There are some difficult decisions to be made at the General Assembly. The General Assembly report is detailed. Problems are outlined and some suggestions made.
Herman Augsburger (IAMFE Representative for Latin America) has prepared an additional report, to be presented at the GA adding further to these observations and suggestions/recommendations. This meeting is most important. I would like to encourage as many people as possible to attend and participate so that the correct decisions can be made to secure the future of IAMFE.

With these words, I would now like to declare the 13th IAMFE Conference open. May you have an enjoyable and productive experience by sharing and expanding your information and experience base. Long live IAMFE!
Field trials are essential for modern and environmentally friendly agriculture

Author
- Carl Åge Pedersen, Director, Danish Agricultural Advisory Centre, Crop Production
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One of the main reasons why Danish crop production despite very strong environmental regulations is profitable is that Danish farmers are skilled. They have the practical knowledge of farming and they very quickly adapt new knowledge of the best varieties, fertilizing correctly, using optimal doses to control diseases etc. The newest knowledge on how to obtain the best results in the field is primarily generated in The Danish field trials.

Denmark has a very long tradition for building the plant production advises and decision support on solid knowledge based on impartial field trials conducted by their own organization: The Danish Agricultural Advisory Service, DAAS (See below).

The Danish field trials

For more than 100 years The Danish Agricultural Advisory Service has carried out more than 150,000 trials (Figure 1). Presently approximately 1,200 trials are carried out every year.

These trials have from the beginning ensured that the Danish farmers continuously have been able to increase productivity and at the same time do it in an environmentally friendly way.

The field trials are placed all over the country and normally in farmers fields. The testing close to the farmers practice ensures that trials are relevant to the farmers and the new knowledge is faster transferred to the farmer.

Testing of varieties of cereal, pulse, grass and oil-seed takes place in close collaboration between variety testing authorities, plant breeders and DAAS. DAAS also tests a range of new products, e.g. fertilizers and plant protection products from commercial companies. The contribution in this testing is
often an important part of marketing a new variety or product in Denmark. The impartiality and the publishing of all results have a long tradition in Denmark.

The Danish field trials are impartial which means that the income of the advisers and technicians making the experimental plans, the practical work in the trials and reporting is total independent of the results. The breeders and the agricultural companies give financial support to the field trials, but it is the independent and impartial specialist from DAAS that are responsible for the final design of the experimental plan, and this way it is ensured that a product is always tested against the best alternatives. The importance of field trials is given in the following example. Pesticides are sold with a recommendation of dosage. For the fungicide Opera, the recommended dose is 1 liter per hectare. However, 11 field trials have proven that 1/8 liter results in the same net yield as 3/4 liter (figure 4). By applying this knowledge the farmer saves more than 40 Euros per hectare and at the same time the environment much less chemical stuff.

**Figure 3.** Farmers visiting the trials. This way the farmers have a firsthand knowledge on new varieties and methods

**Figure 4.** Net yield of the fungicide Opera in winterwheat (Danish Field Trials).

**Publication of the results**

Some researchers, experimental stations and others carrying out field trials are not very keen on rapid
publication of results. At DAAS we find it essential that all results are published as fast as possible. Every year just before Christmas, we finish and publish the annual report with more than approximately 1200 individual field trials, and in beginning of January the results are presented at Plantekongressen (a Danish conference on plant production with app. 2000 participants – www.plantekongres.dk).

Figure 5. The annual report on field trials is released just before Christmas every year.

Besides the quick reporting all results are also available on the Internet only few hours after harvest and analysis of the samples. This fast presentation of the results is very important to the farmers, advisors and breeders. They have thus access to new varieties and methods earlier than farmers in the neighboring countries. A conservative estimate indicates the value of the earlier introduction of new varieties to be of more than 5 million Euros per year.

The quick reporting is due to a well functioning data management system, Nordic Field Trial System, NFTS which in a very efficient way can optimize the administration, processing and publication of the results. The system is now used in Norway and to some extend in Sweden. Later in this conference this system will be presented to you.

NFTS could be beneficial for other countries too and it could promote further co-operation between countries and at the end of the day give much more value for money for the farmers in the Northern Europe.

Conclusion
Due to the Danish field trial system Danish farmers have the knowledge of

Danish Agricultural Advisory Service
Farmers are both owners and users
The Danish Agricultural Advisory Service (DAAS) is a partnership made up of 46 local advisory centers and a national centre. This unique two-level advisory system is both owned and used by Danish farmers. The partnership employs app 3,500 professionals. DAAS’ history dates back to around 1875 when farmers’ organizations started to employ their own advisers. Today, DAAS is one of the leading agricultural advisory services in Europe.

The National Centre
The National Centre is located just outside Aarhus in Jutland. We employ a staff of app. 500 who are organized into departments according to professional expertise. The role of the National Centre is to create, gather and make use of knowledge from home and abroad. We carry out these tasks in co-operation with local advisory centers from across the country. Among other things, our customers benefit from our close co-operation through:

- Highly specialized advisory services which match the needs of each farmer
- Full-range services at all local advisory centers - at a high quality
- Access to the most recent products and methods
- Advisory services at competitive prices owing to rational procedures
- Products developed to match the actual, local requirements

The most important task of the National Centre is to build bridge between research and farmers. Among others we do this by participating in research projects, and together with our colleagues from the local advisory centers we make sure that the new knowledge is put into practice on farms.

Professional areas
Our advisory services cover the following professional areas: Crop production, Cattle, Pigs, Economics and law, Horses, Poultry and Fur animals.

Ownership and board
The National Centre is owned and run by Danish Agriculture, the main organization of Danish farmers. We are headed by a board of directors with representatives of both the political and day-to-day management of the organization Danish Agriculture.
• Which varieties are the best at the moment?
• When is plant protection needed?
• Which pesticides to use in the individual situations?
• How small dosages are sufficient to solve a problem?
• How to apply animal manure to archive maximal fertilization effect
• Etc.

The farmers rely on the Danish field trial system and in general only use products which in these impartial trials have proven to be efficient and beneficial.

Danish agriculture is in these years under a very strong political stress.
• The possibility for applying nutrients to the crops is limited to 85 percent of what is needed from an agronomic point of view.
• Up to 75 per cent of the total N in animal manure has to replace inorganic fertilizer.
• Hence some farmers hardly are allowed to use inorganic nitrogen fertilizers.

• Only a few chemical plant protection products are on the Danish market due to a very strict registration regime and the fact that Denmark is a small country.
• There is up to 50 percent levy on plant protection products
• Despite the fact that Danish farmers are using much less pesticides than their colleagues in e.g. the UK, Germany and France, the Danish parliament is at the moment discussing how to reduce it by approximately further 30 percent.

This pressure in fact enhances the need for field trials. It is, however, very expensive to carry out field trials, train field trial workers, maintain machinery and data management systems. Nevertheless it is more expensive to discontinue the field trials because this will eventually result in a decline in productivity, increase the expenses and the strain on the environment.

It is my wish that this conference will strengthen field trial work and strengthen the international cooperation in this area.
Field trials - their importance to agriculture in emerging economies

Summary
The development of agriculture within emerging economies, particularly in Sub-Saharan Africa, has not kept pace with population growth, leading to starvation and poverty. Over the past 10 to 15 years, annual investment in research and development in agriculture has declined, except in a few countries. The mechanization of agriculture in Sub-Saharan Africa is almost non-existent. Consequently, manpower is used to work most of the arable land. Under these conditions, resulting productivity is very low and resulting yields seldom exceed 10% of obtainable yields. The only way to increase production and food security under these conditions is to increase research and development through massive and intelligent investments. However, it is not sufficient only to increase research activities. A holistic view must be adopted ensuring clear lines from research to subsistence farmers; conducting on-farm field trials is a method of pursuing this goal. Development of new farming tools, setting up of input systems and establishing trade markets must also take place.

Article
Field trials are the key to modern agriculture. And, agricultural modernization is a key element in the development of most African countries. Field trials and research are thus very important, particularly because agriculture in Africa represents 70 percent of full-time employment, 33 percent of gross domestic product and 40 percent of its exports earnings (IFPRI, 2002), not to mention food security. The increase in yields in developing countries over the last 40 years has mainly been obtained by expansion of arable land at the cost of forests, soil fertility and water. This non-sustainable approach to increasing yields has to be substituted by producing more food per hectare and higher productivity per agro-worker while applying a sustainable approach. Traditional farming methods are often praised, mainly because they are compared with large scale production methods that require high levels of inputs for mechanization, fertilizer and pesticide usage. However, traditional farming methods have only seldom proven able to guarantee food security, besides they require considerable manpower resources and vast land area due to the bush fallow system. Therefore traditional farming has to be replaced by more productive farming systems adapted to the local conditions and with consideration of the given input factors.

The above mentioned facts support the view that research and field trials are of utmost important and must be given higher priority in order to develop and implement new farming systems, practices and methods in agriculture. When talking about developing countries, this article primarily focus on Sub-Saharan Africa and my own experience as an adviser with field trial work in Mozambique 1992-95.

Agricultural research spending
During the year 2000, approximately 1.5 billion dollars were spent on agricultural research in Sub-Saharan Africa (Table 1). When adjusted for inflation there is a decrease in public spending in agricultural research in Sub-Saharan Africa compared to other developing countries. It is interesting to note that the growth rates on spending for R&D in agriculture (after adjustment for inflation) has been reduced considerably since the 70’s (Figure 1) and has even declined in high income countries in the 90’s. As we will discuss later, a decline in developed countries will have a negative impact in developing countries.

During the period 1981-2000, spending almost doubled in other developing countries in general, while China has even tripled its investments. The decline

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During the period 1981-2000, spending almost doubled in other developing countries in general, while China has even tripled its investments. The decline
in R&D investments in Sub-Saharan Africa will cause the area to fall further behind in the development of sustainable and profitable agriculture. This will reduce its ability to compete in the global market, which again will lead to limited willingness to invest in the agricultural field in the Sub-Saharan Africa. This again will create further separation between Sub-Saharan Africa and the rest of the participants at the global market. A descending spiral will crop up, if it does not already exist.

Agricultural R&D in Sub-Saharan Africa (and the rest of the world) is seriously under prioritized. The neglect of investments in agriculture in the poor countries is a huge error which today is one of the reasons for the unstable food prices. The reason for lack of willingness to invest in agricultural research may be caused by the poor return on investments. In Sub-Saharan Africa the growth rate in agricultural production has been less than 1% from 1980-2000 (Pardey et al., 2006). In relation to this, it should be

### Table 1. Global public agricultural-research spending, 1981–2000 (Pardey et al., 2006)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing countries</td>
<td>6,904</td>
<td>9,459</td>
<td>12,819</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>1,196</td>
<td>1,365</td>
<td>1,461</td>
</tr>
<tr>
<td>China</td>
<td>1,049</td>
<td>1,733</td>
<td>3,150</td>
</tr>
<tr>
<td>Asia and Pacific</td>
<td>3,047</td>
<td>4,847</td>
<td>7,523</td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td>1,897</td>
<td>2,107</td>
<td>2,454</td>
</tr>
<tr>
<td>Middle East and North Africa</td>
<td>764</td>
<td>1,139</td>
<td>1,382</td>
</tr>
<tr>
<td>Developed countries</td>
<td>8,293</td>
<td>10,534</td>
<td>10,191</td>
</tr>
<tr>
<td>Total</td>
<td>15,197</td>
<td>19,992</td>
<td>23,010</td>
</tr>
</tbody>
</table>

### Figure 1. Annual growth rates in public agricultural R&D spending (Pardey et al., 2006).
taken into account that the potential yields for many crops in Sub-Saharan Africa are at least 5-10 times of the actual yields (Inter Academy Council, 2004), and also here the Pareto principle is valid, saying that the first 80% increase is the easiest to obtain whereas the last 20% that we are chasing in the developed countries is more difficult. Despite the low effect of investments in research in the last decades, they must not be discontinued but must be increased, and at the same time a holistic view must be instigated. It is not enough to focus on traditional academic merits e.g. numbers of published articles. A clear chain from university to sector research to adviser to farmer must be established; and it must be one of the success criteria for those researchers who focus on subsistence farmers including that their research is transferred to this sector. In this context it should be noted that the main reason for the success of the Danish field trial system was the initiation of adviser/farmer driven on-farm field trials right from the beginning, and not as a university driven research. There is a huge task for policy makers, researchers and extension workers to make use of the large potential of agriculture in the developing countries.

**Technology and mechanization of agriculture**

The rule of thumb in Africa is that a subsistence farmer can grow one hectare sown with stable crops (maize, rice, cassava etc.). The single most important tool is the hoe, which is used for sowing, weeding and harvesting. The hoe is not a very comfortable tool to work with, but no changes have been made for more than 50 years except in a few areas in Africa where a longer stick has been introduced. Eighty nine percent of the land in Africa is worked by manual power; animal traction covers 10 percent and only 1 percent is worked mechanically (InterAcademy Council, 2004). It is evident that food security cannot be reached without improvements in farming methods.

In Table 2 it can be seen that there are 1.3 tractors per 1000 hectares in Sub-Saharan Africa whereas in Denmark there are 53.8 tractors. Tractors in Africa are predominantly owned by large farms or farming companies growing cash crops and not available to subsistence farmers. Besides lack of mechanization, usage of other inputs e.g. fertilizer is also very low. In Table 2 it can be seen that the application rate of fertilizer reaches 11.5 kilograms per hectare in Sub-Saharan Africa and e.g. only 3.5 kilograms in Mozambique compared with an average of 91 kilograms in the world and 160 kilograms per hectare in Denmark. To increase productivity and reduce labor input it is imperative to mechanize agriculture in these developing countries. As mentioned above, there are only 1.3 tractors per 1000 hectares in Mozambique while there are almost 2 workers per hectare, which is much more than the rest of the world. This implies that 80% of the population is involved in producing insufficient and insignificant amounts of food. There is only one way to bypass this cumbersome output: Investments in agriculture - from research to mechanization, from infrastructure to economic reforms.

Agricultural technology need not to be home-invented; rather agricultural innovations have always spread across boundaries, take e.g. maize, potatoes and combiners; and in field trials, the plot drilling system. Innovation and new technology in agriculture has been the one reason that developed countries have been able to produce enough food to feed their growing populations while using less manpower. However the spillover of this technology to developing countries has mostly tended to lag behind local population growth.

**Field trial mechanization**

Innovation in field trial mechanization in developed countries is usually driven by key players: Plant breeders and agricultural chemical companies. For the breeders, technological development aims at more efficient harvesters with rapid analyzers and computers to control the thresher and collect data. The overall aim is to reduce manpower and increase the rate of progress (i.e. decrease the time lapse) from cross pollination to selection of desired breeding lines derived from segregating populations resulting in new varieties with better trait performance. For pesticide companies the aim is also to reduce manpower and the time spent per trial, in order to increase the number of trials that can be

![Figure 2. The hoe is the most important farming tool in Africa. It is uncomfortable and hard work to weed with a hoe.](image-url)
sprayed within a relative short spraying period. This has led to the development of high precision motor driven sprayers with several spraying booms, so a trial can be sprayed plot by plot without having to move around in the trial. These examples of field trial equipment are so expensive both in initial purchase and in subsequent maintenance costs that a good estimate says that one harvester cost the same as 50 complete on-farm trial kits for developing countries.

It is worrying that the technological innovation in field trial machinery in / for developed countries leaves none or only little technological spillover for field trials in developing countries. Field trial mechanization in developing countries is on a rather low level. Textbox 1 reports on experiences from a field trial in Mozambique and describes some of the problems with lack of mechanization and infrastructure (Kjaer & Kjaer, 1995). Development of low-level technology for field trial equipment is virtually non-existent in developed countries. Therefore, it has to be driven locally within developing countries taking place either on university or sector research levels. This could be a research discipline in itself, maybe in conjunction with the general discipline of farming mechanization which is, by the way, neglected as well. One could ask if IAMFE could undertake the role of aiding the mechanization of field trials in developing countries. Unfortunately the answer is no. Compare IAMFE to e.g. Alliance for a Green Revolution in Africa (AGRA) that has budget of more than 150 million dollars (www.agra-alliance.org). Besides this it is very presumably that such development cannot be driven by any organization. It must be driven by global, national and local political measures, research grants, private companies with interest in that business area and local farmers organizations.

### Table 2. Indicators on agricultural input. (Source: World Resources Institute, 2003)

<table>
<thead>
<tr>
<th></th>
<th>Average Arable Permanent Cropland in 1000 hectares (2000)</th>
<th>Agricultural labor</th>
<th>Tractor use</th>
<th>Average fertilizer use (kg per ha of cropland) (2000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WORLD</td>
<td>1,497,365</td>
<td>44.3</td>
<td>0.9</td>
<td>26,409,666</td>
</tr>
<tr>
<td>EUROPE</td>
<td>305,891</td>
<td>8.4</td>
<td>0.1</td>
<td>10,982,754</td>
</tr>
<tr>
<td>- Denmark</td>
<td>2,289</td>
<td>3.6</td>
<td>0.0</td>
<td>123,221</td>
</tr>
<tr>
<td>SUB-SAHARAN AFRICA</td>
<td>176,712</td>
<td>62.0</td>
<td>1.0</td>
<td>234,661</td>
</tr>
<tr>
<td>- Mozambique</td>
<td>4,135</td>
<td>80.3</td>
<td>1.9</td>
<td>5,750</td>
</tr>
<tr>
<td>- South Africa</td>
<td>15,712</td>
<td>9.3</td>
<td>0.1</td>
<td>72,300</td>
</tr>
<tr>
<td>NORTH AMERICA</td>
<td>224,703</td>
<td>2.0</td>
<td>&lt;</td>
<td>5,511,465</td>
</tr>
<tr>
<td>SOUTH AMERICA</td>
<td>116,353</td>
<td>17.4</td>
<td>0.2</td>
<td>1,293,036</td>
</tr>
<tr>
<td>DEVELOPED</td>
<td>639,471</td>
<td>7.1</td>
<td>0.1</td>
<td>19,399,767</td>
</tr>
<tr>
<td>DEVELOPING</td>
<td>857,017</td>
<td>54.8</td>
<td>1.5</td>
<td>6,903,108</td>
</tr>
</tbody>
</table>

"In 1992 I set up a trial in maize at our experimental station in Umbeluzi, which lies 30 km west of Maputo. The aim of the experiment was to test the effectiveness of seed dressing pesticides against maize stem borer. But setting up a trial here is something of a task. The first step is to find someone who wants to plough the field at the right time and a working tractor. The fields are irrigated by leading water over the field. In the field there are some deep furrows ploughed, but even if you are careful, it is still difficult to obtain an even distribution of water, which leads to increased variability in the study."
The day before we plan to sow the trials, we had to dress the maize seeds. The problem, however, was that there was no running water, so we ended up having to use some old dish washing water as binder. Nice. We also lacked buckets, stirring sticks etc. Early next morning, we went out to the experimental station. The ‘seed drilling machine’ had arrived, that is eight Mozambican women each with a stick, which is used to dig a hole and then 2 seeds are placed in each hole. Later the field is weeded to 1 plant per hole. We sow 24 plants per row, but it fluctuates with 3-4 plants. The area was irrigated after sowing to ensure a uniform germination. Germination does go fast down here. The maize plants were 12 cm high seven days later. It seems like a growth explosion. But the same also counts for insects. Maize is being attacked already seven days after they are up. Unfortunately, the growth halted a bit after 12 days, because there was no money to buy fertilizer. Fortunately our project got money, so we managed to get the trial fertilized; nevertheless it took 2 days to organize it. The irrigation was also missed once because the director, who received the money to buy diesel for the pump, used the money himself for his car, so he could go on a weekend trip.

Another funny thing is plot markers which are just twigs, cut from bushes and small trees, but they don’t last long. Either the local population uses them for fire wood or the termites build a termiteary. So at harvest time we find a small clay stack built by termites around the stick.

In order to stop the local population picking the corn cobs, the field is fenced and guarded by guards with machine pistols / guns. Beside that it is difficult to guard an experimental field 24 hours a day; there is also the problem that the guards are also hungry!

The experiment showed, after all, how best to combat the maize stem borer, but then came the next problem. The new knowledge should be transferred from research to the subsistence farmers. After three years, it was not yet published.” Kjaer & Kjaer (1995).

Stimulation of investments in research
There are different ways to stimulate investments in agricultural R&D. Motivational mechanisms are required to endorse private investment in agricultural R&D, particular in developing countries. The mechanisms must be designed to incorporate pro-poor crops, traits and technologies and to distribute costs, benefits and risks across more than one agent. The motivation mechanisms can be split up into different kinds of mechanisms.

- **Pull**: Creating or improving favorable market conditions and thereby increase the expected returns or reduce the risks to investments in R&D.
- **Push**: Reduce the costs of R&D, promote basic research to encourage spillovers and reduce the cost for firm’s developing new products.

But how the mechanisms will impact the private R&D investment is difficult to say, because of the matter of culture, world economy, government type etc. Pro-poor agricultural R&D facilitates the development of economic environments conducive to private-sector participation and investment. Pull and push mechanisms can encourage this participation. These are described in Table 3.

Conclusion
Agriculture in developing countries is facing serious problems:

- **Investment in research and development in developing countries, particular Sub-Saharan Africa, is decreasing.**
- **The richest countries are shifting their focus away from developing productivity enhancing technologies towards biomass production, welfare issues and environment.** As a result, the technological spillover will decrease leaving the poorest countries in a vacuum.
- **Research and development as well as farmers and advisory organizations are not structured adequately.**
- **The infrastructure impedes the development and spread of new technologies.**
- **Trade barriers hindering the export of agricultural goods from poor countries to rich countries.**

**Figure 3.** Maize field trial in Mozambique. A minimum of mechanization is necessary in order to carry out field trials.
To overcome these problems a lot of measures have to be taken, e.g. road construction so machinery and input factors can be transported to the small farmers and products from these can be transported to the global market.

Research should focus on:

- New farming systems that give a certain degree of growth assurance; sustain soil fertility and give a fairly high yield with little input of fertilizer and pesticides.
- Development of new equipment and machinery. Suitable equipment for experimental stations and on-farm field trials has to be developed as well. In some cases technology from the developed countries can be adopted while in other cases it is necessary to develop specific low-technology equipment.

Table 3. Research mechanisms and impact on on private R&D. (Source coming up)

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Type</th>
<th>Examples</th>
<th>Hypothesized impact on private R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public-sector research</td>
<td>Push</td>
<td>Support for basic scientific research</td>
<td>Positive if complementary</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Negative if substitutive (crowding out)</td>
</tr>
<tr>
<td>Fiscal policies</td>
<td>Push</td>
<td>Tax credits etc.</td>
<td>Small impact initially, but it will gradually increase</td>
</tr>
<tr>
<td>Public-private partnerships</td>
<td>Push</td>
<td>Public seed development</td>
<td>Successful only where no conflicting incentive structures exists</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Private seed distribution</td>
<td>High transactions and opportunity costs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Risks associated with the use of proprietary assets; and mutually negative misperceptions can be properly managed.</td>
</tr>
<tr>
<td>Research parks and zones</td>
<td>Push</td>
<td>Provision of land and infrastructure near universities</td>
<td>Positive; typically help investors to overcome major entry barriers</td>
</tr>
<tr>
<td>Trade liberalization</td>
<td>Pull</td>
<td>Lifting of trade embargos</td>
<td>Firms and countries may lose market share in some areas but gain elsewhere. This fact is well known when using Wallersteins world theory perspectives (Wallerstein 1974)</td>
</tr>
<tr>
<td>Reward &amp; prices</td>
<td>Pull</td>
<td>Financial prices for research discoveries</td>
<td>Depends on the appropriateness of knowledge, size deadweight losses, and effect of common pool problems</td>
</tr>
<tr>
<td>Intellectual property rights</td>
<td>Pull</td>
<td>Patents, Plant breeders’ rights, trademarks, trade secrets</td>
<td>Impact depends on the nature of the intellectual property rights mechanism and the presence of supporting institutions.</td>
</tr>
<tr>
<td>Third-party brokering</td>
<td>Push</td>
<td>Non-profit organizations</td>
<td>The impact on private R&amp;D will be positive if the costs and risks associated with transferring technologies and tools between the private and public sectors can be reduced</td>
</tr>
</tbody>
</table>

Figure 4. Guard with machine gun protects a field trial (the author in the middle).

- Screening of varieties and development of new varieties with better traits.
The investments, however, should be made in the whole chain from university to subsistence farmer. On-farm trials are an adequate instrument to ensure this. They are characterized by (Koenig et al., 2000; Franzel and Coe 200x):

- Research is carried out on a producer’s farm, which can lend additional credibility to the data and facilitate the adoption of new technology by other producers.
- Large input of trained people is required.
- Farmers and researchers work as partners in the technology development process.
- On-farm trial plots sizes are commonly large and can thus make use of farm equipment
- Only little input in relation to money and equipment is required.
- Equipment used for field work is frequently owned by the farmer.

With no doubt it is crucial, that on-farm trials which primarily have the objective of demonstrating new technology, has to rely on methods developed by the relevant research sector. And, that this research must adopt the role of having the main task of feeding farmers with appropriate and useful knowledge. In this respect it can be assumed that the more often and earlier that farmers are involved in the process, the greater is the probability that the practice will be adopted. On-farm testing is useful as well for evaluating the biophysical performance of a practice under a wider range of conditions than is available on-station. This is especially important because soil type, flora, and fauna on research stations are often not representative of those found on farms in the surrounding community. Moreover, on-farm testing provides important diagnostic information about farmers’ problems.

Research is a long term investment and it will take time to realize results, such that we see improvements in productivity and food security. We can only begin too slowly.

References

- World Resources Institute, 2003. Available at: http://www.wri.org/
Bio energy trials and silage maize trials
– Use of WINTERSTEIGER machines

The number of field trials with energy plants is increasing. WINTERSTEIGER offers two types of machines. The Cibus S is a self-propelled machine, whereas Cibus TRM is an efficient tractor mounted solution.

For bio energy the following crops can be used:
- silage maize
- topinambur
- silage gras
- miscanthus
- sunflower
- gras
- sorghum
- Others

WINTERSTEIGER offers the following machines for bio energy field trials:
- Cibus S
- Cibus TRM

Cibus S
The Cibus S is a powerful harvester for:
- grass

- clover
- other forage plants
- flowers
- silage maize

Advantages
- Modular system:
  - Possibility to customize
  - Broad possible field of application
- Compact dimensions:
  - High agility, simple transport
- Quick, mix-free transport of harvested material
- High user friendliness and drive comfort
- Good overview over the workflow
- Options:
  - Automatic weighing system
  - Automatic sampling system

Basic machine
- Engine
  - VW: 35 kW/48 HP, 4 cylinder, diesel, 1900 ccm, water-cooled
  - Deutz: 56 kW/76 HP, 4 cylinder, diesel, 2700 ccm, air-cooled
- Traction drive
  - Transmission system: hydrostatic, stepless from 0 – 16 km/h
  - Steering: hydraulic
  - Tires: (Standard)
    Front: 11.5/80 – 15.3
    Rear: 200/60 – 14.5

Harvesting attachments
- Maize chopper Kemper C1200
  - Cutting width: 1.25 m
  - Chopping length: 5-30 mm
Advantages:
- Lossless collection of harvested material (twin intake rollers with aggressive teeth)
- Row independent: broad field of application (maize, sorghum, sunflower, silage, elephant grass)
- Efficient feeding, high speed flywheel for best chop/feed quality

Cibus TRM
- 3-point frame
- Weighing hopper 1200l
- Sample quantity adjustable

If you have any further question, please contact our company:
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Fax: +43 7752 919-57
seedmech@wintersteiger.at
Maize trials in Denmark - from design to result

Summary
In Denmark app. 100 maize varieties for whole silage are tested. This gives a number of challenges, because of the huge area these trials cover. Incomplete block design is chosen to minimize the variation. The sowing is done in a short period of 5-6 hours in order to ensure equal germination conditions for all varieties. Maize for whole silage is harvested when the dry matter is app. 30%. Samples are taken from the harvested mass. Drying of the samples starts in the field, in a trailer with a small air blower. One sample per variety is sent to laboratory for quality analysis. All results are publicized in the interactive website SortInfo. Maize is a tropical plant that requires at least 2400 heat units to reach a maturity that gives acceptable yield and quality. Denmark has for several years been the northern limit for growing maize for whole silage while at the same time having a large and very intensive dairy farming industry. Therefore breeders are very interested in testing new varieties of maize in Denmark. The variety testing system is setup in such a way that all breeders can register any variety either for official variety list testing or for supplemental testing. This has resulted in trials with app. 100 varieties. There are a considerable number of challenges in carrying out a trial that covers 2.6 ha. Among these challenges are:

- Experimental design and how to minimize the variation due to large experimental area
- Sowing single plots efficiently
- Harvest within as short a time span as possible
- Determining dry matter and minimizing the difference in dry matter content between varieties
- Eliminating the influence of the harvest time during the day by correct sampling
- Efficient and secure handling of data

This article will deal with these issues by describing the system that was implemented in Denmark in 2006.

Experimental design
It is well known that a large trial with many treatments (varieties) will result in higher experimental error, thus reducing the chance of obtaining a significant result. This is not acceptable, particular in tests where the differences between varieties are small. Therefore it is widely recognized to apply an incomplete block design (Williams, 2000) In 2006 incomplete block design was implemented for variety testing of maize. The randomization plan is created in “PC-Field Trial” (in the “Nordic Field Trial System”), where the algorithm is based on a “dll” from the “CycDesign” program (http://www.cycdesign.co.nz/index.htm). However the regular incomplete block design sometimes creates inadequate designs. The algorithm places buffer plots in the mini-block to fill out the mini-blocks. This is overcome by removing the buffer plots and rearranging the mini-blocks and placing the equal sized mini-blocks side by side. Randomization sometimes leads to the error that one variety more often occurs in one end of the trial than others which can favor or disfavor it. Therefore we use the latinized design which gives a more even distribution of the varieties across the experimental area. Harvesting the trials requires buffer plots so the large harvest machines can move easily around in the field. This is done by placing a row of buffer plots for every 10-15 rows so the distance during harvest is minimized.

Sowing of maize trials
The sowing of the trials must be done in as short a
period as possible in order to ensure that all varieties have the same germination conditions. Also germination percentage and the grain weight must be determined in order to ensure that the number of plants in every variety is exactly the same. The exact number of grains are weighed out for each plot and arranged according to the randomization plan.

The trials are sown in a serpent scheme with a “Baural” single plot sowing machine that can be emptied after each plot has been sown. It normally takes 5-6 hours to sow a trial with 400 plots.

**Harvesting of maize trials**

There is normally a time span of three weeks from the earliest variety to the latest variety is harvested. It would be most correctly to harvest at the time when dry matter content is as desired for each variety. However this is not possible because the data is not available prior to the start of the test and also because it is very costly to harvest at different periods. For whole silage the maize is harvested when

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**Figure 1.** Maize trial design from “PC-Field Trial”.

**Figure 2.** The maize trials are sown with a “Baural” single plot sower.

**Figure 3.** The “Baural” maize sowing machine is very precise placing the corn in the desired depth and distance.
the dry matter is app. 30%.
Harvesting normally starts in the morning after the morning dew has vaporized; however, there is still a gradual increase in dry matter content during the day, which will result in misleading results if it not handled correctly.
The trials are harvested with a “Champion” maize cutter that has been mounted with a “Haldrup” sampler. Of the four rows in each plot only the middle rows are harvested whereby inter plot competition is eliminated.

**Figure 4.** “Champion” maize cutter mounted with a “Haldrup” weighing and sampling unit

The yield is measured on a “Mettler” weight and data automatically transferred to a computer in the tractor, by the use of the software program “Haldrup Harvest Manager”. The randomization plan is imported from “PC-Field Trial” and shown on the computer screen allowing the driver to constantly monitor that the correct plots are being harvested.

**Figure 5.** The harvesting is monitored on a PC using the “Haldrup Harvest Manager” program.

**Sampling**

While harvesting a plot a sample is drawn from the harvested mass a sample of app. 1 kg is taken. The sample is packed in a perforated plastic bag and a printer prints out a bar code label with precise id (Trial, plot etc.). The sample is also weighed and the data sent to the computer in the tractor.

**Figure 6.** The sample is packed in perforated bags and weighed.

Afterwards samples are immediately placed in a trailer. An engine mounted on the trailer blows semi heated air through the trailer where the perforated plastic bags allow air passage and vaporization, thus starting the drying process of the sample. This system has two huge advantages: 1) The determined dry matter will exactly match the measured yield and thereby eliminate fluctuations in dry matter during the day; 2) The quality analysis will be more reliable because this fixes the content of sugar and starch. In air tight bags the sample will start to ensile or rot which can result in useless results from the laboratory.
Figure 7. The samples are placed in a trailer and drying begins with the help of a small air blower.

The drying of the samples continues in the trailer for 24-48 hours. Afterwards the samples are moved to the drying oven – still in perforated bags – and dried for 18 hours at 60 °C.

Quality analysis
The plot samples are after drying subdivided and one sample per variety is sent to laboratory for quality analysis. It is of course preferably that one sample per plot is analyzed for quality traits; however, this is very expensive. In Denmark the samples are analyzed for the following characteristics:
- Crude protein, % in dry matter
- Wood pulp, % in dry matter
- Crude ash, % in dry matter
- Sugar, % in dry matter
- Starch, % in dry matter
- Enzyme digest.OM, %, (cattle)
- NDF, % in dry mat.
- iNDF, % in dry mat.

Statistics and reporting
For the breeder, adviser and farmer the size of the yield matters, but more important is the quality of the yield since the content of sugar, starch, digestible parts etc. determines the value of the crop and in the end how much milk a kilogram of maize will produce. Therefore the yield and the quality parameters are transformed into yield of feeding units per hectare and net energy value for a high yielding milk cow.

The results are statistically analyzed using SAS, Proc mix and where significance is determined using an F-test, an LSD value is calculated.

All results are publicized on SortInfo, which is an interactive website where breeders, farmers and advisers have immediate access to the results.

References

Figure 8. All results from the Danish maize trials are publicized on www.sortinfo.dk.
Status and Strategy of Field Mechanization and of the Mechanization of Field Experiments of Maize Production in Ningxia

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Summary
Status and problem of Ningxia maize mechanization of field experiment were analyzed in this paper. Strategies to improve the mechanization level were put into use and have realized some achievement.

Introduction
1. Geographical location and region feature
Ningxia Hui Autonomous Region is located on the loess table land (north latitude 35°14′ - 39°23′, east longitude 104°17′ - 107°39′) within the middle-up steam area of the Yellow River. The total area covered is 66,400 km². Among the total area, the Yellow River irrigated area is 41%, the southern mountain area is 51%. The total population is 5,800,000 persons.

Yellow River (gravity fed) irrigated area: It is within the arid region of the middle temperate zone. It is a river flat (plane) with the irrigation-silting type of soil. The layer of soil is deep. There are perfect facilities of irrigation-drainage which support gravity irrigation very well. The average land per person is small with intensive cultivation. The level of farm mechanization is relatively high. Main crops are wheat, maize and rice.

Pumping irrigation area: It is also within the arid region of the middle temperate zone. Here water is pumped from the Yellow River to irrigate land. It is a new immigration area. Farm mechanization level is low. Main crops are wheat and maize.

Southern mountain area: It is within the cool area of the arid region of middle temperate zone. Farming relies on rain fall and well or reservoir irrigation with coarse - extensive cultivation. Farm mechanization is poor. The main crops are maize, tomato, wheat and miscellaneous grain crops.

2. Maize production and machinery usage
Total grain growing area is 800,000 hm². Wheat, maize and rice are the three main crops. Over the past ten years, maize growing area increased very quickly. The planted area has reached 200,000 hm². While it is 24% of the total cultivated land it produces 40% of total output. Maize has become an important feedstuff as well as economic crop.

2.1 Main planting models
Only maize: Mainly distributed in state farms of Yellow River irrigated area and pumping irrigation area. The yield is around 12,000 kg/hm². Sowing is by machine. Cultivation, weeding, and fertilizing have been basically mechanized. But harvesting is mainly by labor because of the lack of suitable harvesting machines.

Wheat and maize inter-planting model: It is the main model in Yellow River irrigated area. Wheat is sown in early spring when the maize sowing band is left (unsown). After wheat seedling emergence, maize is sown by spot seeding or mini man power drill. Cultivating, weeding, fertilizing are by hand. The wheat harvesting is by machinery, whereas the maize harvesting is by hand due to lack of machinery. The yield of wheat is 4,500 kg/hm² and maize is 8,000 kg/hm².

Plastic film covered sowing model: It is mainly in southern mountain area with extensive cultivation. Sowing, film covering, weeding, fertilizing, harvesting all are done by hand. The maize yield is 6,000~7,000 hm².

Maize for silage model: Ningxia has a tradition for raising livestock. Since the government policy - ‘return land from grain growing to forest and grass growing, and seal the mountain pass to ban grazing’, livestock raising has become shed-feeding livestock management styles have emerged. As a result the
traditional sources of feedstuffs dried up and had to be replaced by new and alternative sources. This encouraged silage maize to be developed quickly. The river irrigation area is the main dairy industry area. The yield of whole fresh plants of maize is 85,000~95,000 hm². The sowing and processing sectors are well equipped with machinery. However, the mechanization of silage maize harvesting has not been promoted/popularized. Labour inputs and costs for harvesting are high, and the resulting quality of harvested product low which in turn increases transportation costs. The industry of beef cattle and sheep for meat is located in southern mountain area. Here the development of silage maize has been slower to expand. The yield is 75,000 hm². Sowing and processing is poorly developed when compared with the total region.

2.2 Cultivation management
There are many problems for fertilizing. The base fertilizer is not applied deep enough. Usually the base fertilizer is spread on the surface before sowing, then harrowed it into the soil or applied by drill. Using a rotary tiller is a better method allowing the base fertilizer to be distributed 0~15 cm beneath the surface. Even by using this improved method, only part of the nitrogen fertilizer can be infiltrated deep into the soil following irrigation or rainfall water. However this is not enough to move phosphorus fertilizer down into the root zone of maize, to be absorbed by the root system. The industry of beef cattle and sheep for meat is located in southern mountain area. Here the development of silage maize has been slower to expand. The yield is 75,000 hm². Sowing and processing is poorly developed when compared with the total region.

3. Field experiment and mechanization for cultivation and breeding
Crop institute of Ningxia Agricultural Academy was set up in 1950. It includes wheat, rice, maize, variety resource, biology, economic crops, and cultivation improvement etc., seven research groups in total. The Academy focuses mainly on the research of new varieties and its cultivation technology for wheat, rice, maize, miscellaneous grain crops and benne, sunflower, bean economic crops. There are 30 hm² lands for experiments.

3.1 The field experiments for maize breeding
Development of the economy of Ningxia has dropped behind other areas. Its seed breeding continues to use traditional methods. The main processes of maize breeding are in the following: Parent Breeding → Combining Ability Testing → Inbred lines Stabilizing → Hybrids Crossing → Hybrids Identifying → Hybrids Comparing → Yield Testing in different area → Hybrids Approving → Hybrids Generalizing.

There are many tens of thousands of maize materials sown each season in experiment fields. The number of hybrid crosses is also many tens of thousands. The comparative testing of hybrids need to be repeated many times and at many locations. The selected materials (inbred lines) need to be bulked up and seed of new varieties / hybrids produced commercially. To do this, female parents need to be emasculated. The total task including field management and the harvesting results in heavy workloads. There are many different ecological environments to be serviced, many requiring different hybrids / varieties which in turn require considerable additional work for identifying hybrids, hybrid comparison testing, and yield / adaptability testing in different areas. This must be linked with approving hybrids, generalizing areas for their promotion and extending them into the farming community. This long breeding period and the multiple links need equipment. The manual work situation is impairing the progress and experiment quality of maize breeding and production / extension.
3.2 The field experiments for improving the cultivation

Suitable matching cultivation technologies for high yield, high quality, and high efficiency varieties / hybrids are absolutely necessary. Achieving this needs field experimentation to find the best fertilizer type, level, applying time, plant density, farming model, safe sowing period, and optimum coupling effect of fertilizer and density, ridge culture, water saving irrigation, plant diseases and insect pests control. At present because of the shortage of machinery, we mainly rely on very heavy manual work. As a result new cultivation technologies cannot be popularized / extended into production practice.

4. Developing strategy

So far we have purchased some field experiment machinery. It obviously improved our work condition. But we found the maize seed planter was not good enough. The evenness of seed distribution could not easily be controlled to meet the experiment design. We are now looking for cultivators with fertilizer distribution devices, harvester, emasculating machinery.
Optimizing of plot trials in Rapeseed

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Summary
The variety testing in plots for a plant breeder must to the highest degree simulate the situation in practical farming.

The different phenotypes of rapeseed (Brassica napus) can often cause big neighbour-effects when tested in normal single plot trials because of differences in vegetative development, flowering time, plant length etc.

To minimize this neighbour effect the German Breeding Company Norddeutsche Pflanzenzucht (NPZ) has developed a plot drilling-machine for sowing trial plots prepared for harvesting only the centre of the plot.

In these plots totally 9 rows are drilled with a centre of 5 rows and 2 border rows on each side.

Swathing and harvesting of the plots is adjusted to this system. Only the 5 centre rows of the plot are harvested.

Trial results show a big improvement in reducing the neighbour effect between plots.

This trial system is implemented in the German and Danish VCU testing of spring and winter rapeseed.

Materials and Background
In the breeding work of winter rapeseed a very important step is the yield trials of the developed genotypes.

Results
Results from trials comparing 6 different plot systems shown in table 1, shows that there is a remarkable change in ranking of the different phenotypes depending of system.

We believe that the centre plot system gives the most realistic yield results in variety trials.

This drilling and harvest system has been implemented in the German VCU trials and in the Danish VCU and Farmers Union Trials of winter and spring rapeseed.
Figure 1. Diagram of the drilling system.

**NPZ-Drillmaschine für Kerndruschparzellen bei Winterraps**

Figure 2. Photo of NPZ Plot drilling machine
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GD(5%, t-Test) für Interaktion Sorte x Parzellentyp = 8,3

Table 1. Relative seed yield of different winter rape variety types tested in different plot types. 1(OP) Short, high standability; 2(OP) Very short, high standability; 3(OP) Medium length, good standability; 4(OP) Medium length, bad standability; 5 (Hybrid) Long, medium standability; 6 (Hybrid) Very long, medium standability.

References

Study of the Information & Communication technology Project of Chinese Seed Industry

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Summary

With the rapid development of agriculture in most places of the whole world, information technology of China seed project is with great significance. However, the development of information technology of China seed project has just started, and embodiment of information technology in China is only as a platform for information dissemination; there is still a great distance to comprehensive information technology, information exchange through Internet and on-line work. According to the production, management, operations, research and other aspects, it is necessary and urgent to realize information technology of seed project in China. Information technology of seed project can be mainly achieved through the following three ways: management information technology, operation information technology and research information technology. Seed management departments, seed sales departments and seed user departments can realize the comprehensive and rapid development of seed project in China through on-line work, high-speed online business information exchange and omnidirectional communication among the seed scientific research departments. By doing so, level of Chinese agricultural economy will be improved.

Introduction

With the impact of usurping information, facing to the challenge of Agriculture New-Technological Revolution, research and production system of the field of Chinese Seed Industry can’t adapt to the need of the development of modern agriculture. Therefore, transforming the traditional industry with new technology and promoting the development of seed project production become effective methods to develop the inner communication in seed industry, to enlarge the effect of seed research achievements in society and markets, and to restructure operation system of seed industry, and they are also necessary elections to prosper seed project and industry[1].

1. The Current Situation of Chinese Seed Industry Information Development

The shift towards a community based on information & communication technology is a social economic process, in which the industrial economy shifts to the information economy caused by the revolution of computers and internet. This process includes the industrialization of IT, of the traditional industry, of the infrastructure, of the way of production, of the way of management, and of the way of life and so on. In developed countries, virtual agriculture and accurate agriculture based on artificial intelligence system and 3S technology have been widely used. Agricultural IT products develop continually which has impact on agriculture production, scientific research, education and management. Such products as many kinds of database system, the simulated model of crop production, Export System of Propagation, Digital Image Processing System have played a very important role in practical production and developed great efficiency.

In the relatively developed agricultural areas of China, agricultural information networks suitable for agricultural development have been established. For example, there is communication service platform network of agricultural science in Qingdao established by Qingdao Agricultural University (Figure 1). It includes six service systems (Agricultural Information Integrated System of Qingdao, Issuance System of Primary Products Supply and Demand Information, Agricultural Knowledge System, Website Automatic Editing System, Website Statistics System and Expert Technical Support System) and five large databases (Agricultural Production and Technology Information Database, Agricultural Practical Technology...
2. The Necessity of implementation of information & communication technology in Seed Industry

Though the current agricultural information networks provide platforms of information communication, through which the related personnel can obtain or transmit information, it can’t offer a complete platform for science technology communication and cooperation. The seed industry in China needs the establishing of a platform integrating management and communication and that is a require from both research, production and market perspective. By investigation and analysis, the necessity to implement Chinese Seed Industry Informationization embodies in the following aspects: (1) The industry system is not perfect. The overall development is in lack of enough energy resources; technically, cultivation propagation and marketing are adrift and seed science research and seed production management has been operated in two different systems for a long time. (2) Regulation and management are unfavorable, seed quality control system is not sound, means fall behind and enforcement of the detection and monitoring isn’t competent; the seed business network is immature, and the government’s management and control of seed market has difficulties in being instant and effective. Because of illogical management, seed quality decreases constantly, market fluctuates frequently, the phenomenon of multiple and unorganized variety is increasing seriously, and the case of false and inferior seeds frequently occurs. (3) Enterprises and market operation systems are backward. The level of cooperation of enterprise specialization is low. Management variety is limited, and the level of scale management is quite low; meanwhile, business field is special and narrow, whose ability of resisting risk is very low and allocation of production factors is unreasonable. (4) Because of the deficiency of research strength and repeated construction, both national and regional seed production and management as well as the scientific research equipments and technical force of scientific research units are relatively backward comparing to developed countries. There exist universal phenomena, for instance, operating expenses and research funds are insufficient, talents are unsteady and the means

Figure 1. Qingdao Agricultural Technology Communication Service
are relatively falling behind. The inputs of government into seed science research can’t be in accordance with the requirements. Besides, large quantities of low-level repeated researches have wasted the resources and they are unfavorable to the deepening of varieties researches which result in the phenomenon that few, low-quality and fewer breakthroughs of research achievements are appearing in recent years.\(^1\)

Facing the worldwide competition among seed industries, domestic seed industry cooperation’s need to implement information & communication technologies (ICT) to be more competitive on the market. The industries need to explore the oversea market and push the competition and cooperation of domestic seed industry enterprises through integration of ICT. Though cooperation the Chinese seed industry can enhance the competitiveness on the global market.

3. The Specific Measures of Seed Industry information & communication technology

Seed Industry ICT is to realize information communication and share in seed research production management, seed information acquisition and processing, seed expert system, seed system simulation, support system of seed industry decision, seed industry network and other aspects by information technology such as computer, information storage and proceeding, communication grid, media player artificial intelligence, 3S technology (GIS, GPS, PS) etc. Specifically, it can be divided into the following aspects:

(1) Information management

Facing the present fierce competition environment at home and abroad, Chinese seed industry needs to carry on innovation constancy to meet the requirements of age surroundings. Both the whole seed industry and other of the seed production bases plus the scientific research institutions need to push the management innovation of seed industry and realize scientific management. Seed Industry Information & communication technology is based on management information & communication. Accompanied with the different development periods, management information & communication technology is a continuous modernization process. The basic demand of management information & communication is that all information is shared and business communication between government economic departments and management departments as well as seed research institutions, seed running companies and seed users, realizing relevant internet office at the same time. On the premise of economy management information, the government can hold timely and overall the economic operation situation of the economic elements and the economic entity in the whole area; every department can intercommunicate information by rapid track and realize business cooperation; the various related policies, regulations and technology can be issued in public rapidly and the information and business operation of B2G can be realized among the government, seed cooperation and seed research center. The government carries on balanced management to the seed industry and let each area exert its advantages; reporting and renewing the current situation and development of seed in time to help the various production and research institutions to learn about the related seed information at home and abroad fast and conveniently, so as to arouse the strength of each aspect and carry out the seed production and research., etc. The relationship of various main parties is as Graph 2. Secondly, information management of seed production research processes in various areas. It mainly is to strength the application of IT in seed production process. Emphasizing on analysis warning after production, intelligent management in production, tracing back supervision after production, and so on so as to realize IT from respective application to whole-process application, from automatic data acquisition to treatment, planting structure analysis optimization, improved variety intelligent breeding, production management, market operation, economic accounting, price analyzing, market forecasting, application and management of seed production processing machinery, and all the other related economic activities, forming the coordinated process of seed production management.

(2) Seed Operation Information & Communication

Both the fast changing market requirement and the increasing fierce competition environment require seed cooperation’s and the whole supply chain to have faster response speed and the cooperative operation ability as well as advanced insight into supply chain. Through the real-time communication and cooperation with the suppliers and seed users, seed enterprises can make the suppliers have the predictability on the requirements of themselves and provide better prices and services, offering good foresee ability to their supply capability to
provide guarantee for long-term and sufficient supply business. On the other hand, the suppliers can learn about the demand information of seed users themselves in time, keep faster response ability in the changeable market environment, track and monitory the whole process of satisfying requirements and hand products and service to seed users accurately, timely and in high quality. In order to realize the targets of cooperative prediction, planning and supply in logistics activities and response to the best placement of the total inventory on the supply chain, we need to make sure the tight integration of business process between customers and cooperative partners, realize cooperation without resistance or slowness, share business data, make combined forecast, plan, manage, operate, finish performance evaluation and so on. Only if seed companies cooperate with each other, seed circulation can have faster response speed and much more foresee ability, better resist varies kinds of risk, decrease production costs and improve production and meet the various demands of the users.

(3) Research Information & Communication
Superior variety is the headspring and power of seed industry development. Only the varieties according to market requirement can drive and promote the development of seed industry. In general, seed research strength of China is above world average level, but there is still a long distance from the requirement of seed industrialization development. Not only the research strength is dispersing but also the construction is repeated and at a low level: country, province and prefecture are all concentrating on breeding; however, the no-strengthened key point is not favorable to the rational distribution of manpower, property, treasure and other limited resource, and thus leads to huge waste of large input, low output, and low benefit. Research management information & communication takes advantages of the modern IT to realize networking of science research, management process, management method and information communication by exploring and sharing research information resource so as to enhance the efficiency and level of science research, research management and research communication. In order to fully mobilize the limited seed production and research resource in various aspects as well as manpower and material resources, each science research unit should give priority in establishing a huge data information center to fully collect the information such as research projects, the present equipments with its service condition, human resources and so on. Thus, there are various channels to collect information, for instance, using experimental data to test the pictures and other related information with the projects. Only in such a way, can repeated construction of each unit be avoided and limited human and material resources are fully used. Figure 3 shows the pattern of information communication. Each unit establishes an information center to make digitalization management on its resources. The purposes are not only to improve research management level and enhance work efficiency, but also to realize various index putting forward by science research planning institute. Design, monitory, improvement and innovation of procedure must be applied on advanced management concepts and methods which can make them eliminate all the ineffective operation and acquire the best management benefit under joint efforts of the science research manager and the immense S&T workers. By decreasing middle management level optimal research business procedure reduces time delay between decision and performance, accelerate dynamic reaction and adaptability on current events and promote the improvement of science research management.
Through scientific research management information, science research unites can be an effective component of Chinese seed project scientific research ranks, make more reasonable allocation of Chinese limited resources of scientific research, human, material and even finance and give full play to Chinese scientific research potential. Every local seed center does technology subentry, supervising, data collection and treatment to their underling unit; every scientific research unit does especial investigation, overall plan and cooperation according to the assigned task and their resource advantages so as to promote the development of the whole seed industry.

4. Discussion
These projects have completely improved the weakness of agricultural production and operation, made developed countries fully play their original advantages, gradually improved their original disadvantage and greatly enhanced the competitiveness of agricultural products of developed countries in the world market.
At present, competition of the whole modern society is the competition of comprehensive strength, such as resources of finance, scientific research, human, material and so on, and no independent corporations or scientific research unit can survive or develop even more in the extreme competition. The establishment of seed information & communication project can realize share of the informational resources and complementary advantages, and improve its comprehensive competitive strength. The application of seed information & communication
project is also the favorable measure and basic assurance of pushing Chinese agriculture to a new step and constructing new socialist countryside. Though information management has greatly improved entirety advantage of seed industry in China, it can weaken mutual independence and autonomy between seed cooperation and science research units. Therefore, the degree of information & communication management is a process needing continuous development and further exploration.

References


The National\Regional System of Field Experiments for Modern Agriculture

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Summary
New classification of landscapes and soil heterogeneity, established on stability of heterogeneity in time, is considered. On the basis of this classification the hierarchical national system of field experiments for new agricultural technologies development and assessment is prepared. The system consists of following field experiment levels:

- National/Regional (field experiments for nutrient balance study, agro climatic and agro environmental field experiments);
- Zonal and District (landscape, cooperative, precision field experiments and trials for technology testing);
- Special Interzonal (field experiments concerning potatoes or flax cultivation, or meadow and etc.).

The system may be useful for establishment of a field experiment network in the Baltic Sea region as well as other geographical areas.

Introduction
The World needs of food are growing. To increase food production, food manufacturing becomes a task of vital importance. Its decision is linked with great objective difficulties: global warming, a deepening of lack of fresh water, deficiency of power resources and complex environmental problems. But there are also positive features - presence of various high-efficiency techniques, fine varieties of cultivated plants and races of animal, kinds of highly effective fertilizers and pesticides and easy availability of computers and satellite orientation. These open the opportunities for agriculture to overcome arising difficulties as well as to continue further development of manufacture. And the Science should help farmers to use these opportunities as better as possible.

Scientific preconditions should be created for formation of agricultural systems that would provide a counteraction to global and local negative influences and maximal use of natural conditions and technical opportunities of manufacturers. In concrete terms it means, that it is necessary to develop the most effective system of land use for each facilities. Such system would present for each field and crop such technological scheme which would allow to use the genetic potential of variety as well as level of soil fertility, farm material and technical resources most full, and to guarantee Environmental safety.

It is necessary to emphasize once again, that the next general recommendations on designing systems of agriculture and technologies are not necessary. New calculation systems and software for development of concrete projects for a separate facilities and a site with all of them specific features are necessary. On the base of these arguments following conclusion is presented: all necessary data, for calculations, should appear in these systems and programs and first of all characteristics of landscapes and soils. Correlations of these characteristics with crop productivity, interrelations between characteristics and technological actions influence on them should be estimated.

For performance of these tasks we develop offers on creation in our country of systems of field experiments of national, zone and regional levels, and also interzonal systems of specialized experiments. In these systems for performance mentioned above requirements a number of the experiments based on new, original methodology is included.

The landscape – environmental basis of this design is the classification of heterogeneity of landscapes and soils. The classification is formed on stability of heterogeneity in time. By this criterion four categories of heterogeneity are allocated:
• Renewed;
• Spontaneous.

The first category includes features of geomorphology and a soil cover: biases of a surface, soil genesis, them granulometric content, character of mother soil, etc. In the second category are presented the characteristics connected with soil fertility: content of humus and nutrition elements, the acid soil property and so on. The third category are included varying annually and during a season hydro-physical and biological characteristics. Heterogeneity of the fourth category is arises because of soil polluting by heavy metals, radio nuclides, defueling and etc. Classification has hierarchical structure. It is shown that heterogeneity of the first category influence estimations of heterogeneity the second category, and they, in turn on occurrence and agronornical value of heterogeneity of third category. But all these irregularities related to the concrete object, will be shown and be estimated differently at various climatic conditions. It finishes hierarchy of heterogeneity and allows building corresponding hierarchical sequence of systems of experiments.

The National system of experiments (balance experiments, agro–climatic and agro–environmental stationeries) is estimates distinctions in climatic conditions, is establish base parameters of productivity process (use of solar radiation, water consumption, consumption of nutrition elements and so on) and is define the limits of agro ecosystem productivity.

Zone and regional systems of experiments (landscape, cooperative, precision, comparative experiments) differentiate the parameters mentioned above, establish and estimate influence of geomorphologic and soil conditions on soil productivity, develop specifications for designing of agricultural crops cultivation technologies, promote optimization of structure of crops, etc. Specialized interzonal systems will be organized for research in specific tasks, for example, meadow cultivation, cultivation of flax or potatoes through all country.

The organizational basis of systems is as follows
• centralized planning of experiments, unity of techniques and methods of data processing.
• In brief lists of experiments some nonconventional titles are mentioned. In this publication we can comment on them very briefly. The general objective of these experiments — is realization of stated above the statement about necessity of methodical and normative maintenance of new systems of agriculture and technologies, as we believe that to make it on the basis of current experiments is impossible because of impossibility of the polynomial account on small number of samples of supervision.
• In section landscape experiments there are three series: mezó ….; micro….. and nano landscape. The first are intended for studying influence of a landscape position of crops of different cultures on their productivity, efficiency of technologies of different intensity on various elements of landscapes. Micro landscape experiments establish and estimate influence on crop productivity of heterogeneity in genesis and opportunities of technological impact on this influence. Influence on productivity of heterogeneity of soil according it granulometric content is studied in nano landscape experiments.

Essential and original feature of landscape experiments is their construction by transect method. Experimental transects (crop cutting, multiple to width of the sowing unit) cross investigated heterogeneity. As a rule, four paralleled transect are established together with control variant and the technologies are designed according the productivity equal to 1%, 2% and 3% of Sun light utilization efficiency. The account of a crop yield — micro plots. Their quantity should be sufficient for reception of authentic results. At a mezo landscape experiment establishment the number of micro plots were 120 units, and nano landscape one - 250. Precision experiences are intended for an establishment of the statistical regularities connecting efficiency of fertilizers with conditions of their application and allowing as the normative tool to calculate a dosage of fertilizers for the set crop yield with high accuracy.

The most important methodological position in these experiments is changing of their purpose. Instead of a usual establishment of the best variant the hypothesis and the mathematical model constructed on its basis is verified here. Not less important and new feature of such experiments is that in them soil heterogeneity becomes the ally of the experimenter and even a necessary condition. Varying parameters of soil properties become the arguments of the model and from their big number the iterative account selects the most essential. The quantity of variants in experiment is defined by structure of model and number of arguments used in it. In the project of our experiment with phosphoric fertilizers it is stipulated three blocks (sites with phosphorus content in soil equal to 50, 150 and 300 mg/kg of soil) with total number of variants
Conclusion

1. For obtaining sustainable crop yield in long perspective at changing World the new approach of applied research is needed.

2. Field experiment is the main tool of many agricultural sciences and researchers. But it, alone, produces data that are not possible to spread on big area or in a future. Moreover, obtaining of reliable information from field experiments became more and more expensive.

3. The new system of field experiments is offered. It may be realized at one big country, or on the international base at the big region. The system allows obtaining of valuable information that may be used for technologies adaptation and many other means more rapidly. But such research has to be cooperative.

174. The establishment of experiment with such quantity of variants is carried out on transect. The cooperative experiments that are designed by a uniform technique in different conditions are specially intended for revealing and an explanation of mutual relations in system soil - weather - technologies - crop. In them the same four-variant scheme, as well as in landscape experiments is used. For result processing reception of “logic tree” by means of which combinations of conditions and technologies consistently are established, from the best up to the worst. The substantial analysis of this sequence allows revealing the reasons of distinctions in results of weather and soil conditions on expediency of use of technologies of different intensity. The organizing of such experiments with three grain crops on six experimental fields of the Northwest zone of Russia has shown rather high efficiency and self descriptiveness.
Efficiency of incomplete split-plot designs – a compromise between traditional split-plot designs and randomised complete block design

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Summary
The paper shows how incomplete split-plot designs can be constructed from a-designs and how they can be analysed. The incomplete split-plot design can be regarded as both a practical and statistical compromise between traditional split-plot design and randomised complete block design. The efficiency of the design is compared to traditional split-plot design and randomised complete block design using data from 5 trials carried out using incomplete split-plot designs in Denmark through 2004-2007. The comparisons showed that the incomplete split-plot design were superior to traditional split-plot design in most cases – and in all cases when comparing differences among treatments in the whole-plot factor. The incomplete split-plot design was in many cases also better than the randomised complete block design.

Introduction
Split-plot design is convenient to use in many types of field trials with two or more treatment factors (called whole-plot factors and sub-plot factors for factors randomised to groups of plots and individual plots, respectively). However, the efficiency of comparisons between levels of the whole-plot factors is usually very low, partly because whole-plots very easily become large and partly because the number of degrees of freedom for estimating the whole-plot error usually is few. If the number of sub-plot treatments is large also the efficiency of comparisons between sub-plot treatments may be low because of large whole plots. The alternative of using a completely randomised block design may be unfeasible partly because the pieces of land that should be treated individually will increase, partly because the area of land that need to be used for guard areas may become too large and finally because the number of plots in each complete block may be very large. In such cases an incomplete split-plot may be a good compromise between the traditional split-plot and completely randomised block designs. In this paper the description of such designs will be given together with the efficiency as compared to traditional split-plot and randomised complete block designs on the same piece of land.

Methods
The applied incomplete split-plot designs were based on α-designs (Patterson and Williams, 1976). The reason for choosing α-designs was that they can be constructed for almost any number of treatments in two or more replicates and with a broad choice of block sizes. The construction of an incomplete split-plot design from an α-design can be done in the following way for a trial with t treatments for the whole-plot factor and v varieties for the sub-plot factor in r replicates:

1. First choose an α-design for the examination of v varieties in r replicates with an appropriate block size, k, and number the blocks within each replicate from 1 to s.
2. Copy this design t times and add labels to the plots within each copy so that they also are identified with their copy number, i.e. all plots from the original α-design get number 1, those from the first copy get number 2, those from the second copy get number 3 etc up to the last copy where all plot are label with the number of treatments, t. We now have rtv plots labelled with replicate numbers, block numbers, treatment numbers and variety numbers.
3. Rearrange the plots so that all blocks from
the same replicate are next to each other and within each replicate and so that all blocks with the same block number are next to each other. We now have the final, but un-randomised trial, with the following hierarchical structure: replicates → groups of blocks with same number → blocks with each treatment → plots with a subset of varieties

4. Randomise the trial in the following five steps:
   a. Randomise the ordering of replicates
   b. Randomise the ordering of groups of blocks with same number within each replicate
   c. Randomise the ordering of treatments within each combination of replicate and block
   d. Randomise the ordering of plots within each combination of replicate, block and treatment
   e. Randomise the actual varieties to the variety numbers

Figure 1 shows the final design for a small incomplete split-plot design with two treatments and nine varieties in two replicates each with three blocks (except that the actual variety names are not randomised to the numbers).

Incomplete split-plot design can also be based on other types of incomplete block design (Hering and Mejza, 2002. Ozawa et al., 2004 and others), which can be obtained either from textbooks and papers or from software such as Alpha+ (Williams and Talbot, 1994) and CycDesigN (Whitaker et al., 2006).

Five trials that have been carried out in Denmark with incomplete split-plot design are considered here. Four of those are part of the project “Characteristics of spring barley varieties for organic farming” and were carried out in 2004 and 2005 at three locations (see also Østergaard et al. 2008). Two variables were chosen for analyses: Grain yield (hkg ha⁻¹) and disease severity of powdery mildew (% leaf area of top three leaves on a scale with 11 classes (0%, 0.01%, 0.1%, 0.5%, 1%, 5%, 10%, 25%, 50%, 75% and 100%) was assessed two to three times during the season. The variable chosen was disease severity corresponding to growth stage 70 (beginning of grain filling) calculated by linear interpolation. These disease severities were subsequently transformed to their third root before entering the analysis). The whole-plot factor was ± under sown clover grass mixture in organic grown trials. The fifth trial is from the project “Screening of the potential competitive ability of a mixture of winter wheat cultivar against weeds” carried out in 2007. The whole-plot factor was ± herbicides. The sub-plot factor consisted of four pure varieties, three two-component mixtures and one three component mixtures of the varieties.

<table>
<thead>
<tr>
<th>Incomplete split-plot after the first 4 steps of randomisation</th>
<th>Used a-design</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 2 5 8 2 5 1 4 7 7 4 1 3 6 9 9 6 3</td>
<td>1 4 7 2 5 8 3 6 9</td>
</tr>
<tr>
<td>9 7 8 7 8 9 4 6 5 6 5 4 2 1 3 2 1 3</td>
<td>1 2 3 4 5 6 7 8 9</td>
</tr>
</tbody>
</table>

Figure 1. Incomplete split-plot with 2 treatments (± bold and underscore), 9 varieties, 3 blocks (double framed) in each of 2 replicates (each replicate is one row). The α-design used for the construction are shown to the right

Table 1 Dimensions of used trials lay out as incomplete split-plots

<table>
<thead>
<tr>
<th>Trial no</th>
<th>Locality</th>
<th>Year</th>
<th>Plot size m’m</th>
<th>Number of Replicates</th>
<th>Treatments</th>
<th>Varieties</th>
<th>Blocks</th>
<th>Plots per block</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Jyndevad</td>
<td>2004</td>
<td>11.0’ 1.5</td>
<td>2</td>
<td>2</td>
<td>48</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>B</td>
<td>Flakkebjerg</td>
<td>2004</td>
<td>10.2’ 1.5</td>
<td>2</td>
<td>2</td>
<td>48</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>Foulum</td>
<td>2004</td>
<td>8.5’ 1.5</td>
<td>3</td>
<td>2</td>
<td>35</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>D</td>
<td>Foulum</td>
<td>2005</td>
<td>8.5’ 1.5</td>
<td>3</td>
<td>2</td>
<td>35</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>E</td>
<td>Flakkebjerg</td>
<td>2007</td>
<td>12.0’ 1.5</td>
<td>3</td>
<td>2</td>
<td>8</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

1 Trial number A-D is from the project “Characteristics of spring barley varieties for organic farming (BAR-OF)”
2 Trial number E is from the project “Screening of the potential competitive ability of a mixture of winter wheat cultivar against weeds”
From this trial seven variables were chosen and analysed: Grain yield at harvest, vegetation cover (%) according to Hansen et al. (2007) on June 5, wheat and weed fresh weight on June 19, leaf area index (LAI), mean tilt angle (MTA) in degrees and the fraction of diffuse non-intercepted radiation that reaches the soil surface (DIFN) all sampled on June 21. LAI, MTA and DIFN were measured with a LICOR-2000 Plant Canopy Analyser (LI-COR Biosciences, 4421 superior St., Lincoln, NE 68504 USA). The size of the trials is given in table 1. All data were analysed using a mixed model. The model includes the fixed effect of the two factors and their interaction together with the random effect of replicates, groups of incomplete blocks with replicate, incomplete blocks and residual variation. The model can be described mathematically as:

\[ Y_{rvtb} = \mu + \delta_v + \tau_t + (\delta \tau)_{vt} + A_r + C_{rb} + D_{rbt} + E_{rvtb} \]

where

- \( Y_{rvtb} \) is the analysed value of variety \( v \) for treatment \( t \) in block \( b \) of replicate \( r \),
- \( \delta_v, \tau_t \) and \( (\delta \tau)_{vt} \) are the effect of variety, treatment and interaction between variety and treatment. \( \delta_v, \tau_t \) and \( (\delta \tau)_{vt} \) are fixed effects
- \( A_r, C_{rb}, D_{rbt} \) and \( E_{rvtb} \) are the the effect of replicates, group of blocks, blocks and plots, respectively.

They are assumed to be random effects (although \( A_r \) and \( C_{rb} \) can be treated as fixed effects) that are iid normally distributed with mean 0 and variances \( \sigma^2_A, \sigma^2_c, \sigma^2_D \) and \( \sigma^2_E \), respectively.

In addition to this model all variables in all trials were analysed in two mixed models to estimate the variance components that would be relevant for a traditional split-plot design and a randomised complete block design. From each of these three analyses the LSD-values for comparing the following four types of estimates were calculated: 1) comparison of two varieties for a given treatment, 2) comparison of the two treatments for a given variety, 3) comparison of the overall estimate (mean) for the two treatments and 4) comparison the overall estimate (mean) for two varieties. For more details on mixed models see e.g. Searle et al. (1992). All analyses were performed using the procedure mixed of SAS (SAS Institute, 1999).

Results and discussion

The results are shown in table 2 and 3. For trial A, C and D the LSD-values for all four types of comparisons were smaller for the actual design than if a traditional split-plot design had been used (column 3 and 4 in table 2). In all trials the difference was largest when comparing the main effect of the two treatments. In trial B the LSD for a split-plot design was about 13.5 times larger than that for incomplete split-plot design. The LSD-values for comparing the effect on yield of two treatments for given variety were reduced considerably both when compared to a traditional split-plot design and when compared to a randomised complete block design. The LSD-values for comparing varieties were reduced considerably when comparing two varieties at a given treatment and when comparing the main effect of two varieties and the differences were largest in trial C and D. The incomplete split-plot was not as efficient as the randomised complete block design when comparing the main effect of treatments. For the other three types of comparisons the incomplete split-plot was more efficient than the randomised complete block design.

For coverage of powdery mildew the benefit from using incomplete split-plot design were generally smaller than for grain yield indicating that the pressure of powdery mildew seems to be distributed more evenly over the whole area than soil fertility.

For trial E, where then number of varieties was much less than for trial A-D, the general pattern of effects was similar, but the size of the differences between designs was usually smaller. Compared to traditional split-plot design the LSD-values for comparing the main effects of herbicides were reduced considerably by the use of incomplete split-plot. Also the LSD-values for comparing the two herbicides for a given variety were reduced considerably for most variables by the use of incomplete split-plot design. The reduction in the LSD-values for comparing two varieties by using incomplete split-plot in stead of traditional split-plot were in all cases small (ranged between -7% and +6%) probably because in this trial the block size was small (only 8 plots) for the traditional split-plot. When compared to a randomised complete block design where the block size was larger (16 plots) the reduction was most often larger and ranged between 0% and 33%.
The LSD-values for comparing the two herbicides for a given variety were reduced in most cases when using the incomplete split-plot in stead of a randomised complete block design. However, the LSD-values for comparing the main effect of two herbicides were increased in most cases when using the incomplete split-plot in stead of a randomised complete block design.

The effect of using incomplete split-plot in stead of traditional split-plot and randomised complete plot designs are a combined the effect of changing the area of land within which the comparisons are made and a better balance between degrees of freedom. In the traditional split-plot the whole plot factor are compared by comparing “large” whole-plots within replicates and the test used for this has few degrees of freedom (1 or 2 in the trials studied here). In the incomplete split-plot design the whole plot factor are compared using smaller blocks within groups of blocks and the number of degrees of freedom are increased (to 5-15 in the trials studied here). The smaller blocks used in incomplete split-plot designs tend to decrease the random variation. Both the smaller blocks and larger number of degrees of freedom increase the efficiency of treatment comparisons. The increased number of degrees of freedom for comparing the whole plot main effects depends only on the design whereas the effect of decreasing the block size depends on the variability in the field and how sensitivity the variable is to this variation. The smaller number of degrees of freedom available for comparing two varieties in the incomplete split-plot than in a traditional split-plot designs tends to increase the LSD-values, whereas

<table>
<thead>
<tr>
<th>Trial no.</th>
<th>Grain yield, hkg ha⁻¹</th>
<th>Powdery mildew severity, transformed %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LSD</td>
<td>Relative reduction,</td>
</tr>
<tr>
<td></td>
<td>Plan</td>
<td>Split-plot RCB</td>
</tr>
<tr>
<td>A</td>
<td>Variety:Treat 6.5</td>
<td>7.9 8.04 18 19</td>
</tr>
<tr>
<td></td>
<td>Treat:Variety 6.7</td>
<td>10.1 8.04 34 17</td>
</tr>
<tr>
<td></td>
<td>Treat 2.2</td>
<td>11.3 1.16 81 -90</td>
</tr>
<tr>
<td></td>
<td>Variety 4.6</td>
<td>5.6 5.69 18 19</td>
</tr>
<tr>
<td>B</td>
<td>Variety:Treat 8.4</td>
<td>8.5 9.19 1 9</td>
</tr>
<tr>
<td></td>
<td>Treat:Variety 8.4</td>
<td>16.9 9.19 50 9</td>
</tr>
<tr>
<td></td>
<td>Treat 1.7</td>
<td>23.2 1.33 93 -28</td>
</tr>
<tr>
<td></td>
<td>Variety 6.2</td>
<td>6.0 6.50 -3 5</td>
</tr>
<tr>
<td>C</td>
<td>Variety:Treat 4.9</td>
<td>7.9 8.92 38 45</td>
</tr>
<tr>
<td></td>
<td>Treat:Variety 5.3</td>
<td>19.7 8.92 73 41</td>
</tr>
<tr>
<td></td>
<td>Treat 2.4</td>
<td>27.0 1.29 91 -86</td>
</tr>
<tr>
<td></td>
<td>Variety 3.5</td>
<td>5.6 6.31 37 45</td>
</tr>
<tr>
<td>D</td>
<td>Variety:Treat 2.0</td>
<td>2.8 2.86 29 30</td>
</tr>
<tr>
<td></td>
<td>Treat:Variety 2.2</td>
<td>3.1 2.86 29 23</td>
</tr>
<tr>
<td></td>
<td>Treat 1.0</td>
<td>1.7 0.48 41 -108</td>
</tr>
<tr>
<td></td>
<td>Variety 1.4</td>
<td>2.0 2.02 30 31</td>
</tr>
</tbody>
</table>

1) The column heading has the following meanings: Plan: The actual incomplete split-plot design, Split-plot: Traditional split-plot, RCB: Randomised complete block design.
Table 3. LSD-values for comparing the efficiency of the actual plan as compared to traditional split-plot design and randomised complete block design for some variables recorded in trial E.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Design: Comparison</th>
<th>LSD</th>
<th>Relative reduction, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plan</td>
<td>Split-plot R</td>
<td>Split-plot C</td>
</tr>
<tr>
<td>Grain yield, kg ha(^{-1}) at harvest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variety:Herbicide</td>
<td>5.8</td>
<td>5.7</td>
<td>6.2</td>
</tr>
<tr>
<td>Herbicide:Variety</td>
<td>5.9</td>
<td>7.6</td>
<td>6.4</td>
</tr>
<tr>
<td>Herbicide</td>
<td>3.7</td>
<td>7.8</td>
<td>4.6</td>
</tr>
<tr>
<td>Variety</td>
<td>4.2</td>
<td>4.1</td>
<td>4.4</td>
</tr>
<tr>
<td>Wheat June 19 g 0.25m(^{2})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variety:Herbicide</td>
<td>161</td>
<td>167</td>
<td>165</td>
</tr>
<tr>
<td>Herbicide:Variety</td>
<td>174</td>
<td>210</td>
<td>225</td>
</tr>
<tr>
<td>Herbicide</td>
<td>119</td>
<td>204</td>
<td>237</td>
</tr>
<tr>
<td>Variety</td>
<td>115</td>
<td>118</td>
<td>117</td>
</tr>
<tr>
<td>Log Weed June 19 Log g 0.25m(^{2})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variety:Herbicide</td>
<td>2.8</td>
<td>2.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Herbicide:Variety</td>
<td>2.8</td>
<td>2.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Herbicide</td>
<td>1.0</td>
<td>2.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Variety</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Vegetation cover (%) June 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variety:Herbicide</td>
<td>.052</td>
<td>.055</td>
<td>.048</td>
</tr>
<tr>
<td>Herbicide:Variety</td>
<td>.055</td>
<td>.057</td>
<td>.080</td>
</tr>
<tr>
<td>Herbicide</td>
<td>.032</td>
<td>.041</td>
<td>.097</td>
</tr>
<tr>
<td>Variety</td>
<td>.036</td>
<td>.039</td>
<td>.034</td>
</tr>
<tr>
<td>LAI June 21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variety:Herbicide</td>
<td>.059</td>
<td>.60</td>
<td>.60</td>
</tr>
<tr>
<td>Herbicide:Variety</td>
<td>.059</td>
<td>.62</td>
<td>.62</td>
</tr>
<tr>
<td>Herbicide</td>
<td>.026</td>
<td>.44</td>
<td>.44</td>
</tr>
<tr>
<td>Variety</td>
<td>.042</td>
<td>.42</td>
<td>.42</td>
</tr>
<tr>
<td>MTA June 21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variety:Herbicide</td>
<td>5.7</td>
<td>5.8</td>
<td>5.7</td>
</tr>
<tr>
<td>Herbicide:Variety</td>
<td>5.7</td>
<td>6.0</td>
<td>6.1</td>
</tr>
<tr>
<td>Herbicide</td>
<td>2.0</td>
<td>4.3</td>
<td>4.6</td>
</tr>
<tr>
<td>Variety</td>
<td>4.1</td>
<td>4.1</td>
<td>4.0</td>
</tr>
<tr>
<td>Log DIFN June 21</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>.052</td>
<td>.52</td>
<td>.53</td>
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<tr>
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<td>.40</td>
</tr>
<tr>
<td>Variety</td>
<td>.37</td>
<td>.37</td>
<td>.38</td>
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</tbody>
</table>

1) The column heading has the following meanings: Plan: The actual incomplete split-plot design, Split-plot R: Traditional split-plot with whole plots “randomised” to row of plots, Split-plot C: Traditional split-plot with whole plots “randomised” to groups of 4 columns within each replicate, RCB: Randomised complete block design.
the smaller blocks used in the incomplete split-plot design tends to decrease the LSD-values. However, the decrease in degrees of freedom for testing varieties are usually less important as the number of degrees of freedom in both plans will most often be relatively large and therefore, these LSD-values were most often decreased.

The use of incomplete split-plot in stead of randomised complete block design decreased the block sizes for all types of comparisons. However, number of degrees of freedom was decreased much for the main effect of the whole-plot factor and therefore, the LSD-values for comparing whole-plot treatments most often were larger for the incomplete split-plot design than for the randomised complete block design.

The calculations done here assume that the same area of land can be used for all three types of designs. This assumption may not be possible if there is a need to have large guard areas around each whole-plot treatment in order to avoid competition or other types of neighbour effect. In such cases the area need for performing the trials may be larger for the randomised complete block design than for the incomplete block design which again will be larger than the area needed for a traditional split-plot design. This will make the incomplete split-plot design less attractive than shown here when compared to the traditional split-plot design and more attractive than shown here when compared to the randomised complete block design.

**Conclusions**

The use of incomplete split-plot design was in most cases the most efficient design when comparing the main effect of two varieties, the effect of two varieties for a given treatment or the effect of two treatments for a given variety. The randomised complete block design was in most cases the most efficient design when comparing the main effect of two treatments. However, in the randomised complete block design the treatments have to be applied to each individual plots, which may be more laborious and may introduce larger competition between plots unless larger guard areas are used around each individual plot.
References


Past and Present Statistical Issues in Design of Variety Trials

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Summary

In this article some past design issues are reviewed and some present issues of practical importance are highlighted.

Lattice designs are common in plant breeding. Control varieties are included for comparison of varieties from different lattices. When the varieties are related by pedigree, the related varieties are sometimes grouped in consecutive plots. Alpha designs should be preferred in both these cases.

In presence of interference, neighbour-balanced designs may improve the precision. Straw height differences could be used as a covariate.

Spatial analysis may be more efficient than traditional block analysis. However, restricted randomisation is still needed. An exact theory for the relationship between design, randomisation and analysis is wanted.

Article

The randomised complete block design could be considered as the standard design for variety trials, used successfully since the 1920s. In the past century, statistical theory was developed for design and analysis of incomplete block trials. Efficient designs for resolvable incomplete block trials have been available, for all common numbers of varieties and replicates, since the introduction of alpha designs by Patterson and Williams (1976). Models including neighbour effects and spatial patterns are today easily fitted with standard statistical software. In this paper we review and discuss research on design of variety trials in presence of interference, competition and spatial patterns. Also, we highlight some new research on design for breeding trials, which could be of practical interest.

Breeding trials

In plant breeding trials, the number of entries is usually large. Several hundreds of entries could be included in one single trial. The entries are often laid out in small square or rectangular lattices with 2 – 3 replicates and 5 – 10 entries per block. A trial then consists of a set of such replicated lattices. Some entries, called checks, are included in all lattices, in order to connect the results and make possible comparisons of entries from different lattices. The efficiency of these multiple lattice designs was investigated analytically by Piepho, Büchse and Truberg (2006). Compared with alpha designs, the multiple lattice designs are usually less efficient. The average variances in the pairwise comparisons were larger for multiple lattice designs than for the corresponding alpha designs, in almost all of the investigated cases. When the number of checks is small, the efficiency of the multiple lattice designs compared to the alpha designs is sometimes as small as approx. 60%. Furthermore, multiple lattice designs always require more plots than the alpha designs, since the checks need to be included in all lattices.

On basis of these results, plant breeders should, for statistical reasons, consider using alpha designs instead of multiple lattice designs.

In breeding trials it is often reasonable to model the treatment effects as random. The entries included in the trial could be regarded as a random sample from a larger population. Because the entries are often related by pedigree, it is natural to model a correlation between related entries. Bueno Filho and Gilmour (2003, 2007) showed that the optimal design for this situation is dependent on the covariance structure. As design criterion, they used the average variance in pairwise differences, under assumption of known covariance parameters. Often plant breeders use split-plot designs with groups of related entries randomised on whole plots, and entries within groups randomised on subplots. If the
differences between the groups are large, these differences should be easy to detect. It should then suffice to investigate differences between groups on whole plots. Similarly, if the differences within the groups are small, entries from the same group should be compared on subplots. On the other hand, Williams and John (1999) proposed alpha designs restricted to include entries from as many groups as possible per incomplete block. Piepho and Williams (2006) investigated this issue by simulation. They compared split-plot designs with restricted and unrestricted alpha designs. In the investigated cases, the alpha designs performed better than the split-plot designs, with regard to ranking of entries. The alpha designs were not much improved by the restriction proposed by Williams and John (1999).

**Interference and competition**

Interference is present when the response in one plot is affected by the treatment in a neighbouring plot. For example, in plant nutrition experiments, fertilizers may leak to neighbouring plots. Also effects of pesticides and irrigation could spread to neighbours. In presence of competition, the response in one plot has an effect on the response in a neighbouring plot (Martin and Eccleston, 2004). Competition is likely to occur in many situations. In variety trials small plots can result in problems with competition, because taller varieties could shadow shorter varieties, and the plants could compete for nutrition and water through roots.

The safest method for avoiding problems with interference and competition is to use large plots, rather than small, and to include borders. The borders can be rows on the sides of the plots, or full border plots. However, larger plots and inclusion of borders increase the costs and may extend the experimental area much, with increasing variance as a consequence. This is a problem especially when there are many treatments, as is often the case in variety trials.

David and Kempton (1996) proposed that treatments be classified into ‘interference groups’. Varieties could be classified according to height, for example into three groups of tall, medium sized and short varieties, respectively. They suggested block designs with interference groups arranged within each block in an ordered cyclic pattern. A restricted randomisation, including cyclic permutation and reversion within blocks and treatment allocation within interference groups, should be carried out. In absence of interference, and with the ordinary complete-block analysis, this restricted randomisation gives weak validity. Thus, the hypothesis test of no treatment differences is valid, because under this hypothesis the expected treatment mean square equals the expected error mean square (Bailey and Rowley, 1987). But it is a problem with these designs that they are not strongly valid. In other words, they do not produce unbiased estimates of variances in treatment contrasts.

Interference because of differences in straw height can be taken into account by covariance analysis. The average difference in height is then introduced in the model as a covariate. This requires guard plots only at the ends of the blocks. The heights of these border plots are measured, and used in the analysis, but the yields are not. Clarke, Baker and DePauw (1999) analysed 65 spring wheat trials, and estimated that the yield decreased 4% per decimeter difference in height. Kempton et al. (1986) reported an effect of 2% per decimeter in five triticale trials. In a study of neighbour effects, including 3 barley varieties with different straw heights investigated in 17 trials, Åssveen (1991) recorded effects of approx. 3.5% per decimeter. However, it was not clear whether the neighbour effects were due to height differences only.

David, Monod and Amoussou (2000) recommended neighbour-balanced designs for covariance analysis when the variety heights are not known in advance. Neighbour-balanced designs are optimal for estimating the effect of the covariate, and also efficient in minimizing the average variance in the treatment contrasts. A design is neighbour-balanced if all pairs of treatments are neighbours equally often. In directionally neighbour-balanced designs each treatment has each other treatment once as a right neighbour and once as a left neighbour. In nondirectionally neighbour-balanced designs there is no distinction between being a right and being a left neighbour. Neighbour-balanced designs require many replicates when the number of treatments is large. As a rule, for an experiment with t treatments, (t – 1)/2 replicates are needed for nondirectionally neighbour-balanced, and t – 1 replicates are needed for directional neighbour-balance. In variety trials, the number of treatments is often large. Thus, partially neighbour-balanced designs, in which treatments are neighbours at most once, are especially useful. Partially neighbour-balanced designs, with a randomisation procedure that gives validity for the usual complete-block analysis, were given by Azaïs, Bailey and Monod (1993). Druilhet (1999) showed that circular neighbour-balanced designs give optimal estimates of treatment effects, among equireplicated designs, when the model contains additive left- and right-neighbour effects.
Spatial design

Experiments should be performed without systematic errors. By randomisation, systematic errors are transformed into random errors. It is well accepted that trials with experimental strata, such as blocks, rows and columns, should be randomised with regard to the strata, and that the statistical analysis should correspond to the performed randomisation.

However, many studies performed in the last decades have shown that spatial analysis could produce smaller variances in treatment comparisons (Cullis and Gleggson, 1989; Baird and Mead, 1991; Grondona et al., 1996; Qiao et al., 2000; Sarkar, Singh and Erskine, 2001). In classical randomised block analyses or row-column analyses the variation in the field is estimated indirectly as effects of blocks, rows and columns. By spatial analysis, the variation in the field is modelled directly, by estimating trends and correlations between plots. Because the spatial analysis does not need blocks, rows and columns, it could be argued that restrictions in the randomisation, according to such strata, are not needed.

On the other hand, blocking is an efficient method for reducing experimental error. Restrictions can also be used for practical reasons, as is often the case in split-plot experiments. Resolvable block trials are convenient, because the blocks could be managed one at a time without increasing the variation in the treatment comparisons. Kristensen and Jørgensen (2007) recommended, based on a simulation study, that terms relevant to the randomisation process be included in the spatial model, to control type I errors.

Williams (1985) suggested for one-dimensional spatial analysis that efficient alpha designs be used, but improved by reordering of the varieties within the blocks to obtain optimal neighbour-balance. A similar method was developed by Williams, John and Whitaker (2006) for row-column designs. The trials can be analysed as conventional row-column trials, if the spatial model does not fit the data. The spatial improvement can also be made on t-latinized designs (John and Williams, 1998), with complete replicates in both row and column directions.

Azaïs, Monod and Bailey (1998) investigated by simulation the validity of some spatial analyses, as dependent on the design. They found that spatial analyses often were approximately valid, because the estimates of the treatment differences and their variances were almost unbiased. The same conclusion was reached in simulation studies performed by Brownie and Gumpertz (1997). However, Monod, Azaïs and Bailey (1996) remarked that the randomisation method proposed by Williams (1986) is too restricted to be valid.

Discussion

Patterson and Hunter (1983) reported, based on 240 cereal variety trials, that randomised block designs produced 42% larger variances in pairwise comparisons than alpha designs and other generalized lattice designs. Yau (1997) reported 18%, based on 714 trials with barley, durum wheat and bread wheat. As discussed by Yau (1997), the reasons for the difference in these results are not clear. But it is clear that alpha designs are efficient, and recent research indicates that breeders could gain by using alpha designs.

Kempton et al. (1986) and Åssveen (1991) did not recommend covariance analysis with difference in straw height as covariate in variety trials where differences are likely to be small. Åssveen (1991) disapproved of classification into interference groups, because it does not prevent competition through roots, and it requires restricted randomisation. Instead, Åssveen (1991) recommended harvesting only the middle rows of each plot. By excluding two rows at each end of the plots, the problems with interplot competition could be reduced. However, the arguments for not using difference in straw height as a covariate are not clear. In practice, it may be a good strategy to include the covariate when it is significant, and exclude it otherwise. Balanced, or partially balanced, neighbour designs with valid randomisation could be recommended for this analysis.

It has been shown theoretically that balanced neighbour designs have good properties for models with additive neighbour effects. But often, in practice, interference effects do not follow simple statistical models. In nutrition experiments, for example, it is likely that a high level of nitrogen supplied to one plot has a larger neighbour effect when the neighbouring plot does not get any nitrogen at all, than when the neighbouring plot gets a medium level of nitrogen. Because such phenomena may be hard to model correctly, harvesting centres of larger plots, or adding border-plots, could be preferable.

In pharmaceutical statistics, much research has been made on carryover designs for experiments with subjects that receive multiple treatments over time periods. In these experiments, there is a carryover effect from the treatment in the previous period, and carryover is absent in the first period. Kempton, Ferris and David (2001) suggested a model with
interference effects proportional to treatment effects, and noted that neighbour-balanced carryover designs showed good optimality properties. Bose and Stufken (2007) studied designs for this model under varying values of the proportionality constant, and Bailey and Kunert (2006) showed that totally balanced designs (Kunert and Stufken, 2002) could be optimal. With slight modifications, these and other methods for medical trials might be useful for field trials.

With modern statistical software the analyst has access to a palette of methods for modelling data. It is possible to model gradients in the field by smooth trends and covariance components. Effects of neighbouring plots, possibly dependent on the treatments, could be estimated. However, the statistical analysis should take the design into account. For example, in a split-plot experiment, it does not suffice to include the variation between the subplots in the analysis; also the variation between the whole plots should be considered. Thus restrictions in the randomisation imply restrictions in the analysis. Clearly, there is some link between design and analysis. Given the design of the experiment, the analyst is not free to choose among all of the methods on the palette. And given that the experimenter would like to make some special statistical analysis, perhaps including interference effects or spatial correlations, some designs might be better than others. This link between design and analysis is not clearly defined in the literature. We have discussed some few results from statistical research. For example, there are randomisation methods for neighbour-balanced designs and partially neighbour-balanced designs that are valid for usual complete-block analysis of the data (Azaïs, Bailey and Monod, 1993). But incomplete block designs or row-column-designs, optimised according to some neighbour-balance criterion or spatial consideration, could lack validity. An exact theory for the relationship between design, randomisation and analysis is wanted.

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Research of Seed Coating Technology in China

Summary
This paper introduces an overview of the historical and the present status of seed coating technology research and key feature of the chemical for seed coating in China. The paper is also an analysis of the issues the researchers met when they demonstrated the technology to seed companies and farmers in 1990s, in regarding to be able to evaluate and obtaining experience for the integration and the development of the seed coating technology in China. Another goal of this paper is to forward suggestions for developing tendency of seed coating technology in the future.

Key words: Seed Coating Research Extension

Characteristics of Chinese seed coating Formulations
These are the characteristics of seed coatings:
• Compound formulation, the formulations are designed to give an integrated control against both insects and diseases by fungicides, insecticides and micro-elements into a combined formulation.
• Region specific.
• Lower prices; the prices of local productions is one fifth to one third compared with the chemicals from abroad.

Since 1985, the Ministry of Agriculture has demonstrated the developed seed coating chemicals through numerous lab and field studies, and the data collecting in the field trial showed us: It not only get the effect of anti-disease and anti-insects in the seedling stage, but also help the crops growing, and can increase the yield when harvested the crop by coating. So the farmers accepted the technology and increased the areas of using coated seeds gradually. The area increased from to 10 million hectares for the accumulated areas of sowing coated seeds nationwide from 1986 to 1992.

Issues met by the researchers when demonstrating the seed coated Technology in China
The increased use of seed coating raised different problems:
• The types of formulation cannot meet the different environmental conditions; one region may need more than one formulation to control the disease and insects.
• The local quality of formulations had to be improved compared with the products from abroad.
• A need to create an industry standard related
Conclusion

These efforts resulted in a remarkable improvement and made a significant contribution to Chinese agriculture through extending the area sown with coated seeds. The areas of sowing coated seeds reach over 33 million hectares in 2000, and the sowing areas for corn coated seed increased rapidly and reached to 44.2% of the total sowing areas.

Outlook of seed coating technology in China

Nowadays the technology of seed treated is applied most of the corn, wheat, soybean and cotton, and its research and development included three stages, trial and study in field, rapid and stable development. But we still continue to study the technology coming from local and abroad, and develop formulations with high effect or low poison to farmer and users. Our priorities include:

- Promoting the quality of the formulations and coating machines.
- Enlarging the region of technical applications, and increasing the sorts of crops for dressing or palletizing to rape, vegetable, flower and forage grass seed.
- Developing new styles seed coating formulations for soybean and rice seed in north and south China.
- Development of a new style seed coating formulations for drought area.
- Development of new style seed coating formulations for anti-counterfeit in seed market of China.
- One formulation to control the diseases and insects of crops seedling.

Table 1. The development in areas (in million hectares) sown with coated seeds from 1993 to 2000 in China (Ministry of Agriculture, 2002).

<table>
<thead>
<tr>
<th>Year</th>
<th>93</th>
<th>94</th>
<th>95</th>
<th>96</th>
<th>97</th>
<th>98</th>
<th>99</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Areas for seed coating</td>
<td>1.53</td>
<td>2.9</td>
<td>5.4</td>
<td>3.24</td>
<td>16.59</td>
<td>26.35</td>
<td>30.26</td>
<td>33.48</td>
</tr>
<tr>
<td>Areas for corn seed coating</td>
<td>1.52</td>
<td>2.93</td>
<td>4.75</td>
<td>8.42</td>
<td>13.55</td>
<td>14.28</td>
<td>14.81</td>
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</tbody>
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**Management and Design of Field Experiments**

**SICAT - Satellite, internet and computer aided trials for plant production**

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**Summary**
In an ongoing research project between University of Aarhus, University of Southern Denmark and AgroTech Denmark, the goal is to develop software for automated creation of route plans for auto guided agricultural machinery. The key software module is the ROPMO (Route Planning Module), which is able to generate route planes to auto guided tractors carrying out field operations. As an example, the software can be used for the seeding operation, where the route plan automatic guides the tractor carrying the seeder to the plots, which should be seeded the current setup. In the same project, the NASMO (Navigation Support Module) module is being created which is able to guide an experimental technician or a machine by use of Global Navigation Satellite Systems (GNSS). Hence NASMO enables manual and/or automated data acquisition with field plot in correct symbiosis with existing data acquisition equipment.

**Introduction**
Plot trials are standardized methods for investigating different treatments on crops and/or soil in both scientific and commercial environments within agriculture and horticulture. Such trials are labor intensive with regard to planning, execution and data analyses (Heisel, 1996; Noack, 2006). Furthermore, the manual execution of plot trials may introduce errors and bias in form of human related handling errors and bias compromising the reproducibility (Hicks & Turner, 1999). Currently, only few attempts have been made to rationalize and automate the design and execution of plot trials (Demmel et al., 2006). These attempts have been focused on specific aspects of the process and not the entire process with its full integration from planning to execution of the trials using automated machinery for both data acquisition and analysis.

The benefits of automatically guided agricultural field machinery have been well established (Tucker et al., 2002; Dunn et al., 2006). GPS auto-guidance systems have the ability to reduce overlaps between application of chemicals, increase operational performance, increase position awareness, etc. Specifically, auto-guided field operations allow a higher complexity in the experimental design and an increase in the number of repetitions, thereby increasing the value of the statistical analysis of the acquired experimental data. Experiences from using auto-guided systems show the working environment of the tractor driver is significantly improved with respect to reduced stress and increased work quality (Keller, 2005). Also, Jørgensen et al. (2007) have shown it is possible to implement and benefit from these systems in practical field trials where 15 factors are handled with 56 repetitions.

**Methods**
The software modules are developed with a user-driven approach, on the basis of a detailed analysis of the technical background, user experiences and the need for different types of field trials with different types of agricultural machinery. The key area in the research is making the specification for the software, making it usable for practical field trial experiments. To clarify the needs and challenges to such a system, three different approaches are used to identify the specifications. The QFD (Quality Function Development), an international litterateur review and a workshop are use in combination in the process.

**QFD – Quality Function Development**
The QFD method involves the end user in the initial design, and are usable in many different kind of innovative processes and products. The QFD is a structured way to identify user requirements. (Chan
Results

The results of the research are two software modules, hence the ROPMO (Route Planning Module) and the NASMO (Navigation Support Module). The ROPMO (Route Planning Module), is able to generate route plans to auto guided tractors carrying out field operations. As an example, the software can be used for the seeding operation, where the route plan automatic guides the tractor carrying the seeder to the plots, which should be seeded the current setup.

The NASMO (Navigation Support Module) module is able to guide an experimental technician or a machine by use of Global Navigation Satellite Systems (GNSS). Hence NASMO enables manual and/or automated data acquisition with field plot in correct symbiosis with existing data acquisition equipment.

References


The Tasks and the Conditions of Field Experiments for Assessment of Environmental Status of Agricultural Crop Production Technologies

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Summary
At present, a farmer has two basic tasks:

- To produce enough amount of the high-quality agricultural products;
- To lower impact of agricultural activity on an Environment to a level close to Natural.

The aim of field experiments and experimenters - to select, to estimate and to correct the best agricultural technologies and to disseminate the best practices among farmers. The important condition of such experiments is the estimation of a nutrient flows and the calculation of nutrient balances at implementation of agro technologies. For this purpose we should elaborate the list of environmental indicators as well as field experiments should be equipped by devices and systems for quantitative estimation of these indicators. Methodological approach of the task solving is discussed at the article.

Article
The Agriculture is one of the main sources of nutrients load in the water system and a reason of Eutrophication. The Baltic Sea Action Plan provides transition of agriculture on the best ecologically safely technologies which will sharply limit nutrient losses out Agroecosystems to water bodies. However such technologies and methods are poorly known at the market, they have not been certificated as environmentally safely, as a rule, and they are not adapted for local conditions. Farmers have not possibility to choose best technologies to their needs on the base of impartial assessment of the Environmental impact.

The basic sources of nitrogen and phosphorus emission outside agro ecosystems are agricultural fields after application of fertilizers and soil cultivation, and animal farms due to losses animal industries wastes enriched by nitrogen and phosphorus compounds. The big number of researches has been lead both in the Baltic sea region, and in other countries of the Europe and in the USA during which values of losses of the nutritious elements, caused by agricultural activity were determined, number of technological decisions and political measures were offered. In the new HELCOM Baltic Sea Action Plan on 2008 - 2012 serial of actions on decrease in agricultural pollution and Eutrophication are planned.

However, the majority of measures provide sharp decrease in use of fertilizers and quantities of cattle, pigs and hens, that in turn can lead to decrease in efficiency of an agriculture, incomes of framers, and then and to pauperization of soils.

The opportunity of complex use of new methods of crop and animal nutrition for essential decrease in losses of Nitrogen and Phosphorus outside agricultural ecosystems and nutrient cycling may be studied at special Environmental field experiments.

In crop production such methods include preparation and use of new kinds of mineral and organic fertilizers of adjustable composition and availability and the prolonged action are as well as soil cultivation.

The research will include both laboratory and microfield experiments, and field experiments. The purposes of field research consist in the following:

- To estimate speed of dissolution/mineralization of fertilizers in soil conditions;
• To estimate possible scales of leaching of nitrogen and phosphorus from soil and losses as a result of runoff from a soil surface concerning considered fertilizers;
• To make balance of nitrogen and phosphorus in agricultural ecosystem;

The field experiment for environmental assessment of agricultural technologies and methods has a range of circumstances. First of all the experiment is accompanied by the list of indicators, which are describe the environmental status of soil and vegetable cover and assess the impact of technique work and cultivations on Environment. It is obvious, that such list of indicators will consist of groups of indicators that determine:

• physical and chemical soil properties;
• biological properties;
• crop conditions.

We should prepare the list of possible machine’s impacts on agro ecosystem and determine their parameters.

Soil solution is an integral object of ecosystem and it reacts on various changes of physical and chemical conditions. This is why, first of all we should observe the water regime of agroecosystem – experimental field. And after that – to estimate the concentration of nutrients in soil solution and the temp of their changing and moving.

On the base of these requirements the Environmental field experiment should be equipped by the system of estimation of water and nutrients flows and balances for all experimental fields as well as for each experimental plot.

Such field experiment should be equipped by following devices and equipment:

1. Automatically weather station with rain measuring instrument;
2. System of drains and/or lizimeters and the order of water samples taking and analyzing. It will allow to estimate inside soil water/nutrients moving;
3. Runoff platforms for estimation of nutrients moving with runoff
4. A net of gauges for water content measuring at soil profile.

We are needed to know about crop biomass growing. Most simple and labour-consuming method is to cut and to analyze crop samples regularly. This method leads to establishment and to increasing of not cropping area at the experimental plot. More interesting method is related with Ground based remote sensing (1). In this case we will get information about crop growing (and may be nutrients accumulation) by not destroying optical method.

In the frame of mathematical model, with use of experimental data collected from all plots, the balance of nitrogen and phosphorus at different agricultural ecosystems will be considered, in view of system soil - fertilizer - plant.

The obtained results on opportunities of decrease in losses of nitrogen and phosphorus from agricultural ecosystem and their economic estimation will be used for creation of software expert system for farmers and recommendations for administrations of local municipalities on management of a condition of nutrients in municipalities. The information on most ecologically effective technologies and necessities of their use will be placed on a web site and widely to be duplicated.

Such kinds of field experiments we plan to establish on 2009 at the Experimental field of the institute. We hope that the Centre of best agricultural practices will be established on the base of such experiments later.

We ask our international colleagues to establish such experiments also and to organise their net. These will give good opportunity for rapid assessment and spreading of best agricultural practices.

**Conclusions**

1. New, Environmental friendly agricultural technologies are needed and special Environmental field experiments for their construction and assessment are offered.
2. The Environmental field experiments have to be well equiped and to allow the estimation and the calculation of the agricultural technique impact on Environment and data concerning nutrients leaching and running off.
3. The mathematical models and software will allow to elaborate optimal scenariums of crop cultivations on the base of experimental data.
4. The international net of Environmental experiments will allow more rapid assessment of best Environmentally friendly technologies and their dissimination.

**References**

Nordic Field Trial System

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Summary
Nordic Field Trial System hosts all experimental plans and results from field trials carried out in The Danish Agricultural Advisory Service. The system is an online, open system that allows everybody to look up experimental plans and results on the internet. The system consists, besides the internet pages and a hand terminal, of a PC-program that is used by the field trial worker to enter data and by the researcher to set up experimental plans. The system is particular suitable to carry out several trials in the same series, collect data from several locations and report the results immediately.

NFTS supports four languages, viz. English, Danish, Norwegian and Swedish. At the moment, the system is implemented in Denmark and Norway, and it is being tested in Sweden.

Introduction
In many countries, a large number of field trials are carried out within agricultural research and agricultural advisory organizations. Field trials are often based on the same experimental principles in different countries. Also, the subjects being studied in field trials will often be of general interest in more than one country. For instance, trials with various cropping systems, varieties, fertilizers, and plant protection products etc. may be relevant in a number of countries with similar agricultural practices. Consequently, it is beneficial to share methodology as well as results across borders.

Since 1992 the Danish Agricultural Advisory Service has constantly been developing data systems designed to manage field trials in an efficient way (Kjaer 2000; Kjaer 2004). Most recently, a common Nordic system for management of field trials has been developed and is named Nordic Field Trial System (NFTS). The system consists of different modules specifically designed to manage geographically.

Figure 1. Diagram of the system and dataflow in Nordic Field Trial System.
distributed field trials. It consists of the following modules: Central database/server (SQL 2000), PC-Field Trial, Experimental Planning, administrative facilities, Hand terminal (SmartTrials) and web pages. The modules will be described in details in this article. The purpose of the system is to meet the increasing demands for efficient management of field trials and easy exchange of data between institutions and countries. NFTS supports four languages, English, Danish, Norwegian, and Swedish. The system is used in Denmark and Norway and is in preparation for being implemented in Sweden. (It is estimated that NFTS will be used to manage approx. 2500 trials per year.) In 2007 NFTS is used for managing approx. 1500 field trials. This large number of field trials will evidently reduce the cost of data management per trial considerably compared to other systems. But more importantly, all data are stored in a uniform and secure way and can easily be exchanged between institutions.

Experimental planning
A study on organization of field trials in the Nordic countries revealed that most experimental planning is carried out in non-database systems, e.g. Word or Excel, or in databases that are not designed to compile results from different trial units (Kjaer and Haastrup, 2005). The disadvantages include poor standardization, making data collection less uniform and compilation of results less efficient. Experimental plans in the Nordic Field Trial System are elaborated in a database system where the different elements (treatments, design, assessments etc.) are looked up in standard tables. This ensures that all trials are carried out according to the same standards and units. There are 29 standard tables, e.g. with crops, varieties, pesticides, characteristics, fixed text sequences etc. The standard tables contain a language_id and a country_id. The language_id identifies the language of the parameter while the country_id designates the relation to country allowing country specific parameters and formulas. In figure 2 is given an example of an assessment parameter in a standard table.

The system with standard tables and language identification makes it possible to publish experimental plans dynamically in various languages on the Internet thus reducing or eliminating the need to send out papers to the field trial worker.

Distribution of field trials
Frequently, a number of field trials based on the same master experimental plan are carried out at different experimental stations (geographically distributed). The master plan is elaborated by a researcher or coordinating organization that distributes the experimental plan, seeds, pesticides and other materials to the experimental stations. Data from the trials are collected by the coordinating organization and subsequently compiled and published. It is a big task to administer several field trials; however, much of this work is automated in NFTS. After the finalization of the experimental plan in NFTS it is published on the Internet. The trials are then, in an administrative module, assigned to a field trial unit (experimental stations / field trial worker). This assignment of a trial automatically triggers a series of events:

- A unique single trial id is created and linked to the field trial unit.
- The experimental plan is ‘copied’ to the single trial
- Tables for entering registered data from the single trial are created in the database
- The overview tables of number of trials, location, trial supervisor etc. on the Internet are updated
- Sample labels and relevant forms are created

Entering data via PC-Field Trial
The local field trial unit accesses the single field trial in the database via the module PC-Field Trial. It is a software program developed in Delphi running on the local PC, but all data are uploaded to the central database directly. The program contains different elements: General trial information, general treatments, design, experimental treatments, assess-

Figure 2. Example of how an assessment parameter is described and identified in four different languages in Nordic Field Trial System.
Figure 3. Example of an experimental plan in Nordic Field Trial System. Only the section on assessment times and assessments is shown.

Figure 4. Example of table for entering field trial assessments via the module PC-Field Trial in Nordic Field
Hand terminals - SmartTrials

The most secure and efficient way to register data in the field is by use of hand terminals, which eliminate papers and reduce potential errors when writing data on paper and subsequently typing the data on a PC. For the NFTS system we have developed a program in .NET that in general can be used on all hand terminals with Windows mobile 5 or 6 operative system; however the program is optimized for a Psion Workabout Pro II.

Results and reporting

The system facilitates a very fast reporting making it possible to use data during the season, e.g. occurrence of diseases. The fixed tables and structure makes it easier to make the assessment and ensures uniform results.

All data in the database can be accessed on the Internet unless the trials are classified "confidential". The web pages are programmed in aspx and are thus dynamic. That is, when you want to the see the result page of a trial all data are fetched directly in the database and presented. Some data, such as yield, need calculation. For this purpose we have developed a 'robot' that monitors data input. When yield data (kg / plot) have been entered, it is automatically transformed to hkg / ha (or whatever unit has been chosen) and the data are automatically analyzed statistically by an F-test and a LSD value is calculated.

Figure 5. Example of design and data in "SmartTrials". The hand terminal for Nordic Field Trial System.

Figure 6. Example of field trial results in Nordic Field Trial System as they are published on the web.
This automated reporting system makes it possible to see the results of a trial only a few hours after harvest.
At this stage all trials are designated "preliminary trials". Within 24 hours the trials are quality checked in relation to a series of statistical criteria by an expert. Trials are classified according to this check and only approved trials will be published.

**Future perspectives**
Farmers will in the future continue to demand new knowledge on varieties, plant protection strategies and crop production methods. The primary source to this knowledge is field trials. The farmers and the agro industry will in the future require rapid publication of results that will speed up breeding programs and the introduction of new varieties. It is estimated that the fast publication of results in Denmark allows new varieties to be marketed one year earlier compared to a traditional testing system. The value of this exceeds, in a conservative estimate, 10 million Euros (estimates by Danish Agricultural Advisory Service).

The increasing globalization of agriculture will result in demand for sharing of results across institutional and national borders and there will be increased focus on the cost of field trials. In order to meet these demands research and field trial organization have to join forces and set up networks and a system that allows sharing of results and will bring down the costs. In the Nordic region cooperation between Denmark, Norway, and Sweden has been established already, reducing the cost of carrying out field trials, and in the near future sharing of results will be initiated.

This cooperation can be further extended to Germany, the Baltic region, Poland and other European countries and regions. Nordic Field Trial System is designed for efficient data management, rapid publication of results and sharing of results, and as such it may be developed further for use in other countries.

For further progress in field trial work, it is necessary to exploit new technology. We will in the future always be online and we will have access to central servers, GPS, sensors, RFID tags and other new inventions that can make the field trial work more efficient and precise. In order to exploit these possibilities we will have to work together. Nordic Field Trial System is a beginning.

**References**


Experiments with plant sensor on pesticide production in cherry plantation

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Summary
We started to make experiments four years ago with different types of Hungarian and import sprayers in the frame of OTKA project. The project number is T-042594 titled: “The possibilities of reduction of pesticides by spray technology”. Test results in plantations proved the advantages of using of new technology methods compared to the using of traditional sprayers. The modern methods yielded more favourable pesticide deposition on the leaves next to the application of same quantity of pesticides than traditional sprayers. The coverage was proper when we reduced doses of spray so we could work with less quantity of pesticide.

Objective of the research work: to promote home widespread of chemical reducing, environment friendly, and plant protection technology by the approach of technologies producing diversities in the accumulation of the aimed surface, under the given outdoor circumstances.

In the last year of the project we compared the work of a made-in-abroad plantation spraying machine with a similar category of a home made spraying machine with plant sensor, in all the cherry plantations.

2. Presentation of the examination method

The character of the examination: comparison examination

To be completed examinations:
• determination of coverage characteristics, and
• control of pesticide saving.

Steps of the coverage examination:
• recording the examination circumstances,
• presentation of the examined machines,
• description of target surface, plantation,
• recording the parameters of machine setting,
• placing water sensitive test papers,
• completing spraying operation,
• collecting the test papers,
• determining the coverage characteristics, and
• evaluation of examination results.

The steps of controlling pesticide reduction:
• recording the examination circumstances,
• filling up the tank with the given amount of pesticide,
• spraying the pesticide,
3. Results of the coverage examinations

The examinations were performed with applicable similar pesticide doses determined by the technical characteristics of the spraying machine.

It may be highlighted on the basis of the derived examination results that the abaxial leaf surface coverage during the plantation spraying with much lower than usual pesticide doses of about 250 dm³/ha applied was also suitable in the case of KERTITOX BORA spraying machine. It is significant because the pathogens and parasites can be usually found on the abaxial leaf surface.

The coverage ratios of about 1.00 colour-backside can be counted as excellent by the application of KERTITOX BORA machine without plant sensor, however, on the lower level of the leafage it brought forth too coverage (diagram 4).

On the basis of the examination results it can be established that the specific drop values (diagram 5) of the KERTITOX BORA machine during spraying

---

Table 1. The set-up data of the machines

<table>
<thead>
<tr>
<th>Machine type</th>
<th>Work speed (km/h)</th>
<th>Pressure (bar)</th>
<th>No and sign of working nozzles (piece, colour)</th>
<th>Liquid doses (dm³/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KERTITOX BORA</td>
<td>7,0</td>
<td>25,0</td>
<td>10 yellow</td>
<td>230</td>
</tr>
<tr>
<td>VULCANO</td>
<td>8,0</td>
<td>16</td>
<td>4 yellow, 6 red</td>
<td>245</td>
</tr>
</tbody>
</table>

---

Figure 1. KERTITOX BORA axial fan spraying machine equipped with plant sensor.

Figure 2. VULCANO axial fan spraying machine.
significantly over-passed in every case the expected minimum 50-70 drops/cm² value of fungicide spraying.

**The results of controlling obtainable spraying reduction**

The examination results of pesticide carried out with KERTITOX BORA spraying machine with plant sensor switched on and off, under similar operation characteristics, can be seen in table 2.

The results show that 34.2% was the pesticide saving with the application of plant sensor at practically smaller 2-year-old leafage plantation. The 24.6% saving at the 3-year-old plantation treatment can be considered significant as well. On the course of protection one-third of pesticide can be saved in younger fruit-gardens, while one-quarter results at the older ones.

### 4. Conclusions

On the basis of the comparison examination it can be established that of all the machines applied in the examination with similar parameters, KERTITOX BORA ensured more favourable work quality values than the VOLCANO spraying machine besides the given examination air circumstances and machine set-up parameters.

The standard deviation of work quality characteristics with such set-ups adjusting better to the given plantation characteristics, can be reduced at each leaf crown level.

It can be clearly established from the examination results that without a significant change of the coverage characteristics meaningful liquid and pesticide savings can be obtained in loose lined young plantation as well.
Table 2. The examination results of pesticide reduction.

<table>
<thead>
<tr>
<th>Machine type</th>
<th>Operation mode</th>
<th>Plantation</th>
<th>Specific pesticide use (dm³/ha)</th>
<th>Savings (dm³/ha)</th>
<th>Savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KERTITOX BORA</td>
<td>Plant sensor switched off</td>
<td>2 years cherry</td>
<td>234</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>KERTITOX BORA</td>
<td>Plant sensor switched off</td>
<td>3 years cherry</td>
<td>175</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>KERTITOX BORA</td>
<td>Plant sensor switched on</td>
<td>2 years cherry</td>
<td>154</td>
<td>80</td>
<td>34.2</td>
</tr>
<tr>
<td>KERTITOX BORA</td>
<td>Plant sensor switched on</td>
<td>3 years cherry</td>
<td>132</td>
<td>43</td>
<td>24.6</td>
</tr>
<tr>
<td>VULCANO</td>
<td>Plant without plant sensor</td>
<td>3 years cherry</td>
<td>212</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

References


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A Mole collecting fingerprints: A gamma ray sensor for measuring physical properties of top

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Summary
With the upcoming of precision agriculture the need for detailed soil information increases. General (grid) soil sampling simply becomes too costly for a farmer. Several techniques are therefore introduced to map soil with a high resolution and if possible for reasonable costs. The use of gamma radiation sensors is new in this respect. This paper describes the basic principle of this technique: fingerprinting. And more specific, the fingerprinting of physical soil properties.

A brief historic overview
With the introduction of the personal computer and the development of new materials for scintillation crystals measuring gamma radiation, the State University of Groningen decided to start the development of an in situ gamma ray sensor in the early nineties. The heart of the idea was that the earth’s crust consists of different radioactive trace elements that could be measured with such a sensor system. Trace elements that could tell us something about the composition of soil, e.g. texture, minerals, and that—combined with GPS—could be mapped with a mobile device. The Soil Company adopted this technology and developed THE MOLE: A mobile system for on-the-go gamma measurements to map top soil.

The technology and the accompanying principle of full spectrum analysis to derive concentrations of radioactive trace elements is described in detail in van Egmond et al (2008) and Hendriks et al. This paper focusses on the principle of fingerprinting, which is the statistical analysis of gamma ray values and soil properties. Fingerprinting is one of the activities in the process of turning field measurements with THE MOLE into a soil map.

Fingerprinting
A gamma ray sensor such as THE MOLE is in general capable of measuring concentrations of Th232, K40, U238 and Cs137 as well as the Total Count rate. The complete Mole system is designed in such a way that the concentrations of these radioactive trace elements are calibrated. This results in quantitative outcome (Bq/kg) for every point that is logged in the field during a measurement. In general, one point value has the size of a circle with a beam of 2 meters and during a measurement on average 800 points/ha are collected. The logged “raw” gamma ray data is real time visible for the operator. The operator uses this data to collect physical soil samples. For the purpose of fingerprinting the sample results and gamma ray measurements on those spots are combined in datasets.

Comparison of the concentration of the radioactive trace elements and the lab results (pH, clay

Picture 1. THE MOLE sensor in back lift.
content, etc) by statistical analysis of these sets of data is called finger printing (de Meijer, 1998). This results in a mathematical formula describing the relationship between a dependent and independent property, for instance Th$_{232}$ and clay. The results of the sensor readings are interpolated into a base map with GIS software. And with the derived mathematical formula a soil property map is composed.

![Picture 2a and 2b](image).

**Picture 2a and 2b.** From base map to soil property: Th$_{232}$ turned into clay.

### General principles of finger printing

The Soil Company has collected gamma ray and soil property data from several countries: the Netherlands, Germany, Sweden, Poland, France, UK and Egypt. Most of the collected data stems from our homeland. In the Netherlands it was found that the principle of fingerprinting can be applied for large geographical areas for physical soil properties such as clay, loam or sand (50 micron), grain size and organic matter. This means that once a database with gamma ray measurements and the mentioned soil properties has been set up it becomes possible to predict the field variation of mentioned properties very well with a small number of extra calibration samples. In practice, The Soil Company collects one calibration sample for texture for every 10 ha that is scanned with THE MOLE.

All radioactive trace elements play a part in the fingerprinting process regarding physical soil properties. The main general correlations are the following. Clay content is best predicted with Th$_{232}$. It has a general R$^2$ of 0.75 up to 0.9. The correlation is positive and basically linear. The variation of loam (or sand) content is very well described by the combination of Th$_{232}$ and U$_{238}$. It has a comparable R$^2$ to clay. The R$^2$ of grain size and K$_{40}$ is in general a little bit lower, but nonetheless good, 0.7 to 0.8 on average. K$_{40}$ is negatively correlated to grain size. The combination of K$_{40}$ and Cs$_{137}$ is in general very useful for predicting the organic matter content. Finally, Total Counts turned out to be a very useful parameter showing soil types or the presence of unnatural or non-parent material.

The measurements with THE MOLE in other countries showed that the found correlations hold true on different soil types as well. E.g. when comparing clay content with the different radioactive trace elements it turned out that it remains best corre-

![Graphic](image).

**Picture 3.** Correlation between Th$_{232}$ and clay in Sweden.
lated with Th$_{232}$. This means that the Mole is suitable for the acquisition of top soil data on a wide variety of soils that can be easily transferred into soil maps. This can be beneficial for soil scientists, but also for farmers who are conducting precision agriculture.

**From fingerprint to water content**

One of the advantages of this fingerprinting principle is that it allows us to map within-field variation of physical soil properties relatively swift and cheap. Soil properties that are relevant for the behaviour of water within a field. In the Netherlands so called pedo-transfer functions are modelled for 36 different soil types (Wösten et al, 2001). This allows us to calculate the water-related properties of soil for an entire field; also showing the in-field variation of these properties such as permanent wetting point, bulk density or saturated hydraulic conductivity. Water being one of the most important elements for crop growth, THE MOLE measurement can be helpful for managing water in agriculture.

**Conclusion**

THE MOLE is a very powerful sensor for mapping physical top soil properties on a quantitative base. Although the principle is not widespread yet, the measurements in different countries show that general principle of fingerprinting holds true. This makes it possible to create reliable high resolution soil maps at relative low cost. This information is applicable for soil scientists, farmers conducting precision agriculture or for other soil related topics.

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**References**


Determination of canopy properties of winter oilseed rape using remote sensing – techniques in field experiments

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Summary
The aim of the study was to evaluate fast and less costly methods for determining the N-content and plant density of winter oilseed rape in field experiments. In this paper, only results from the autumn 2007 are presented. The N-content in the crop (analysed from crop samples), ranging from 3 to 80 kg N ha⁻¹ and on average 18 kg N ha⁻¹, was well described (r² = 0.81) by the oilseed rape index S1 (OSR) (measured by the handheld Yara N-Sensor). The number of plants per m² were in general less using the image analysis compared with manual counting but there was a strong relationship (r² = 0.95) between N-content and the fraction covered by crop, estimated from the images.

Background
The use of vegetation indices of visible and near-infrared (NIR) light allow for prediction of quantitative growth properties in winter oilseed rape such as shoot dry matter and shoot N-content (Behrens, 2006). Yara research center in Hanninghof, Germany, has developed a vegetation index S1 (OSR) for oilseed rape that well describes the biomass and the N-content in plants (www.nuere-rapsduengung.de). In field experiments determining plant density, crop biomass and N-content are important for understanding crop development and crop management but also work-intensive and often erroneous. In two-year field experiments of winter oilseed rape from 2007 to 2009, in southwest Sweden, investigations were carried out in order to evaluate the use of the handheld Yara N-Sensor and the index S1 (OSR) of oilseed rape for determination of biomass and N-content in comparison to N-analysis of crop samples in the laboratory. In addition, the use of digital photography to determine N-content and plant density with the purpose to reduced time consuming counts of plants by hand in field experiments. In this paper, only results from the autumn 2007 are presented.

Materials and Methods
Field experiments
Two one-year experiments are being carried out from 2007 to 2009 in Västergötland, southwest Sweden (58°22'N). The experiment is performed in 40 sampling areas of 12 x 15 m distributed on four different fields with varying plant density (Bjertorp10, Bjertorp 15, Ribbingsberg and Prinshaga). Winter oilseed rape (Brassica napus L.) was sown with row spacing of 0.12 m. Nitrogen (N) fertilisation, plant protection and P-, K- and S-fertilisation was done according to general Swedish recommendations. Three of the fields (Bjertorp 10, Bjertorp 15 and Ribbingsberg) were photographed 27 Sept. 2007 from the air with a near-infrared enabled Canon digital Ixus-60 (6 Mpix) camera mounted on a small unmanned aerial vehicle (UAV). The UAV used was a SmartPlanes SmartOne mini-UAV which is described by Rydberg et al. (2007). The images had a resolution of about 0.1 m and image mosaics were created for the three fields. Field plots were located according to the variability in the mosaics, but in some cases the locations were slightly adjusted manually in the field (figure 1). The purpose was to select as homogenous plots as possible in areas with different plant vigour and soil types.

Crop measurements
N-sensor measurements and digital photos were made in late autumn and early spring just before doing the plant counts and cutting of crop samples for measurements of dry mass (DM) and N-content.
Figure 1. Mosaic of UAV-images of Bjertorp 10. The colour indicate NIR reflection, light green and yellow are low and dark blueish-green is high. The numbered white squares are the field plots. In the background is shown an older ordinary aerial IR photograph.

Figure 2. The relationship between N-sensor measurements and DM- and N-content in winter oilseed rape plants 17 oktober 2007, n = 40.
This was done in two 1 x 1 m areas positioned diagonally within each sampling area (with as even plant density as possible). Crop samples were cut at the soil surface and subjected to analysis of DM, after drying at 60°C, and plant N concentration using Dumas elemental analysis. N-sensor measurements was done from four directions at the two 1 m² crop sampling areas with a hand-held Yara N-Sensor which registers the reflectance in several wave-lengths from green to NIR. The oilseed rape index S1(OSR) was used to describe DM- and N-content in the plants. Digital images were obtained with a Nikon D70 digital camera. The camera has a resolution of 2000 x 3008 pixels and the images are stored in a low-compressed jpeg-format to achieve the best possible image analysis. The images were acquired with the camera mounted on an arm stretching out from a tripod about 1,4 m above ground. A white, 1 m² square-shaped frame was put on the ground to delimit the area used for image analysis.

An automated image analysis algorithm for the analysis of coverage and number of weed and crop plants from ordinary digital photos were created in MATLAB (MathWorks, USA). The process is a sequence of methods for removal of irrelevant information (soil) in the images and separation of weed and crop through a combination of a number of image processing methods (Nyman, 2008).

**Results and Discussion**

**N-content in plants in the autumn**

The N-content in the crop in the late autumn 2007 (17/10) was on average 18 kg N ha⁻¹ and ranged from 3 to 81 kg N ha⁻¹ (std.dev. = 15). The relationship (r²), for a linear regression, between the sensor values and biomass in kg DM ha⁻¹ and N-content (kg N ha⁻¹) was 0.83 and 0.81, respectively. In these trials the cost for N-sensor measurements was only 38% of the cost for cutting the crop and analysing the N-content in a laboratory. The results indicate that the method could be a faster and less costly way to determine the DM- and N-content in oilseed rape in field trials. This could improve the possibilities to further investigate the dynamics of N-uptake in oilseed rape in future field experiments.

The area fraction of ground photographs covered by crop estimated by the image analysis algorithm were also very well correlated (R² = 0.95) with the N content of the manually cut crop samples (Figure 3). However, the samples at Prinshaga differed from the data of the other fields. The crop percentage was generally very high at that field, but in most samples the measured N content is much less than

![Figure 3](image-url)
Figure 4. Number of winter oilseed rape plants per m² 11 Oct. 2007 in sampling areas in the four investigated fields. Red bars are field plots at Bjertorp 10 (plot no. 101-119), pink bars Bjertorp 15 (no. 201-209), green bars Prinshaga (no. 301-306) and blue bars Ribbingsberg (no. 401-406).

Figure 5. Manual counting of winter oilseed rape plants compared with detection using image analysis (plants per m²) $r^2 = 0.56$. 
expected compared with the data from the other fields.

**Number of plants in the autumn**
The number of plants in the autumn was according to general recommendations in all fields in the investigation. In one of the fields, Prinshaga, green bars in Figure 4, the number of plants were higher than on the other fields since an open pollenator cultivar was sown with a higher seeding rate than the hybrids sown on the other fields. Using image analysis, fewer plants were detected compared with manual counting. This was accentuated when the plant density increased. Therefore a logarithmic curve best described the relationship between manual counting and image analysis (Figure 5).

As can be seen in Figure 6, the results from the image analysis vary quite a lot with the same number of plants. This is an effect of the fact that the plants are often growing too close to each other in order to be detected by the algorithm.

**References**


At Skaraborgs läns Hushållningssällskap, Sweden, we have developed a new and very efficient system for handling samples plot wise from the combiner all through analyses and storage. To be able to do this we developed a plastic container of app. 1 litre volume. The walls are closed but the bottom has as much open space as possible without letting even the smallest seeds of oilseed.

The possibility to use rapid analyses with NIT-equipment for moisture content, protein, starch etc. have made it economically possible to record not only yield but also quality parameters plot wise in field trials. This gives us much better possibilities to study how treatments in the trials influence quality of the harvest. To make a efficient and secure chain for handling grain samples we then need new and better systems.
rape get through. 24 pieces of this small containers fit into larger standard containers with slotted bottom which allows us to dry the samples directly in the containers.

Under transport we seal the whole larger container with a lid that also seals the small containers.

The marking of the samples is done by putting a tag on the bigger container with the trial ID and if it is sample 1-24, 25-48, 49-72 etc.

The single sample is marked by permanent labels which shows which number it has 1 to 24, 25 to 48 etc. see pictures.

At all the part of work that has to be done we take one container at the time for weighing, cleaning, analysing and the sample goes back to the same container.

In this way we think that we have got a very efficient and reliable system which also gives the possibility for storing the samples for some months in an easy way.

We own the tool for making the small plastic containers and can sell the complete concept to other interested conductors of field trials. The price varies of course depending to volume and will be given on request.
Detection of emerging plants with computer vision

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Summary
A new technological breakthrough opens new possibilities for scanning of emerging plants. With a line-scan camera working in the red and near-infrared wavelengths, it is now possible to measure the leaf areas and the positions of the individual plants with a high precision. Data from subsequent scans can be compared on the level of individual plant positions. The system can generate various statistical information. Output data can be imported into spreadsheets like Excel.

Article
The detection and counting of emerging plants can be carried out manually by a person walking in the test field counting the number of emerging plants. The vigourance of the plants are normally judged by looking at the rows asserting the average size of the plants.

• The problems with this approach are obvious:
  • It is labour intensive and requires a relatively large number of persons.
  • It can pose a problem to hire many people for a relatively short period.
  • The work must be carried out independently of holidays or weekends.
  • The vigourance assessments depend on individual judgments and are not accurate.
  • Human errors, either in the counting or in the data handling can degrade the dataset.

It is therefore desirable to carry out the detection and counting of emerging plants in test plots automatically. The main challenge building a plant detection camera which can detect the relatively small leaves is to cope with the varying light conditions in the test field.

The vision system is based on:
1. A number N of cameras mounted on a tractor, see Fig 1. Also fitted on the tractor is a measuring wheel which accurately relays the position to the recording cameras so that their position data can be incorporated into the DataStream.
2. A storage device in the cabin of the tractor.
3. A number of markers which are placed at the beginning and of the end of every Nth row.
4. A server with the data processing software.

Figure 1.

The soil reflects light depending on a variety of factors some of which are: the chemical composition, the texture, the humidity and the colour of the light.
The green leaves reflect mostly the infrared wavelengths and absorbs the red and blue light, see fig 2. Therefore it is possible to detect the plants by measuring the relation between reflected infrared and red light. This index is commonly referred to as the NDVI (normalized differential vegetation index).

**Figure 2.**

In the field the situation gets more difficult because the relationship between the amounts of red and infrared wavelengths can vary with the ambient light, (sunlight). Cloud coverage influences the absorption of infrared light in the atmosphere thereby offsetting a detection threshold.

We have minimized this effect by fitting a strong floodlight adjacent to the camera. The effect is that the composition of the light hitting the plants varies less. In addition, the artificial light puts a lower limit on the intensity of light in the field of view. This is particular important if there are both sunlit areas and areas in deep shadow in the field of view. Poorly lit plants in the deep shadow are more difficult to detect because data gets quantified. A remedy for this effect is more bits, at the cost of complicating the system.

Another problem is highlights. Both leaves, especially wet leaves and glossy stones can present a problem because their strong reflection can cause the sensor to saturate if the dynamic range is not sufficient high.

**Camera**

The incoming light is split by an infrared mirror separating the light into two separate channels. Each channel constitutes complete optical detector system with lenses, filters and CCD chip and data acquisition hardware.

The data from the red and from the infrared channel is fed to the camera computer which performs a pre processing of the data and controls the performance of the camera. The resulting raw image is subsequently relayed to a storage disk located on the tractor.

The data are afterwards transferred to a server which performs the analyses of the images.

**Principle of operation**

Firstly the sowplan must be uploaded to the server. Data is then transferred to the removable storage disk. After start-up the cameras connects to the disk and the information containing plot numbers and names are automatically transferred to each camera.

The driver of the tractor is being prompted after each track in order that the system can keep track of the scanning progress. The marker at the beginning and end of the row at camera No 1 is also scanned and later processed.

A GPS system can help the driver steering the tractor along the track marks produced by the sow machine.

The entire test field should be scanned every second day.

When the data from the subsequent scans has been transferred to the server, the software performs a number of tasks, one of which is calculating the NDVI, calculating the geometry, analysing the images and detecting the markers. Because the camera is a line scan camera, it generates one long image with a length corresponding to the length of the scanned track.

The areas of the detected leaves corresponding to the individual plots are calculated and the results are stored together with the information of the individual plant positions. This information includes the coordinates and calculated features such as the orientation, area and shape of the objects constituting the plant position. If a plant is solitary with a distance to its neighbours greater than 1.5 x its diameter, a plant position constitutes only this single plant. If however, 2 or more plants are more closely spaced, a plant position will encompass the whole group of plants.
Fig. 3 shows a picture of the same plot of emerging sugar beets taken 6 days apart.

The accuracy of this vision system is high. Fig. 4 shows the errors (differences between two subsequent set of measurements of the same plot taken within 2 hours). It has to be taken into consideration that the two takes not necessarily covers the same patches of ground. The driver drove without GPS assistance and there is no compensation for the weed present. The data was generated in 2006.

Fig. 5 shows a graphic representation of the data from a test field before the first sugar beets emerge. The white spots are weed. Every pixel represents the total leaf area within a square of 30 x 30 cm. Fig. 6 shows a graphic representation of the leaf areas from 2 trials sowed with 10 days apart. Fig. 7 shows a graphic representation of 10 successive scans of a whole test field. Every pixel represents a plot of 15 meter.

Fig. 8 shows how the leaf area evolves for different types of sugar beets.

Variations of the genetics and variations of the manufacturing processes of the seed correlates with the data from scanning of leaf areas of the emerging plants.
Figure 8.

Figure 9.
Fig 9. shows how the scanned leaf areas correlate with the manually counted emerging plants.

None of the dataset in this paper has been adjusted for weed yet.

Discussion

This scanning technology offers several advantages: Trials can be planned considering which sowing period would be the optimum and not how many people would be available when the emerging plants must be counted. Therefore trials will better reflect the same weather conditions under which the farmers operate if they were scanned with vision technology rather than counted manually.

This accurate measurement of the leaf area of individual plants offers the possibility to study how the variations in genotypes and seed manufacturing recipes effect the variation of leaf area of the emerging plants. However, when the field emerging tests solely rely on this technology, one is hampered by long periods of rainy weather. The soil must be able to carry the load of tractor otherwise it is not possible to use the scanner.

One would expect that a sugar beet would gain more leaf area at a steady pace whereas a weed plant would decay at a steady pace from the date of application of the herbicide. The marker at the beginning and end of the scanned track enables the comparison of subsequent scans on the basis of plant positions. In the final processing all the data from the subsequent scans can be compared on the basis of plant positions. By comparing the data from individual plant positions from scan to scan it will be possible to monitor every single plant position in the whole trial field. Thus it will be possible to track the growth of the individual plants and generate statistical information of how a leaf area evolves. The implementation of GPS steering of the tractor helps in achieving this goal because the cameras can be mounted closer to the ground and a higher quality image can be obtained.

If the weed pressure is high, the results can be biased by weed because the camera will detect all leaves. However, the subsequent data processing will be able to compensate for this effect in two ways. Firstly the weed can be recognised because the leaf areas will diminish after the spraying of herbicide. Therefore it is possible to generate a weed map for the entire field. This map can be subtracted from the dataset. Secondly, because the weed can be assumed to be locally evenly distributed whereas the plants are situated in a row, plants off the row can be ignored in the data processing. In this way it will be possible to adjust the data from the first scans in order to compensate for weed in the test field.

It still remains to be seen how much the accuracy of the plant counting and measurements of leaf area can be improved. We are currently working on this project.

References

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Entry level solutions for field trials

Summary
WINTERSTEIGER offers easy to use machines from seeders to combines and laboratory equipment for precise results in field trials.

Article
WINTERSTEIGER offers a wide range of machines for field trials, from seeders up to combines or laboratory equipment. Each machine has to be adapted to the specific purpose of each country and each customer. Here we want to present some machines that allow precise results, whereas the machines are easy to use and to maintain.

- Plot combine: Classic
- Stationary plot combine: Classic ST
- Self propelled precision planter: Monoseed TC
- Tractor mounted drill machine: Plotseed S
- Self propelled drill machine: Plotseed TC
- Hand pushed single row planter: Rowseed 1R
- Laboratory dresher: LD 180 and LD 350
- Laboratory sheller: LS 230
- Laboratory seed dresser: Hege 11

- Diesel engine Perkins 52 PS
- Hydrostatic drive, hydraulic steering
- Cutting width 125/150 cm, Uniflow-header
- Quick change system for concave
- Quick change system for shaker and sieves
- Pneumatic grain delivery
- Multifunction lever
- Weighing system and grain tank (option)
- 2-row corn header (option)
- Many other options
- Gras version for very quick cleaning (option)
- Transport weight: 2.000 - 2.400 kg

Stationary plot combine Classic ST

Plot combine Classic

- KUBOTA diesel engine
- Electric engine
- PTO shaft for electric engine

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**Self propelled precision planter**  
*Monoseed TC*

**Area of application:**  
- Selfpropelled precision planting

**Features:**  
- Non-stop or Stop&Go planting system  
- wide area of application  
- easy adaption to different applications  
- easy operation

**Tractor mounted drill machine**  
*Plotseed S*

**Area of application:**  
- Precision drilling of plots

**Features:**  
- accurate adaption of plot length  
- levelling device  
- quick + easy adjustment of track width and row distance  
- continous drilling device for conventional drilling  
- easy operation

**Self propelled drill machine Plotseed TC**

**Area of application:**  
- Selfpropelled precision drilling of plots

**Features:**  
- accurate adaption of plot length  
- levelling device  
- quick + easy adjustment of track width and row distance  
- continous drilling device for conventional drilling  
- easy operation

**Hand pushed single row planter**  
*Rowseed 1R*

**Area of application:**  
- handpushed 1-row seeder for all seeds

**Features:**  
- adjustable plot length  
- different filling funnels for several quantities  
- levelling device
Laboratory dresher LD 180

Area of application:
• thresher for plants, ear bundles and small plots

Features:
• threshing, de-awning and cleaning of cereals
• no breaks, loss and mix of seeds
• 18 different concaves
• regulation of wind speed and threshing drum speed
• bag holder
• seed collecting drawer

Laboratory dresher LD 350

Area of application:
• laboratory thresher for grains, peas and fine seeds

Features:
• foot pedal for open the drum and empty the seed drawer
• adjustable dreshing drum speed and wind
• chaff and stem residues are blown into a sack or onto the field

Laboratory sheller LS 230

Area of application:
• gentle and precise threshing of corn kernels by shelling

Features:
• kernals pass through a sieve into a seed drawer
• spindles fall out of the machine
• performance: 300 kernals per hour
Laboratory seed dresser Hege II

If you have any further question, please contact our company:

WINTERSTEIGNER AG, 4910 Ried/I., Austria, Dimmelstrasse 9
Tel.: +43 7752 919-0
Fax: +43 7752 919-57
seedmech@wintersteiger.at
www.wintersteiger.com

Area of application:
- dressing of small seed quantities

Features:
- high dressing quality by exact dosing of dressing
- optimal distribution of dressing
- careful handling means preservation of germination
- 3 different dressing containers - easy to change:
  1 litre volume: 20 - 100 g
  7 litre volume: 80 - 1000 g
  14.5 litre volume: 500 - 3000 g
**Haldrup Harvest Manager Software**

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**Summary**
Haldrup Harvest Manager Software is a software for handling the weighing and other data during harvest. The data is collected in several files. The user can make a field map on the spot or import prefabricated field maps, from e.g. Excel.

**Haldrup Harvest Manager Software**

In 2002 J. Haldrup a/s started to develop its own harvest software. The result is a Windows based program, which is very user friendly, called Haldrup Harvest Manager. The field plan is displayed on the screen, which gives the driver a clear sight of his/her position in the field. Here the driver can see the plots which have been harvested (red), the plot which is in the machine (combine) and the plots which still have to be harvested.

The program is easily to translate into every language. The translation is made in MS Access. At present Haldrup Harvest manager is available in, Danish, Norwegian, Swedish, German, English and Dutch.

**Harvester Setup**
Her you choose if you are working with a combine, TWIN combine, grass/maize (silage) or stationary NIRS piston and conveyor module, as well as the extra equipment connected to the machine i.e. NIRS, 1 or 2 weights, temperature, moisture or extra options.

**Alarm Setup**
A device which can take automatically take a sample when the value lies outside the given parameters.
the lower and higher value. When this occurs there will be shown a warning sign on the screen: “value…”.

Control Sequences
This is to set the timers for the weighing bucket, sample taking and if working with NIRS CORA analyzing (grass). Mainly the following devices are set:

Weight: When to shut the weighing bucket, how many times weighing (average)
Sample: Delay time, sample time and take sample from every plot

The Control Sequences differ when using the system for grain, grass with or without NIRS. Once the Sequences are set they can be loaded every time.

Printer Setup
It’s possible to connect 4 printers, a line printer, 2 Zebra printers and a fourth one:
1. Line printer: Prints all data from every plot
2. Zebra 1: Prints only results from sample taking
3. Zebra 2: Prints labels when sample is added up to the plot weight
4. Extra options

Log destinations
Here is given the destination where Harvest Manager saves the data from the plot, normally in a map Data on C:\. It is possible to view the data of the last 4 plots when harvesting.

Log destination gives you also the possibility to make a back up on a USB-key or disc. This means that when you have connected a line printer and a USB-key the data is saved 3 times, one time on the computer, C:\, the USB-key or disc and on paper. The program is designed to make comments for every plot or for random plots. In some cases you would like to give grades, which is also possible, when choosing this options you have to give every plot a grade before you can harvest the next plot.

The Haldrup Harvest Manager Software allows you to make your own field plan or to import a field plan. On the top bar there’s a pull down menu which is called Files.

The first one is “Create field” here you start with giving the field a name/number – afterwards you choose the control sequence: grass or grain, followed by how many ranges and rows and then the harvest sequence: Serpentine, sequential or circular and finally the driving direction. When all’s set press the OK button and you have created a field plan.

Load field is the function to recall an already used field plan, i.e. a field plan which hasn’t been finished. Import field gives you the possibility to import a field plan from ex. MS-Excel. Those files have to be converted to a comma separated file, .CSV.

The program can import 2 types of field plans:
1. Grid-based import, where every cell represents a plot, i.e. Excel
2. Table-based import where every row represents a plot with user defined information

Data files
Harvest Manager saves all information in 3 different file-types:
.DAT Information of the harvested plots: weight, temperature etc.
.FLD Information of the field plan: size, driving direction, last harvested plot etc.
.FCA This file type is only used for imported field plans.
The development of a field experiment method for being used in practice in agriculture

Author
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Summary
Expert software for grass cultivation management is presented by author. The data base for the software was formed from field experiments (carried out at Leningrad region) results as well as expert’s information. The expert software has field scale; it sets up for concrete site and uses the local data. The calculated information is represented in two ways - graphic and text. The software may be useful for Extension Services.

Article
Let me submit you the paper about the new development in the field experiment methods. This development may be used in agricultural practice.

The project work was created in the field of science with the goal to "optimal decisions in agriculture economy". The aim of such project is the optimal use of all resources: the sun energy, genetic plant properties, the mechanism of flexible agriculture production management, scientists researches etc. The final aim is to harvest, over the entire grassland growing season, fodder (first of all hay) of the best possible quality as well as to store as much as possibly of biological nitrogen in the soil. This will fulfill the general aim of increasing the agriculture production profit. The studied problem includes an economy as well as ecology. Such project shows the way towards sustainable land use.

It is known that fodder for cows on grasslands is cheaper and more useful than other ones. The red (cow) clover is especially useful. That's why the new field experiment method was accomplished by using red clover grasslands as an example.

Let us discuss this new method. The main object of our field experiment method was to represent a real field by means of its information and then use a computer model so that the sowing conditions are clearly defined for different experts. Such kind of models make it possible to plan and forecast the clover grasslands harvests and give the opportunity to take into account how the properties of the grasslands change in time. The necessary personal and equipment may be planned by using these models.

Before mentioning methods, models and technical means it is important to show the difficulties and specific features of this work. An agronomist can almost never foresee the crop development while surveying clover grasslands. Neither could an average qualified agronomist do prognosis about the future of the plants, or make optimal technological decisions. Often depends on farm managers ordering the technological activities. The climate change must now also be taken into account.

As for clover grasslands used for stock hay, the farmers miss the optimal phase for cutting and are often too late. It's difficult for them to plan agriculture production taking into account weather and the sowing state when stocking up fodder. Usually, as a result of such organization, the hay quality is not the best - often low. This circumstance leads to income loss for agricultural firms.

The quantity of protein and the productivity of such hay are then less while the percent of cellulose is higher. One part of the fodder energy is needed for cellulose digesting. The biological value of protein depends on the amino-acid content in the hay. In the Leningrad region the hay quantity has been reduced over the last years. The hay does not contain oestrogen which is necessary for reproduction.
functions of agricultural animals. This factor influences the long cows barren period. There are other negative facts - reasons of long cows barren period. Furthermore, the clover sometimes (usually very often) freezes out on grasslands after winter. Specialists of agriculture production do not know how to avoid such phenomena. Special-ists are too busy to think about optimal approaches during the summer season.

At the same time there are the scientists that know quite well both agricultural science and practice. It is sufficient for them to survey the field to do prognosis about plant growth and development. Of course, they must be supplied with both previous and operative data about the clover fields. The experts' knowledge is based upon both the agriculture science and practice as well as upon their personal experience. Weather forecast is also needed. Such experts can also explain the reason of various situations in practice and therefore can realize the so called "problem based learning" in future.

The information and then the computer model of agriculture field were invented by the author in the year 2002. It may be applied for any grown agricultural crop. I have not seen a similar model in articles, books and patents. The basic advantage of this kind of modeling is the opportunity of taking decisions of practical tasks with the help of experts being far away by using new information technologies. The second important advantage of such a model, and which distinguishes it from other known models, is the fact that it does not use mathematics. Therefore such models can represent the situation in the fields for experts and agriculture specialists without special knowledge in mathematics. Such a model is not a copy of real agricultural sowing. Instead, this model presents the essential features of agricultural sowing including making decisions on personal and equipment for technological operations. The computer model looks like a file -- a set of separate records or frames in the computer memory. Each frame corresponds to one point of the field (one feature of sowing). That is a photo of the certain part of the sowing reflecting the information about two sowing features - the crop phenological phase or the sowing architectonics (plants mutual arrangement in the sowing). There is also other information about the agriculture firm, the various field passes, the crops being planted, the previous technologies, meteorological station data and etc. in this file.

The computer system program (from Microsoft operation system) can look through all frames - points of the field in definite order. So it's sufficient to create computer model of a situation in a certain field in a certain time to transfer it to an expert who is far away to receive the expert’s recommendations. This computer modeling is a new scientific method of practical tasks decision at distance. It's important to note that such a computer model represents information in two ways - graphic and text, so it's a multimedia model. Besides video frames the voice information may be added. Such kind of modeling allows to inspect the sowings state (agricultural production) very quickly and to do it before harvesting, to see situation inside the sowing. Such models of clover grasslands were constructed by me with the help of specialists in Leningrad Research Institute for applied agricultural science of Russian Academy of agricultural science in the years 2003, 2004 and 2005. The results of experiments were approved by the experts of this Institute and All Russian Plants Institute. This data were captured in two ways. Optimal conditions for the clover grasslands clipping were determined for the agricultural grassland and for small, experimental, grassland by me, scientists at these institutes and by agronomists with the help of the meteorological station data.

For realization of such approach it is necessary to have adequately trained specialists, supplied with appropriate equipment such as a car, a notebook with modem, digital video- or camera etc. Different technical means are used for modeling the sowing. It's important to note that no expensive equipment as a planes or space photos are needed. Everything may be done on the ground except the weather prognoses.

The described approach may be the way to adapt for climate changes and the way to a new high-tech economy in agriculture. These technologies are leaving the West behind. These technologies can be used and marketed all over the world where agriculture has similar problems. Afterwards, they can be used for various agriculture plants.

A new methodology of education in different areas based on the information technologies is developed. It is based upon computer models of practical tasks with short abstracts from various disciplines. They all provide educational material taken from a broad range of sources. The material is presented in the form of an electronic textbook. Multimedia is used to provide its mastering. The efficiency is achieved thanks to the methods of active teaching. In the example of plant technology, knowledge from biology, biochemistry, biophysics, ecology, economics and informatics is provided. It is a qualified education during the short time. It expands one's analyti-
cal thinking, provides the ability to integrate knowledge from different areas, teachers to formulate tasks and make optimum decisions.

This program is oriented to specialists who will organize consulting while described technologies of high-tech economy are realized. They will be studying examples from problem situations. For West partners, the teaching may be organized on the base of non-state Saint-Petersburg structure. An interesting culture program may be applied.

Conclusions
1. This expert software for grasses cultivation management was elaborated and tested for Leningrad region conditions,
2. This expert software may be used by farmers and Farmer Extension services.
Selection clover seed huller

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Summary
A selection clover seed huller, providing uniform processing of a heap practically without crushing and a high scale grating, has been developed. The selection clover seed huller is completely self-cleaning from residues of the treated seed mass.

The Article
One of the important tasks of agriculture is to increase the production of qualitative forages as a precondition for increased animal industry productivity. For this reason the manufacture of high-quality grass seeds, including bean grasses, is crucial. The heap of bean grasses, obtained from a combine, contains a mixture of free seeds and plenty of the seeds not cleaned from flower covers - this quantity can be from 15 up to 45% depending on conditions of harvesting. Therefore, the technology of after harvest processing of bean grass seeds is obligatory contains operation of seeds wiping which is carried out on clover seed huller.

The clover seed huller for should be able to process grasses, obtained from experimental selection plots, with a high degree of seeds cleaning (not less than 90%), with a minimal crushing and should be completely cleared of residues from the processed culture.

The clover seed huller developed at our institute fulfills these requirements (Picture 1.). It consists of a frame where the wiping device is located at the top and the driver device with the block of the electric motor management at the bottom.

Picture 1. Scheme of Clover Seed Huller:

| 1 – Body; | 2 – Head - stator | 3 – Pins of the stator |
| 4 – Loading tray | 5 – Cover of the tray | 6 – Rotor |
| 7 - Pins of the rotor | 8 – Vane of the spinner | 9 – Distributing cone |
| 10 - Drive axis |
DATA MANAGEMENT, SAMPLING AND ANALYSIS METHODS

However in this case the most part of a stator space remains non-working and some raw material may not be treated at all.

If we increase the number of pins on the rotor to five, and arrange them in regular intervals through 72 degrees (Picture 2, b), but keep four pins on the stator, the rotor will work in regular intervals without shock loadings and all stator space will be filled by grass mass uniformly.

Let’s assume, that the number of pin lines on the rotor were six and they are located in regular intervals through 60 degrees (Picture 2, g), and the number of pins lines on the stator is still four. Then the shock loading on working bodies of a device drive will be double. From these considered variants of pin arrangement on the rotor, preference should be given to the variant with five pins lines on the rotor 72 degrees apart.

The quality of the grass mass processing is also influenced by the rotational speed of the rotor. Our experiments on processing clover grass mass with a humidity of 14 % have shown that with increased rotor frequency the degree of seeds cleaning raises.

The wiping device includes:
- A cylindrical body with an output branch pipe,
- A horizontal disk - rotor with vertically established pins and a distributive cone on the top part and blades of the fan-blower on a bottom,
- A disk-stator with vertical pins which is also a cover of the body.

A loading funnel is placed on a cover at the center. The rotor is driven from the electric motor through a wedge belt transfer.

The overall dimensions of the device are 940 x 700 x 980 mm. The weight is 100 kg. The established capacity of the electric motor is 2.2 kW.

The incoming grass with seeds to be wiped is captured by rotating pins of a rotor and set in motion by them. Other pins on a motionless disk (stator) are disturbs the free movement of grass with seeds and force them to pass through the limited space between the pins of the rotor and stator. During this phase, a short-term compression of grass volume occurs due to the friction from the pins and seeds are removed from flower covers. It occurs due to grass mass deformation in two directions: along a line which is passing on the centers of pins at their concurrence, and perpendicular to it.

From this follows, that the intensity of seeds extraction from the grass mixture depends on a number of cycles of a meeting between processed material and the rotor pins, but also on the number of the pins participating in this work. The quality of the clover seed huller work depends on uniformity of grass mass distribution on the working surfaces and of the way the pins are placed on the rotor and the stator.

Let’s consider possible variants of pin placing. The number of pins, placed on stator, should be just enough to provide duly tap of the processed material. It is necessary to place pins on a certain distance from each other. Each pin of the rotor should interact with pins on the stator, alternating by time with other pins - instead of successively – in order to avoid increased loadings.

If we would arrange four lines of pins on the rotor and four lines on the stator exact on axes of diameters through everyone 90 degree (Picture 2, a), then all pins of the rotor will meet the pins of the stator simultaneously.

In this case there is a non-uniform quadruple shock loading on working surfaces in regular intervals, without double shock loadings.

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Let’s assume, that the number of pin lines on the rotor were six and they are located in regular intervals through 60 degrees (Picture 2, g), and the number of pins lines on the stator is still four. Then the shock loading on working bodies of a device drive will be double. From these considered variants of pin arrangement on the rotor, preference should be given to the variant with five pins lines on the rotor 72 degrees apart.

The quality of the grass mass processing is also influenced by the rotational speed of the rotor. Our experiments on processing clover grass mass with a humidity of 14 % have shown that with increased rotor frequency the degree of seeds cleaning raises.

The results of clover seed huller testing on processing grass mass of clover meadow, hybrid and creep-
ing, and also amaranth have shown, that the device provides a productivity from 60 up to 146 kg/hours with a degree of seed cleaning up to 97-99 % at a seed humidity from 10 up to 14 %.

Conclusion

- A new clover seed huller was developed to meet crop breeding needs.
- A few regimes of clover seed huller work, at different conditions of the treated materials, were studied and the optimal one was chosen.
Multi-purpose plot machine modules: More flexibility and lower costs - The Flexiseeder Approach

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Abstract
Multi-purpose equipment for field experiments needs to include modern technology, be affordable and meet tough requirements on interchangeability, accuracy, reliability and maintenance. It must plant zero tillage, reduced tillage and cultivated ground with equal application to accommodate the change over from historical cultivation. Required levels of technology vary for different countries and applications. By developing, assembling / combining working modules, plot machines can be tailored to meet these new demands, at lower prices than otherwise possible. The module approach is useful for most machine operations in field experiments. The paper introduces and discusses standardization issues for developing these modules, for example free space requirements and interfaces between working modules. Examples of modules are given based on the design and development of two new multi-purpose (Machines equally suited to zero (eco) tillage, reduced tillage and conventional cultivation). “Flexiseeder” plot drill prototypes. If the use of working modules can be increased, production costs can be lowered because of module re-use in different field operations, the use of standard machine components and the local manufacturing of some modules / module components.

Acknowledgements
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Introduction
The demand for multi-purpose equipment for field experiments has grown substantially over the past five years, out stripping available purpose-built technologies including plot seeders and other research equipment suited equally to zero (eco) tillage, reduced tillage and conventional cultivation. During this era, useful technologies introduced and discussed in this paper have been borrowed / adapted / exchanged / interchanged with farmer equipment under the Flexiseeder Project (www.flexiseeder.com, which is part of the IAMFE / IAU Seed and Seed Drilling Technology Help Group - International Association for the Mechanization of Field Experiments / Global Institute and Agricultural University Internet Hub (IAU Trust)) using a modular approach to help “fill the gap”, to economize and to reduce differences between plot and farm technologies, with excellent results (Described in detail at this conference by Stevens et al, 2008 and Fraser et al, 2008). When considered as modules, these technologies have broader application for field experimentation including spray and fertilizer application as well as for specialized cultivation besides general agriculture, horticulture and viticulture.

To proceed further, relevant standards need to be developed for these multi-purpose modules to help refine and bring them into common use, along the lines used more than 30 years ago under IAMFE, for defining standards for arable plot drills (Hallerström, 1992; Oyjord, 1996). This paper in-
introduces and discusses several “multi-purpose module standards”, based on working examples developed over the past four years under the IAMFE / IAU Seed and Seed Drilling Technology Group Flex-seeder project. It is backed up with six technical papers listed in the References, also presented as posters at IAMFE 2008 and included in the proceedings.

Background
Key points:

- What do modern multipurpose plot seeders have that is not needed on farm machines?
- What must they have at same time to ensure a good correlation of field experiment results to cultivation/farmer recommendations?

The most important difference with farm machines is probably that plot equipment must allow a high level of control of the operation (setting up the treatment and monitoring of the result). It must be easy to initialize the treatment for each plot and there should preferably be no interactions between the treatments of each plot. Factors such as carry-over effects, contamination and remains of tested products (for example residues in combines or seed mixtures in drills) must be avoided. Plot machines need to apply products in well-defined portions for each plot, to harvest crops without intermixing between plots, to take representative samples of products and to measure yields, applied rates of products, etc.

- On the other hand, many other demands are the same for plot and farm machines.

Several examples of this are provided in the paper by Stevens et al (2008). Needed are a support system with components for driving/carrying (wheels, engines, lifting and steering systems etc) and for environment and protection (driver cab, protection devices). Farm and plot machinery have rather similar demands on reliability and maintenance. The increased use of precision agriculture systems also applies for plot equipment. In order to simplify and to save costs, tractors or tool carriers (more or less advanced) are often used.

- It is useful to try and define what special operation modules needed in plot experiments and to set up some requirements / criteria for how these can function together with the support systems.

Examples of this are requirements on free space for the modules and on how to exchange information and control implement.

Plot machine module examples - use and characteristics
The following multi-purpose working modules are used regularly in modern field trials and warrant defining as multi-purpose modules.

1. Planting - portion feeder for granular materials
   The normal (Oyjord) and belted cones are widely used with mechanical, air or air-assisted distribution to coulters on standard and precision planters and fertilizers machines. Air is also used for cleaning out (especially precision drills). The cones normally rotate one turn over the plot length. The metering system controls the carousel rotation angle as a function of the traveled distance. If the drill stops, the application stops. Lamellae height within the cell wheel varies from between 4.0 mm and 25.0 mm and space between lamellae also varies depending on the size of portions distributed / plot length. Standard 400 mm diameter cell wheels usually contain 48 lamellae, reduced to 24 in some instances while the 320 mm diameter wheel contains 32 lamellae reduced to 16 in some instances. The drop hole can be located towards or away from the operator.

2. Spraying – liquid application systems
   Sprayers can apply a fixed or a changed dose over the plot length. Chemicals can be mixed for each plot or treatment, or concentrated chemicals in syringes can be used. The application rate is often constant (travel speed also fixed as far as possible) throughout the plot or, if linear change of the dose is used, the rate is a function of the traveled distance. In most instances, if the sprayer stops moving, the application/spraying continues at the latest applied rate, until manually stopped.

3. Tool bars for mounting coulters, nozzles etc.
   Various tool bars are useful when rapidly changing the experimental setup. Tool bars on drills can be lifted/lowered and/or rotated. For maximum flexibility (standard planters) a frame can support up to 4 bars with coulters - all with adjustable angles (rotated mechanically or by hydraulics). It should be possible to set two bars at different depth and/or angles compared to the others. The coulter frame would fit most arrangements (used together with two portion feeders): normal drilling (2 bars); combined fertilizer-drilling (1+2 bars); double drilling (2+2 bars for main crop and grass/clover under-crop); technical experiments (sets of row distances, seed rates etc.).

4. Metering – positioning systems
   Some examples are: Navigation based on the
Global Positioning System (GPS); Precision agriculture work operations using Graphical Information Systems (GIS); land-wheel controlled inputs, other steering/tracking/guidance systems. Flexibility is increased if the controlled units are electrically driven. Different drive algorithms can be used for planting and spraying. It is easy to utilize GPS input data and to add various on/off/start/stop functions. Furthermore, the metering system can be easily portable for use on different machines. If standards could be adopted, the control from the metering system will control different applicators/feeders in the same way (according to plot length settings and used regulating algorithm). Development work should be based on international standards like DIN 9684 and ISO 11783.

5. Collecting and weighing units for harvested products
Such modules are needed on forage/grass harvesters, maize harvesters, plot combines, root crop harvesters etc. There are many other measuring devices besides scales, like near-infrared reflectance (NIR) instruments. Often, readings are transmitted to data collectors via computer serial (RS-232 etc.) interface, but cable-less communication methods like Bluetooth (including converters to RS-232) are also available.

6. Coulters including harrows and rollers
The module system should allow for the use of a wide range of different coulters for direct, reduced tillage and normal conditions for different soils and weather conditions. Row and tool bar spacing / configuration should be adjustable. Examples of coulter types are single/double discs, knife coulters and Suffolk coulters. Rotating tool bars and adjustable tool bar axle height can allow for most types to be used. A simple and affordable solution is to use standard S-tines for mounting of the hoes, knives or discs (here combined with supporting arms). Typically, rakes (harrow) and/or pressure rolls follow the seed coulters. If not attached directly to the coulter, a common set of straight or sweep types of harrows and/or pressure rolls follow the seed coulters. If not attached directly to the coulter, a common set of straight or sweep types of harrows and/or pressure rolls follow the seed coulters. While knife coulters can penetrate hard ground with little down pressure, plot drills may lack enough down pressure for direct drilling systems using disc coulters (disc coulters are preferable, for example, when there are large amount of residues). Here the possibilities are to add the weight of the operator onto the frame, transfer (by hydraulics) down-pressure from a tractor or tool carrier to the frame or using semi-trailed plot drills and adding weights to the drill frame. Two-point linkage options allow operator weight to be effectively canty levered onto the disc assemblies, by mounting these assemblies well forward on the seeder frame, and positioning the operator(s) toward the rear. Only the front (driving) wheels need to be lifted off the ground for turning, if the back wheels are designed as free steer.

7. Conventional boxes / arrangement for applying basal fertilizer and / or other products
In many cases, specific plot technology will incorporate standard farm components. Examples are seed bins, continuous feeders like commercial cell wheels feeding air delivery systems (also available as plot machine options) and feeders for fodder mix, manure etc. Besides fluted rollers, peg rollers and foam feeds are used either as simple gravity drop or combined with air assistance for delivery of product to the coulter. The use of independent drivelines and air assistance can be helpful in many situations where gravity feed becomes impractical and/or product tends to lodge in hoses to speed up the adaptation of farm technology (for example, in direct drilling) for use in field trials. With air delivery, consideration may be given to including diffuser / cyclones (www.d-cupdiffuser.com) attached to coulters to prevent seed bounce.

Results/examples and discussion
In this section examples of multi-purpose modules developed under the Flexiseeder project for plot machines, especially planters, (Modules have been placed in the public domain for all to use. Besides technologies, members of the Flexiseeder group are available on payment, to provide consultancy support) are demonstrated and discussed.

Tractor fork
- Mounting a plot seeder behind a tractor, behind a tool carrier, or mid-mounted on a tool carrier.

A tractor fork can be used for hitching the drill modules to the rear of a tractor. Figure 1 shows a fork with an A-frame quick-coupler inserted inside two vertical profiles. In these profiles a fork can be inserted from the top, that will carry modules for portion feed (Oyjord carousel etc.) and distribution (air system or mechanical rotor), passenger seats etc. At the tower lower end, two support wheels can be inserted from each side (if these are not placed on the drill frame). At the lower rear end a harrow-like drill frame can be hitched. The frame is floating during planting. The rear end is connected with chains so the frame will be lifted off the ground.
when raised between plots.

**Space requirement for tool bars or for harvesting/lifting machinery parts**

Plot equipment will often be mounted on tool carriers and tractors. In a module system, self-propelled integrated/special machines (like self-propelled plot combines) would be less common. Tool bars (or other devices) for planting need free space when they are mid-mounted on tool carriers or high-clearance tractors. For rear mounting, the total weight should be as low as possible and distances as short as possible from the rear vehicle wheel axle to the module’s center of gravity.

It is suggested that the drill frame should not be wider or longer than 1200 mm. However, the frame can be 1800 mm in the driving direction if the width is a maximum of 1000 mm. This will apply to tool carriers and tractors having an inner clearance between wheels of a minimum of 1300 mm. Coulter bars can stick out to the required working width in the 1200 mm cleared zone or further to the rear if placed in the centre zone of maximum 1000 mm width. The drill frame can alternatively support fertilizers nozzles/coulters, weeding hoes etc.

For mid-mounting (only), a ground clearance of minimum 800 mm might be useful. This will give space for lifting tool bars between plots. Also smaller cutting tables can be mid-mounted – with band transport to a rear mounted bin (with, for example, weighing and sampling devices). A ground clearance of minimum 600 mm can be acceptable for drilling and mechanical weeding.

**Space & height requirements for fitting application modules**

Tool carriers may have a central body/main bar or two side bars. Application modules (cones, or liquid applicators, module 1-2 above), can be designed for being clamped-on to:
- the centre bar on tool carriers with one mid-bar
- each side bar on tool carriers with two sidebars
- the tool bar frame’s both side bars, placed to the left/right or in the middle.

For clamping on tool carriers, the maximum clamp gap should not be less than 120 mm wide and 160 mm high. For clamping on coulter tool bars, the possible clamp gap should be at least 80 mm wide and 120 mm high.

When mounting these modules on tool or coulter bar frames, the modules cannot be wider than 1200 mm if used on mid-mounted frames for tool carriers with two side bars. If used on frames mounted on mid-bar tool carriers, the modules should be placed at least 200 mm from the centre line. In the driving direction the module must be inside the free 1200 mm space.

Picture 1 shows tool carriers for mid-mounting where certain space is available. The drawing (right) is one example showing free zones for fitting tools to either tool carrier type.

The drill bar can be attached directly to its links for mid-mounting (or via a simple implement A-frame with rear, short, floating arms for the drill frame). The portion feeders and distribution systems can be clamped to each side of the frame or clamped to
the tool-carrier’s upper mid-bar. A driveline could be attached to the rear of the drill frame or be mounted on the drill frame itself.

**Drill frames and tool bars**

The possibility to choose type of coulters means that drill frames are most flexible if they can allow for depth, angle (rotating tool bars) and row spacing adjustments. Figure 2 show a frame attached to a 3-point linkage.

Picture 2 shows a couple of drill frames that have adjustable supporting wheels and tool bar axles that can be rotated. The drill frames can be quite simple with two side bars. The side bar should either have a small angle in the driving direction or be about 200 mm narrower in half its length. The frames’ front and rear end can be altered (frame rotated 180 degrees). In this way different row distances can be used without coming in conflict with the side bars. Then 2-4 coulter bars can be clamped to the side frames. 2 or 4 supporting wheels can also be clamped, if needed. The coulter bars are more or less like harrow S-tine bars and it should be possible to rotate the bars by a mechanical handle or with hydraulics. It should also be possible to mount at least two coulter bars at a different depth than the others, and to use a different rotating angle for two bars. If the distances between the coulter bars are fixed with links between the clamps, the rotating part can be set centrally by using parallel links with many holes to select from. Alternatively, the angle can be set with a handle for each bar.

Normally the frame has four wheels that can be adjustable in height (not shown in figure). The frame may also have only two wheels or none – if fully supported by the tractor/tool carrier – but then ground contour following may often decrease. When hitching coulter frames with support wheels,
 Floating arms are needed so that lateral contour following is possible (compare with old mounted harrows). See also Figure 1 and 2. Picture 3 shows other examples of drill frame details.

**Cell wheels and distributors**

Regardless of whether portion feeders of different kinds or adopted farm feeders and cell wheels are used, the equipment needs to be easy to clean (go clean) between plots and to calibrate.
Standard/normal Oyjord cones can be used for portion feeding. They will work fine for both seeds and fertilizers. Sometimes, the friction between the base plate and the carousel can be rather high (especially when using brass material for both). Even though the step-motor driveline (See Fraser et al., 2008 for details) produces the torque needed, it is possible to reduce the friction by approximately 50% by inserting a wear sheet of ultra-high-density plastic (UHMWPE-BR (www.ludoplas.com)) in between. Comparative torque data are available.

We have used Oyjord cones manufactured by S&N International Ltd in New Zealand (Picture 4). Both 320 and 400 mm carousels are available. The lamellae height can be from 4 to 25 mm (almost 25 mm in the picture). 48 and 32 lamellae are standard for 400 and 320 mm units. For a modest set up cost, a variety of other lamellae spacing and heights can be supplied. There is provision to cast and supply additional rings which fit under the S&N cell wheels, as per the diagram. Wind covers as well as a range of interchangeable tube sizes are also available. S&N
Field Trial Machinery and Equipment

Cell wheels fit directly onto existing Oyjord base plates.

Cones and distributors (both mechanical and air delivery) are sensitive to slopes. Picture 4 shows automatic leveling devices on the S&N drill sold to Norway (see also Picture 8 later in this paper). Research is under way to also apply this principle to air riser pipes and distributors. Direct coupled S&N electrically driven manual distributors plus variator are available (see Fraser et al., 2008) and the next section in this paper) which can be adapted to existing Oyjord distributors.

Mechanical seed metering devices and distributors

Standard farm seed / product metering systems and devices including fluted rollers, star wheels, pegged drums, and sponge feeds have been used routinely for more than 50 years on plot seeders to meter basal applications of a range of products besides seed (including fertilizer and granular insecticide, for example). This same equipment has also been used routinely for continuous sowing of field trials, alleyways and border areas around plots, particularly where a high degree of accuracy is not important and / or low product application rates are not required.

Between row CVs of less than 10% are to be expected and repeatable settings are obtained when this equipment is properly maintained, operated according to manufacturer specifications and coupled to modern gearing / drive systems with finely tuned adjustment. In order to obtain this, the project found that the quadrant / adjustment arms on commonly used gear boxes (Zero-Max for example) may have to be strengthened overall and doubled or trebled in length. Spare parts are still available for most of this farm-based equipment (new and old), making it suitable for either adapting or bringing forward onto modern multi-purpose equipment provided it is operated within the manufacturers specifications for product types and sowing rates.

Y2 Zero – Max gear boxes should be fitted with a suitable torque delimiter (available from S&N), to prevent equipment failure should the system overload if something jams.

Older style farm equipment, unless specialized, is seldom suited to metering small seeds / fine products (brassica and/or insecticide prills for example) at low rates of application. For this, modern equipment is required. Thian (www.thianagri.co.nz) modular farmer foam feed units work well for plot seeders, coupled with modified Zero-Max Y2 gearboxes shown in Picture 5. They may be mounted in custom-build boxes, one per row for gravity feed units, or singularly, in tandem, or triplicate feeding into air delivery systems.
Modified Zero-Max Y2 gearboxes (or Flexi digital gearboxes – see Fraser et al., 2008) can be used to provide fine (over-ride) adjustment to fluted rollers (Mistral and Accord, for example) commonly used to meter seed and other products into air delivery systems. This adaptation (applicable to plot seeders and farmer drills) is especially useful for adjusting these cell wheels while they are loaded with seed (product), particularly for reducing delivery rates by reducing the speed of the input shaft, independent of ground speed, rather than trying to force the flute closed. On air seeders, this also allows for more accurate metering, particularly at low rates. Digital systems may in time be connected to GPS systems to enable seeding rates at plot and field levels to be adjusted to soil maps / ground variation / plot plans within the blocks sown.

The impellors of Oyjord mechanical distributors (Picture 5), designed to rotate counter clockwise have been driven mechanically from a land driven wheel, electrically using a converted 12 volt vehicle generator (dynamo) or comparable DC motor, or hydraulically using a small hydraulic motor. Impellors were usually cast from aluminium. Recommended rotational speeds for these impellors range vary between 600 rpm for big beans, 750 rpm for soya and peas, and 900 rpm for grain, oilseeds etc. Fertilizer requires at least 900 rpm. Therefore ranges of working speeds are required between 500 and 1500 rpm or at some fixed speeds 600/750/900/1050/1200. This is achieved mechanically using gearing systems, varying the power supply to the motor, or controlling oil pressure / flow.

Mechanical drive systems are much less flexible for positioning / leveling the cell wheel assembly, compared with direct coupling electric and hydraulic drives. Electric drives are cheaper than hydraulic drives. Electric drives must have sufficient torque to withstand the impact of seed samples loading them, without slowing in rotational speed. For this a heavy motor is required, of at least a power of 180 W. While the project found that vehicle dynamos would suffice as motors (as suggested by Prof Oyjord based on his past experience), they rotated clockwise, were not designed to operate vertically and for direct coupling, required the inverse of the original Oyjord impellor to be cast. This was achieved successfully by the project, retro-fitted to a Farmall up-graded to the Flexiseeder system. Subsequent to this, with the assistance of John Brooks Ltd NZ (Fraser et al. 2008), a much superior (constantly magnetized) 12 volt motor and mechanical variator module was developed and brought into the commercial market. This motor could be rotated either clockwise or counter clockwise. It may be retro-fitted to existing Oyjord systems. It also has the potential to be fitted into distributor heads in air delivery systems.

Besides the Brooks motor and mechanical variator combination, S&N Flexiseeder replacement impellor blocks (clockwise and counter-clockwise rotation) are also available cast either in bronze or aluminium to be machined to retro-fit existing Oyjord as well as other distributor systems. Using the variator to control the impellor speed on this electrically driven combination, means that as the impellor slows, torque increases, since the motor continues to rotate at full speed. A bronze impellor, although heavier and more expensive than its aluminium counterparts, stands up well to fertilizer and acts as a fly-wheel with stored energy, meaning it is unlikely to slow when a sudden dose of seed hits it as the seed tube is tripped. Because of the weight (2.3 kg before machining and balancing (Balancing is achieved during machining, by drilling cores out of the underside of the base)) it should be run constantly between plots. The aluminium block weighs 0.69 kg.

**Air assisted distribution**

Air can be used for both distribution and transport or just for transport after another distribution de-
vice (below conventional seed bins or after a mechanical impellor/spinner).

We have used an air system for both transport and distribution. There are several makes like Accord (very common system for farm drills), a Canadian make (Flexi-Coil) and the Australian make Smallaire. Smallaire provided a reasonably compact and quite hydraulically driven system that could work on plot drills while at the same time is used on farm drills. Picture 6 shows Smallaire air distribution system components. Thumbnail inserts show improvements made by Norway, (i) plastic cone placed in distributor to reduce CV between outlets and (ii) 60 Mbar pressure gauge for quantitative calibration / repeat settings.

During tests done at the BioForsk Apelsvoll field research station (Small et.al., 2008), it was found that the air distribution heads needed a modification so that no seeds were left in the heads between plots. Smallaire modified the heads to solve this issue. Bioforsk also tested the distribution variation between coulters. A coefficient of variation (CV) of less than 15% is deemed necessary. Such a variation means that, in worst cases, the amount of material distributed to each coulter could vary by approx. 40% from the maximum to the minimum amount. Within this variation, the crop (with limited row spacing like 10-20 cm) will compensate for most of the differences provided that it is a random variation and not systematic in a section of the head. Ideally, a CV of 4-6 % would be targeted.

In horizontal position, the CV was found to be from 4 to 13 %. However, which is also normally the case for mechanical spinners, the CV increases if the head is not horizontal. We have not investigated the CV in more than 15% slope and there the CV increased to around 15% or slightly more. A leveling device is therefore recommended for hilly conditions. One important measure is to connect the coulter houses to the distributor head alternatively to the left and right of the machine in order to minimize systematic variation because of a leaning distributor head.

On the Norwegian plot drill, the cones are leveled but not the air distributor heads. We have discussed if adding an extra spinner/propeller in the distributor head would improve the CV % in slopes. Also other types of heads and riser pipes plus self leveling devices for the riser and distributor will be tested but we have not had time to do this.

In order to calibrate blower speed it is also necessary to have a speed meter on the fan or to use manometers to monitor this. In certain cases, you may wish to put cyclones where the seed is delivered into the coulters, especially if blower capacity needs to be very high (large farm machine) or the seed is light and you drill very shallow. We have not needed to fit cyclones for the cereal and grass crops we have sown so far, but we haven’t enough experience to be sure.

Requirements on a metering module / land wheel

In the simplest case, the metering system will just measure and/or indicate the traveled distance. For controlling seeding/fertilizing, the system can advance the cones (or cell wheels etc used for continuous feeding) at a fixed gear ratio. Mechanical
drive (chains, cables etc.) or mini-hydraulics can be used instead of electrical pulses and (step-) motors.

**Driveline**

A driveline can be arranged from the wheels on a tractor fork. A more flexible system, however, is to use a separate land-wheel that controls the feeding mechanism. Cable (Cable whip is common compared with the more positive drive of chains, shafts, sprockets and universal joints) and links/universal joints can be used, but the most flexible solution is letting the land-wheel control an electrical step-motor via a control box. In this way, the driveline can be used for many different purposes. The same control unit could be set/calibrated for planting, broadcasting fertilizers, for liquid application etc. If the system is standardized enough, a unit that fails can quickly be replaced by another backup unit. If attached to the drill frame, the land-wheel can be activated when the drill frame is lowered. With a step-motor system, the motor(s) on the feeders can be started manually or simultaneously with the release of material onto the cones. The motor(s) will stop shortly after the land-wheel stops sending pulses or when the total plot length has been traveled (with some extra margin).

Picture 7 shows a driveline with land wheel, control box and two step motors controlling one Oyjord cone and one Mistral (Accord type) cell wheel (for continuous fertilizing). On the control box plot lengths are set for the cone. The plot length setting is also used to set the speed of the motor driving the Mistral cell wheel. The cell wheel also has an adjustable outlet and two gearbox speeds. On the driveline control box the plot lengths can be fine-tuned depending on the actual rolling diameter of the land wheel (now programmed for a diameter of 600 mm). The control box also has start/stop switches for the step motors. The step motor driveline is further described by Frazer 2008.

**Enhanced controlling algorithm**

As soon as you wish to change the rate within the plot (like a linear or step-wise changes), the frequency/speed of a step motor can be changed at small distance intervals. For liquid application you often set the frequency after the location (traveled distance) within the plot. You try to keep the speed constant at a preset level. The actual speed is often recorded so that one can document the real application rates afterwards. When you wish to adapt the frequency to a variation in speed, the control program will calculate both the intended and the actual dose and decrease/increase the frequency when you travel slower/faster. In addition you must amplify this increase/decrease so that the total number of motor revolutions (the integral sum of frequency over a distance) matches the intended application curve.

A program example is shown in Table 1. The frequency is adjusted when a new distance pulse is received. This will work if the program execution is fast and the microprocessor has a timer with accuracy of one millisecond or better. Alternatively, one may count the number of received pulses at each of the timer’s shortest interval.

The very lowest frequencies of the step motor will be less accurate. If the step motor has, for example, 4000 ticks and you use the range 40 to 2000, you can vary the plot length with a factor of 25 (for example from 2 to 50 meters). At the lower frequency of 40, the minimum dose/frequency change possible is 2.5% (1 of 40 ticks).

If you set the amplifying factor (YC in Table 1) to
zero, the step motor frequency will just be adjusted according to the traveled distance from the start of the application. This is often preferred in pesticide application. However, the true application rate will be different from the planned dose, so the speed should be registered and controlled afterwards.

When you use the step motor program to control the rotation of, for example, Oyjord cones, corrections for uniform speed must be made. Setting to a value greater than zero means that the motor will be controlled so that the planned and actual total doses become as equal as possible. The rotation of the Oyjord carousel should then correspond to the traveled distance in the plot. The higher amplification (YC) factor, the quicker the S and A sums will converge but, on the other hand, the step motor frequency will flicker a lot. The choice of YC value will depend on driveline setup (how many pulses per meter and timer accuracy) and the possibilities to travel at a rather constant speed through the plot. Probably, a YC in the range of 0.1 to 0.3 will be suitable in many cases.

Requirements on GIS/GPS control systems
Plot equipment will follow the development and standards used in precision agriculture. The German standard covers the signal exchange between con-
trolling units and machines DIN 9684 and the international ISO 11783. In this project we have not worked with this, but a step motor driveline provides a good base for using these control systems instead of a land wheel.

Coulter assemblies
Keeping in mind the basic principle of a contour following drill frame with height adjustment and rotating coulter bars (like normal harrow S-tine axles), we can think of a wide range of coulters that can be used. Some are commercial products like various tips for mounting on S-tines and the Amazone RoToC single disc coulters. Other alternatives, like Kongskilde double discs, can be adopted for mounting on rotating harrow axles. Other coulters have been developed for this project. Picture 8 shows examples of different coulters.

Picture 9. Prototype drill, under construction, for the Swedish MacTrac tool carrier, spring 2008. The drill will have 12 rows (normally 1.5 meter working width) and is equipped with one S&N 400 mm standard cone feeder and one Mistral cell wheel for continuous feed. The feeders are driven by two step motors (IMS). Disc coulters for seeding (only a few mounted on the picture) are Amazone RoToC. For fertilizing, the S&N module knife tip coulters are used. Please note that drill frame is now re-built to use rotating coulter bars.

**Complete Plot drills – examples**

Picture 9 shows a drill frame connected to the rear of the Swedish MacTrac tool carrier. The model on the picture has no rear hydraulic lift. Instead, the coulter bars are centrally rotated into the soil with hydraulics. A link lowers the land-wheel in the same operation. On the MacTrac (for weight/stability reasons), the feeders and passenger/operator are located to the right and left side in the middle/front part of the machine. An air system delivers the seed/fertilizer to the coulters in the rear end. An electrical drive-line is used to easily connect and control the feeders from the land-wheel.

Picture 10 shows a prototype drill delivered to Norway (New Zealand make S&N Flexi-seeder). The prototype partly incorporates the module thinking discussed here. It has a drill frame where coulter bars can be rotated and depth adjusted and it has two feeders and a fully air-based distribution system. This drill also has a front-mounted bin for continuous (free-fall, not air-based) application of fertilizers (mainly for combined drilling). Coulter bars and transport hoses can be arranged so that the machine can do normal drilling, combined drilling (with the bin or using one of the portion feeders) or double drilling (seed and undercrop, other combinations of seeds, seed rates, row distances). The drill can even do this in combination with applying fertilizer from the front bin (broadcasted or placed in the soil - 5 coulter rows would then be used). The drive-line is mechanical and driven from the front pair of wheels.

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“Flexiseeder”: A new modular approach to help improve correlation/cross-over of results between plot and field research and commercial agriculture, horticulture and viticulture

Summary (abstract)

The application, extension and delivery time to end users of research results can be substantially enhanced in cost effective ways through the systematic use of overlapping equipment components designed as modules. This is particularly so where they are suited equally to reduced and zero tillage as well as conventional agriculture and organic farming. Examples of and the history behind the evolution of the Flexiseeder multi-purpose modular approach (www.flexiseeder.com; equally suited to zero (ecotillage), reduced tillage and cultivated ground) are introduced and discussed. The Flexiseeder resulted from collaboration through IAMFE / IAU (Seed and Seed Drilling Technology Help Group: International Association for the Mechanization of Field Experiments / Global Institute and Agricultural University Internet Hub (IAU Trust)) over the past four years, among research and production workers located in New Zealand, Sweden, Norway, Switzerland and Australia. These Flexiseeder technologies have been placed in the public domain in the hope that they will provide a catalyst for follow-on projects which assist food production throughout the developing and developed world.

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Introduction

New Zealand has many overlapping agro-ecologies, encompassing developing and developed production systems, between which a range of crop improvement technologies have for many years been successfully exchanged. Fodder oats provides a good example (Stevens et al., 2000; 2004). Similar principles have been applied to plot seeders. Frame and coulter assemblies on many early Oyjord plot seeders (Plate 1) and even later models (Plate 2) imported into New Zealand during the 1970s and 80s had to be modified and strengthened using locally manufactured arable field drill components. When knock-on knife tips (Manufactured in Australia and still readily available (www.bluepoint.com.au). These tips have been included in the range of Flexiseeder tips offered, combined with a special Flexiseeder

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cleat allowing them to be attached to 12 mm as well as heavier 5 tyres as part of the Flexiseeder coulter module) were fitted, resulting modifications made these drills “multi-purpose”; they became suitable for reduced tillage and light direct seeding under favourable conditions. In New Zealand and Australia, arable plot drill frames and coulter components have needed to be more robust than in Europe and North America, due to local conditions.

Additional multi-purpose plot seeder frames (Plate 3) were constructed locally during this era, to which Oyjord cell wheels and distributors were fitted. On these seeders, cut down local arable fertilizer (and at times additional seed) boxes were often fitted, in front of the standard Oyjord cell wheel and distributors. These multi-purpose seed drills served equally for the demands of research, early generation seed multiplication and small-scale farmer evaluations and demonstrations. From this equipment, excellent correlation / cross-over of results and tillage modules for cultivated land and light direct seeding were achieved for plot and field research and demonstration as well as commercial agriculture, horticulture and more recently, viticulture.

While most of these machines now have between 35 and 40 years of continuous use, farmer as well as researcher focus has moved from conventional arable agriculture to zero tillage under conditions that go well beyond the performance capabilities of these original drills. Consequently, much of this early equipment is in need of either being up-dated or replaced (Plate 4). This constitutes a major financial burden to programmes, for which affordable alternatives are being sought. These include modular alternatives introduced and described in this paper and companion papers presented at this conference by Leuchovius et al. (2008) and Fraser et al. (2008).

For the past four years, these perceived needs have been addressed voluntarily under IAMFE / IAU by a core global group of of concerned scientists, technicians, farmers and engineers in Norway, Sweden, Switzerland, Australia and New Zealand, organized and co-ordinated by John Stevens and Torbjorn Leuchovius (Entites represented by the Authors of this paper in Norway, Sweden and New Zealand each contributed between 60 and 70,000 US Dollars; Switzerland (Private Farmer) contributed USD18,000. Of the New Zealand component USD 50,000 comprises research and development costs borne by S&N International Ltd, directly associated with developing this project, hopefully to be recovered through future trading / consultancy surpluses). Modifications made in New Zealand to early Oyjord plot seeders and local fabrications to which Oyjord cell wheels and distributors were fitted, provided the group with a working example as well as a proven networking model for setting up and co-ordinating what has grown into the Flexiseeder project, placed in the public domain to help end users help themselves.

Besides building new machines, the aim of this project is also to help end-users re-cycle and up-grade existing equipment in effective and affordable ways. By design, parts for the Flexiseeder including the new deep-walled cell wheels, distributor components, electric drives, digital gearboxes and coulters also serve as spare parts and/or upgrades for early Oyjord seeders, to help extend their working lives. In so doing, the Flexiseeder project fully acknowledges and pays sincere tribute to the application and longevity of these older technologies originally conceived and developed almost 50 years ago by Professor Oyjord and his team. At the same time, full acknowledgement is given to early designers, engineers and manufacturers of robust seed drills and other agricultural equipment in New Zealand, Australia and Scandinavia, dating back more than 100 years. An invaluable legacy of concepts and experience has been given to modern agriculture which is still applicable, when re-interpreted and up-dated. This work is backed up with six technical papers listed in the References, also presented as posters at IAMFE 2008 and included in the proceedings.

Background
When early Oyjord plot drills were converted and other similar drills fabricated locally during the 70s and 80s, a range of interchangeable “knock on” tips were often used (Plate 5). These tips were developed in Australia during the same era for commercial agriculture. They are still available and used today. Depending on the tips used on the day of sowing, arable drills / plot seeders, besides serving for traditional cultivation, became suited to light reduced tillage and zero-tillage for grass, clover and/or brassica. Disc (Conner Shea and Duncan) and 12mm S tyne coulters fitted with (Australian) knock on tips (Duncan Till Seeder) were also used on these early seeders. In other instances, Oyjord cell wheels were mounted directly behind the regular tool boxes on small-scale farmer drills (Plate 6). This type of overlap in equipment (modules) and logic facilitated researchers and farmers moving backward and forward between reduced tillage, light direct drilling and traditional cultivation in plot seeding and farmers fields much earlier than in other countries. This meant that research results often tended to be more directly applicable to farmer fields than elsewhere at the time, and resulting...
farmer up-take of technologies was considered more rapid than otherwise expected.

Out of this experience grew the expectation by New Zealand researchers and farmers that farmer arable plot and seed drill technologies should be equally suited to (light) zero tillage and reduced tillage. As the demand for zero tillage has grown (especially over the past five to 10 years), this historical order of seeding priority has reversed, creating a substantial market demand for robust intermediate technology direct drills also able to be used for reduced tillage and cultivated ground. Meeting this change in demand has been pivotal in developing a vibrant multi-purpose direct seed drill design and manufacturing industry in New Zealand targeting 50 to 120 HP tractors (described and reviewed by Stevens et al. 2000 and 2004), selling into local and foreign markets. By the year 2000, these technologies were reported to already be in use in more than 25 countries including developed and developing economies.

By 2004 small-scale production models of these new generation New Zealand-based “eco / direct” drills had started to enter the research arena at home and abroad (Plate 7), as farmer models retro-fitted with specialized plot seeding equipment. (Following in reverse, the much earlier cycle of development triggered by the original Oyjord plot seeders reaching NZ through the IAMFE network and being modified, subsequently to suit local conditions). Experience and results gained from designing and using these initial prototype conversions was promising; highlighting the need for, and potential advantages of, formally developing a modular research-based approach to help improve the correlation and cross over of drill components as well as results between research and production. This prompted an intensive cycle of research and development over the past three and a half years under the IAMFE / IAU Seed and Seed Drilling Technology Group covering equipment for research, extension, demonstration and commercial use. Besides general production, this also includes early generation seed and variety maintenance, evaluation and demonstration in agriculture, horticulture and viticulture, and recreation and wildlife management.

Materials and methods
Design criteria applicable to multi-purpose plot seeders and other equipment for field experiments have been outlined by Leuchovius et al 2008 (additional details of selected components have been given by Fraser et al. 2008). While developing and testing protocols, it was noted that:

- New Zealand has many “overlapping” seed drill-
Results
Development of the Flexiseeder Project -
Time line in brief
Year 2000
- The international potential of NZ direct drilling
technologies suited equally to reduced tillage and
traditional cultivation was reviewed and reported
at the IAMFE, UK Congress (Stevens et al., 2000)
(As an invited paper). In this article, particular
mention was made of (i) locally developed tech-
nologies being used in more than 25 countries,
including both developed and developing econo-
 mies and of (ii) drills fitted with “laid back” 12
mm S tynes, with substantial under-exploited
global potential. (Including, in developed and de-
veloping economies, hard soil not easily pene-
trated by existing seed drills, especially dry land
ecologies where crop residue is either grazed or
harvested. For these situations there is only lim-
ited simple / light weight / affordable technology available).

- IAMFE Seed and Seed Drilling Technology Help
Group conceptualized at IAMFE 2000, including
provision for developing an agronomy / plant
breeding (end-user) group, (Open to end users
of mechanized equipment for field experiments –
aronomists and plant breeders, for example. See
Plate 2, fodder oats being sown for Keith Arm-
strong’s project using Oyjord plot seeder, autumn
2008) out of which a successful fodder oat pro-
ject subsequently emerged (K. W. Armstrong,
pers com, Oat Breeder, New Zealand Crop and
Food Research Institute Ltd; Armstrong, 2008; www.fodderoats.net).

- The under-utilized global potential of drills with
laid back 12 mm tynes was targeted and an out-
line of follow-up activities conceived, paving the
way for the following.

Years 2001-04
- September 2001: SEMEC Trust, the New Zea-
land / Australia Branch of IAMFE formed in asso-
ciation with the New Zealand Seed Technology
Institute, Lincoln University. (Institute sold into
the private sector in 2003, after which the asso-
ciation with SEMEC ended in 2004).

- January 2004: IAU Trust (Global Institute and
Agricultural University Internet Hub) formed
under IAMFE as a global operational support
umbrella for the activities of IAMFE Centre
including its Branches.

- 2001 – 04: Taege tyne drills (www.taege.com)
were targeted for assistance, fitted with 12 mm S
tynes, laid back and fixed at 48 degrees and
mounted on a rigid frame. Tynes were fitted with
knife points. At the beginning of 2001, seven ex-
perimental units were identified with farmers at a
pilot level. These units were field evaluated by
Dr Stevens within New Zealand during 2001.
Follow-up technical and other applied assistance
was then provided (2002-04) under the umbrella
of SEMEC to help refine and promote the up-
graded design and use of these drills to help ex-
pand them into the local market. Approximately
300 “improved units” were manufacture and sold
by mid 2004 including both farmer and vineyard
drills (Plate 8). Of these drills, approximately 250
farmer units were sold and serviced through an
ad hoc network of farmer help groups set up and
co-ordinated by Stevens under SEMEC. Agron-
omy as well as drill support was provided. Pro-
gress was reported at IAMFE St Petersburg Con-
gress (Stevens et al., 2004).

- June 2004: SLU (Swedish University of Agri-
cultural Sciences) received (at the time of
IAMFE 2004), a Taege multi-purpose vineyard
tyne drill frame (shown in Plate 7). The frame
was fitted with 12 mm S tynes and knife points. It
was purchased from New Zealand and imported
into Sweden for conversion into a plot seeder,
by retro-fitting an Oyjord Cell wheel plus dis-
 tributor, and a local fertilizer box brought for-
ward from an older machine. The drill was set up
to place fertilizer between and below the rows
of seed, fed from this box directly into an addi-
tional row of tynes and knife tips mounted on a
separate (additional) tool bar. This drill is now
owned by, and working for the Ag Society of
Stockholm/Uppsala. Torbjorn Leuchovius and
Carl Westberg led this activity. John Stevens
visited Uppsala after the IAMFE Conference to
help receive, assemble and demonstrate the basic
frame on this drill.

- July 2004: A working group was set up between
Sweden and New Zealand to assist with (a) con-
verting the Taege drill imported into Sweden
and, subject to a favourable outcome, (b) go on
and help identify and further develop follow-on
initiatives, including expanding the core working
group. At this time, a 1970’s “Tume” harrow
manufactured in Finland with rotating tool bars
(Plate 9) was donated to SEMEC by SLU, linked
with the request that it form the basis of a new
style of modular seed drill, suited equally for re-
search, seed industry, extension, commercial
farming, horticulture, viticulture, wild life re-
serves and recreational areas in developed and
developing economies.

- November 2004: Contact made with Mistral
(Agrofinal s.r.o. Slovakia), Agreement reached
with then for the procurement of parts as re-
quired, at OEM prices, including seed metering
and air delivery components.
Years 2005-07

2005

- Research stations and farms searched throughout New Zealand for pre-1980s agricultural equipment which had stood the test of time under rugged field conditions, as a source of proven ideas lying within the public domain, applicable to the group's concept of a "new generation" modular seeder for the global market. Key items located, included:

  - Old (late 1800s) well used horse drawn spring tyne harrows (two sets from different locations) with adjustable tool bars (Plate 10). Both had been used for many years under very rough conditions and survived, which provided useful design information for the Flexiseeder. This idea was combined with the Finnish harrow concept for the Flexiseeder rotating drawbar module.

  - Duncan offset discs with combined trailing and three-point linkage towing device, plus a variety of two-point linkage trailing ploughs, some converted from trailing models. When combined with the drag-link arms used on the Finnish tyne harrow, they provided inspiration for the Flexiseeder floating headstock – cum – drawbar module (Plate 11).

  - Numerous New Zealand 701 Duncan arable seed drills fitted with trailing coulters and interchangeable knock-on tips including hoe, knife (lucerne) and split Blackmore coulters, all sufficiently worn to prove that these technologies had been used to sow many thousands of hectares. These tip assemblies have been integrated into a Flexiseeder module including a universal SG iron bolt-on cleat and a bolt-on knife tip designed and cast by the Project (Plate 5). This cleat, besides bolting on 12mm and other tynes, can also be welded onto hoe coulters. Knife tips are faced with Tungsten encrusted weld.

  - A number of Australian Conner Shea disc drills were located in Otago and the McKenzie Basin where they had worked for more than 35 years in particularly rough / stony conditions and survived after sowing thousands of hectares of native pasture with grass, clovers and herbs. They were also a successful drill for sowing arable forage, fodder and grain crops. While the fertilizer boxes of many of these drills had rusted out, seed boxes and disc assemblies were still fully serviceable. Particular note was taken of how well their disc assemblies had lasts, and that major wear points could easily and affordably be re-built using modern materials and technologies. These disc assemblies are heavier than what has been used historically on European plot seeders and have been up-dated and brought forward to the Flexiseeder (Plate 12).

  - Many simple three- and four-way springing systems were found on early horse-drawn gigs, carts and wagons (from the late 1800s and early 1900s) which allowed the cart frame / driver seat to remain relatively level, while the shafts and the wheel worked independently, on an opposing axis. This provided inspiration for the Flexiseeder tool bar suspension model – cum – universal carrier frame for plot and farmer seeders, sprayers, etc (Plate 13).

- Finnish (Tume) harrow donated to SEMEC by SLU received in Christchurch from Sweden, transported free of cost from Europe by CB Norwood (Palmerston North, New Zealand) with the permission of Vaderstad (Sweden) who prepared and packed it free of cost after it had been delivered to their yard by Torbjorn Leuchovius. Transport to Christchurch from Palmerston North was paid by S&N International Ltd. (E.J. and S.J Stevens, Directors and major share holders).

Once in Christchurch, the harrow was circulated by John Stevens through SEMEC to a number of local engineers (including Taege Engineering Ltd) for quotations to supply (a) an up-dated head stock, including designing and fitting a floating three-point / two-point / trailing headstock; and then, based on field results (b) design and manufacture a stronger pilot seed drill frame / test bed using the combined concepts of a floating head stock and rotating tool bar. This was to be done in a way suitable for rugged New Zealand conditions while also applying globally, based on the wide international agro-ecological overlap New Zealand has. Technologies were to be equally suited to plot seeders as well as farm and other parallel uses including horticulture, viticulture, recreation and wild life management.

Collin Hubbard, Lex Jocelyn and Kerry Quartermain (Hubbards Machinery Ltd) in Ashburton agreed to design and fit the required head stock, free of cost (Plate 9, right side). These modifications were then field tested in Canterbury and the McKenzie country by John Stevens. Field results were successful and on the basis of this, a Hubbard Flexiseeder "open-plan" test bed (Plate
was designed, constructed and field tested successfully across a wide range of agro-ecologies in the South and North Island of New Zealand. This product was paid for and evaluated by S&N International Ltd with assistance from SLU. On the basis of these results, SLU ordered a unit.

2006

- [www.flexiseeder.com](http://www.flexiseeder.com) registered and put on line, hosted at SLU.
- SLU supplied with and open-plan Hubbard Flexi 110 Plot Seeder Frame which included adjustable 13 inch (metric unit required) bolt on wheel module (Plate 14). The frame was designed for 175 cm normal working width. The four wheels were set to a tracking width of approx. 220 cm, thus leaving extra row distances between plots. It normally has two axles with 7 Suffolk shoe coulters each (14 coulters, row distance 12.5 cm) and, for drilling in spring, combined with a leading axle with 7 fertilizer knife coulters. All coulters are S-tyne mounted. The seeding system is a standard Oyjord cone with mechanical distribution (electrical spinner). The fertilizer application is done by a standard bin with free fall (gravity feed) to the coulters.

- Robert Zuerrer (Switzerland) ordered a 2.4m wide open plan Hubbard Farmer Flexi frame fitted with Thian seed box (www.thianagri.co.nz). The frame was started by Hubbard using a scaled-up version of the one supplied to Sweden, but not completed because meanwhile, the business had been sold and Colin Hubbard retired due to ill health. After completing the Flexi 110 Plot seeder for Sweden, the new owners (Hubbard Machinery (2005) Ltd) decided not to continue the line. The incomplete frame was therefore purchased by S&N International Ltd and moved to Thian Agricultural Industries (Southbridge) while the New Zealand part of the Flexiseeder project re-grouped.

- Drill components including the Thian Seed Box were drawn up in CAD by Chris Roberts as a basis for continuing the project once a suitable engineering base could be re-established. This was commissioned by S&N.
- Norway (Apelsvoll forskingssenter) joined the group and ordered a complete plot seeder, against very tight design restrictions of 150 plot widths and to which two Kincaid cones from USA and a Smallaire seed delivery system from Australia, and a Thian Fertilizer box was to be fitted. Once delivered, the Kincaid cones were found to be incapable of dispensing the required range and volume of product, and therefore returned to New Zealand. Up-dated S&N Oyjord deep-lamellae cell wheels were developed and supplied as replacements – see comments under remainder of 2007 and 2008.

- A local foundry (The Casting Shop) and a pattern maker (Collins Patterns) were identified and included in the working group. Patterns and castings made for Flexiseeder tip assemblies and tyne holders (Plate 15) were commissioned by S&N.

- Manufacture of SEMEC rubber tyre rollers (Plate 16, [www.rollers.co.nz](http://www.rollers.co.nz)) started under S&N in support of the Flexiseeder Project. Rollers were designed and manufactured by Geoff Gray Limited of Christchurch in association with S&N International Ltd.

2007

- A proto-type of the tool-bar carrier developed and field evaluated (Plate 13, centre, upper portion).

- A prototype of the “S&N Flexi Plot Seeder – Heavy Duty” was completed (Plate 17), exported to and evaluated by Norway. The frame unit was designed (using CAD) and manufactured jointly by Chris Roberts (Southbridge), Geoff Gray (Christchurch) and S&N International Ltd. Imported components included two Kincaid Cell wheels, Smallaire air delivery system, Zero Max Y2 gear boxes and Kongskilde tyne. Locally manufactured components that were outsourced included the Thian fertilizer box (www.thianagri.co.nz and www.flexiseeder.com). Follow-up work on this machine, explained in detail by Leuchovius et al. (2008) included:
  - Kincaid cones replaced with an up-dated S&N Oyjord-type cell wheel cast with 23mm high lamellae.
  - Manometer fitted to Smallaire distribution system to quantify fan settings.
  - Distributor modified to prevent carry-over residual remaining within head.
  - Plastic cone machined and fitted into top of the air distributor head to reduce variation between outlets.
  - Three-point linkage mounts cut, shortened and re-welded to meet European standards.
  - Operator foot rests lowered to allow for “long Norwegian legs”.

- Manufacture and assembly of drills (excluding Thian Seed Boxes) was consolidated at Geoff Gray Ltd, to which was added the 3/4 time applied input of John Stevens covering both seed drills and SEMEC rollers.
- A Farmall Flexi plot seeder conversion was designed and manufactured for Plant Research New Zealand. This product was paid for and evaluated.
Zealand Ltd (Plate 4), including modifying and direct coupling a 12 volt car dynamo as the motor driving directly, a reverse image of an Oyjord -type distributor impellor, to allow for clockwise rather than counter clockwise revolution of the motor (see Leuchovius et al., 2008).

- A heavy duty Flexiseeder natural rubber seed hose was designed and manufacture as a special order / feature (Plate 15, lower right fitted to Farmall, and Plate 18, fitted to Swiss drill).

- Tyne mounts, tips and seed coulters were standardized through patterns and casting in SG iron including bolt-on knife and Suffolk shoe plus knock-on knife tips and multi-purpose locking cleat assemblies. Samples were sent to Norway and Sweden for evaluation on 12 mm tyne.

- A prototype of the S&N “open-plan” Farmer Flexiseeder (Plate 18) was developed, field tested and shipped to Switzerland (early 2008), including a carrier frame with spring mounts for the tool bar assembly plus an up-graded head stock compliant with European Standards. This was achieved in a way that would apply directly to open-plan plot drills as part of the Flexiseeder modular approach for improved correlation and cross over of components and planting results with research plot as well as other seeders.

### 2008 (Up to June)

Developments described in detail by Leuchovius et al. (2008) and Fraser et al. (2008).

- S&N deep lamellae Oyjord cell wheels (400 and 320 mm diameter) designed, patterns and core boxes commissioned, products cast in bronze, machined and supplied to Sweden (The aim of the MacTrac project has been to make a drill module for this tool carrier. It is a co-project between the Applied Field Research group at the Swedish University of Agricultural Sciences (SLU) / Mapro Systems AB (producer of MacTrac) and the Agricultural Sociey of Halland (user of the drill)). The main part of the component costs are paid by the end user while SLU and Mapro have taken development costs. Components provided by S&N were supplied at cost, and excluded research and development / pattern costs) and Norway respectively, with extended lamellae (23mm high), requiring new pattern making and casting techniques.

- Identified and tested ultra high density plastic bases for cell wheels, as a low friction alternative to bronze base.

- Designed and engineered reversible, bolt-on land wheel module (supplied to Sweden) able to be used either to manually drive cell wheels and/or the encoder for electric drives.

- Identified and tested affordable 7.5 to 1 and 15 to 1 reduction right angle drive worm driven gearboxes as an alternative to bevel gears for transferring power to a range of cell wheels and other mechanisms on plot and farmer equipment.

- Developed and pre-tested a digitally controlled stepper motor combination for powering cell wheels.

- Developed and pre-tested a permanently magnetized 12v motor and manual variator combination for driving Oyjord and other distributors.

- Modified and pre-tested an arable disc-coulter module heavier than European options using 12 mm S tyne to supply down pressure, to be used also for light direct drilling as well as arable seeding.

- Designed, commissioned patterns and cast ratchet self locking system for locating tool bars in various positions on the main frame and for moving internal support bars to give added flexibility of row and tyne spacing.

- Patterns commissioned, and replacement distributor impellors cast in brass and aluminium for Oyjord and other planters. Samples sent to Sweden / Norway for evaluation.

Other achievements included:

- A Swiss Farmer Flexiseeder (Plate 18), completed field tested at multiple locations in the South and North Islands of New Zealand and on the basis of results, was released into the New Zealand market, after which it was dismantled, thoroughly cleaned to meet phytosanitary requirements, and shipped to Switzerland as an ex-demonstration machine. John Stevens will go to Switzerland after IAMFE 2008 to re-assemble this drill, then demonstrate and provide training for its operation.

- An improved bolt-on Flexiseeder Nihard knife shoe was designed, and patterns were commissioned and cast for field testing, as a cheaper alternative to the Flexiseeder knock-on knife tip (Plate 5, left).

### Discussion and conclusions

Perceived advantages of these technologies over those already available include:

- A wide range of components have been developed which are suitable for being integrated into plot machine modules

- The Taeger drill design was more compact while the Flexi approach proved more useful.

- The overall goal of identifying farm machine components that can be used on plot machines will reduce costs and facilitate maintenance.
The module concept means that elements can be replaced by alternative components and still work together with other modules.

Air distribution allows for much more flexibility in designing drills/fertilizers for tractors and various tool carriers. It is convenient not to be dependent on free fall of material during operation.

A universal, stand-alone, driveline system for mechanical or step-motor drive of plot machines gives considerable freedom to use and to adopt plot machines for new demands like GPS monitor/control systems.

The flexi drill frame with depth and tool bar axle angle setting provides a flexible base for using different seeding/fertilizing technologies as well as different row spacing and/or tool-bar separation and configuration when used in conjunction with the S&N Flexi tooth-lock system.

The step-motor driveline can be further developed for use for spraying and for linear changed rates along the plot of seeds, fertilizers or liquids/chemicals.

Global networks for out-of-season plant breeding and the seed trade can be usefully paralleled by seed drill development projects, particularly where conscious use is also made of agro-ecological overlap at the same time. Within this context, New Zealand can play a significant role in helping to develop and supply original technologies to the northern hemisphere, as well as back-up engineering and fabrication support.

Without the internet, it would not have been possible to set up, organize and run the Flexiseeder Project. Further development of engineering, evaluation, application and promotional aspects of this project will depend heavily on the concurrent development of internet support.

By placing Flexiseeder technologies in the public domain for all to use, backed up with the three inaugural papers presented at this international conference, the authors conclude that a useful catalyst has been provided allowing those wishing to apply these principles, to go forward under IAMFE / IAU and mobilize the necessary funding required to realise their goals. This covers both the developing and developed world, to help continue the good will started so many years ago by Prof Oyjord and his team. We wish people well in their endeavours and stand ready to help them where needed, to the extent possible within our limited resources.
List of Plates

Plate 1. One of the first five Oyjord-Schou plot seeders imported into New Zealand during the mid 1970s – owned by Crop and Food Research Institute, which is still operational and being used as a test bed for the Flexiseeder project.

Plate 2. Later model Oyjord - Wintersteiger plot seeder typically strengthened and fitted with locally manufactured Duncan coulter assemblies suited to local conditions; now needing to be up-graded to meet current needs for zero tillage and reduced tillage, while still being suitable for cultivated ground. Shown here, seeding fodder oat trials for Keith Armstrong (Crop and Food Research Institute, Lincoln, New Zealand) - Autumn, 2008.

Plate 3. Locally manufactured “Oyjord plot seeder” typical of those fabricated during the 1970s and early 80s in New Zealand using locally manufactured farm seed drill components and fitted with Oyjord cell wheels and distributors. Here, Duncan coulter assemblies and fertilizer box have been fitted. Note the hoe-type knock on tips from Australia, still used today and easily interchanged with knock on knife tips used for reduced tillage and light zero tillage.
Plate 4. Before and after, left to right - an early Farmall tractor fitted with locally fabricated mid mounted plot seeder; originally fitted with Suffolk shoes (left), successfully up-graded for Plant Research New Zealand Ltd by Geoff Gray Ltd to include the multi-purpose S&N Flexiseeder S Tyne parallel lift and rotating frame and tool bar assembly which is equally capable of seeding zero tillage, reduced tillage and cultivated ground. This conversion cost a fraction of the amount required to replace the whole machine. Previously, this machine was only suitable for planting well prepared arable land.

Plate 5. (i) Right to left, four knock-on tips developed in Australia during the 1970s, still available commercially (www.agpoint.com.au) and in use. (ii) First two tips on the right are heavy-duty Flexiseeder bolt-on tips then a heavy-duty knock on Flexiseeder knife tip, both cast either in Nihard or SG iron with hard surfacing, plus (iii) two models of cast Flexiseeder universal attachment cleats which either bolt onto spring tynes or, can be welded to other tube and hoe coulters. All points are interchangeable using the Flexiseeder cleat.

Plate 6. Early (1970s) models of New Zealand and Australian farmer seed drills from which technologies have been sourced successfully for plot seeders still in use and subsequently included as a up-graded Flexiseeder multi-purpose coulter modules. Left to right, Conner Shea disc drill, Duncan arable seed drill with hoe coulters, Duncan Till Seeder multipurpose tyne drill.
Plate 7. By 2004 small-scale production models of a new generation of New Zealand-based “eco / direct” drills built for vineyards had started to enter the research arena at home (left – Crop and Food Research Institute) and abroad (right – SLU / Ag Society Stockholm, Sweden), as “farmer” models retro-fitted with specialized plot seeding equipment.

Plate 8. Approximately 300 “improved” Taige multipurpose farmer drills were manufactured and sold by mid 2004. Of these drills, approximately 250 units were sold and serviced through farmer help groups set up and co-ordinated by Stevens, under SEMEC.

Plate 9. 1970s era Tume harrow donated to SEMEC in 2004 by SLU as an initial test bed for developing a new generation multi-purpose Flexiseeder. Floating headstock shown on the right was fabricated and attached in New Zealand.
Plate 10. Late 1800s well used horse drawn spring tyne harrow with adjustable tool bars.

Plate 11. Left to right, Duncan “three in one” headstock, two-point linkage plough conversions and floating linkage arms on Tume harrow all contributed to the Flexiseeder multi-purpose headstock module shown on right.

Plate 12. Conner Shea disc assemblies are heavier than those used historically on European plot seeders and have been up-dated and brought forward to the Flexiseeder.
Plate 13. Left to right - simple three- and four-way springing systems on early horse-drawn gigs, allowed the gig base and driver seat to remain relatively level, while the shafts and the wheel worked independently, on opposing axis. This helped provide inspiration for the Flexiseeder tool bar carrier and suspension module shown above, fitted with knife points and rotating 12mm S tynes working at full depth 90 mm in ground that has never been cultivated before. Insert shows cultivation marks at 25mm sowing depth, with reduced disturbance. Achieving good penetration is not a problem!

Plate 14. SLU supplied with open-plan Hubbard Flexi 110 Plot Seeder Frame shown on left, mounted below the SLU tool carrier machine and to the right, set up as a three-point-linkage plot seeder.
Plate 15. First consignment of an on-going series of patterns and castings commissioned for Flexiseeder modules, commissioned by S&N. Upper right, Suffolk shoe option with leading knock-on tip. Lower, single and double hose and knock-on knife tip options. Note heavy natural rubber Flexi seed hose on lower right assembly.

Plate 16. Manufacture of SEMEC rubber tyre rollers started under S&N in support of the Flexiseeder project.
Plate 17. A prototype of “S&N Flexi Plot Seeder – Heavy Duty Model” was completed and exported to Norway for evaluation.

Plate 18. Prototype of S&N “open-plan” Farmer Flexiseeder (fitted with Thian seed box) developed, field tested and shipped to Switzerland.
References


Presentation of Haldrup trial machinery

Summary

J. Haldrup a/s has been producing plot harvesters since 1973, the year when the first Grass harvester was built. Now our program consists of Plot Combine Harvesters, Grass Harvester, Swath Mower, Self-propelled Maize Harvester, Mounted Harvesters and Tool Carriers.

Haldrup Plot Combine Harvester

The first Haldrup combine was built in 1985, since then the combine has gone through a major development phase and the program has been expanded to include a wider range of types.

All Haldrup Combine Harvesters are very strong machines incorporating feeding systems the same as a commercial combine. They are constructed according to the latest designs in order to obtain maximum capacity. These machines have a very limited numbers of belts, chains and lubrication points, so that lubrication, belt and chain tightening only have to be done once a year.

Our combine program exists nowadays of:

- 3-Strawwalker Combine Haldrup 640 (640 is the inside width)
- 4-Strawwalker Combine Haldrup 850 & 850 STOR
- 2 x 3-Strawwalker Haldrup TWIN Shaker
- Rotor Combine Haldrup SINGLE Rotor & TWIN Rotor

The Combine program is divided between traditional Harvesters and Rotor Harvesters.

Traditional Harvesters

The threshing procedure of our traditional harvesters: 640, 850 and TWIN Shaker is as follows:

- Our combines can be equipped with a 1.210, 1.510, 1.740, 2.045, 2.350 mm hydraulically operated head / platform, with provision for quick coupling and reversing rotation.
- A variable distance of between 500 or 900 mm is offered between fingers and feeder housing.
- A continuous supply of air for cleaning comes from a high-pressure blower. The air comes out
directly behind the fingers, from both sides of the cutting table and at the entrance of the

- Head / platform flotation is achieved with the assistance of a 0.75 l hydraulic accumulator responding to ground pressure from the cutting table, set at approximately 50 kg.
- Continuously variable adjustment of stubble height is provided from 50 - 500 mm by electro hydraulically raising / lowering of the head / platform through a master control lever.
- The platform is mounted with a cutter bar, plus two straw dividers and ear lifters at every third finger, plus a straw guide at the right side. (One spare knife is supplied in the knife-box.)
- The reel is operated hydraulically with provision for continuously variable speed adjustment from 0 - 40 rpm. The distance between fingers is 150 mm. Reel height (raising and lowering) is controlled electro hydraulically through a master control lever.

**Threshing drum**
- The threshing drum has a diameter of 450 mm for our Haldrup 640 and a width of 850 mm for our Haldrup 850 & 850 STOR, both with six rasp bars.
- The belt pulley allows threshing at 900 - 1,500 rpm, or 300 – 800 rpm while using an extra pulley and belt.
- Drum speed is regulated hydraulically from the driver’s seat.
- The concave area is 0.3 m² for the Haldrup 640 and 0.40 m² for the 850 with eleven concave bars. Three de-awning bars are included, also. The wire diameter is 11 mm and the concave wrap has a graduation of 90˚.
- The concave can easily be removed from the right side without use of any tools.
- The bottom blower is powered through a belt pulley, which is can be regulated from the drivers seat, to operate between 300 and 1,100 rpm.

**Sieve Box**
- The sieve box is fitted with an adjustable chaffer and bottom sieve. The opposed reciprocating action of the chaffer relative to the bottom sieve provides a thorough cleaning of the sieve and thus makes the combine completely free of vibrations. This ensures maximum accuracy of the weighing results. The total area of the sieve box is 1.92 m².

**Straw Walkers**
- Three straw walkers with a total area of 1.3 m² and length of 2 m.
- Four straw walkers with a total area of 1.7 m² and length of 2 m.

**Grain Tank**
Tank capacities and special features:
- Haldrup 640 tank capacity is 900 litres.
- Haldrup 850 & 850 STOR tank capacity is 1,200 litres (possible to extend to 1,500 litres).
- Both models are fitted with hydraulic discharge auger, discharge height 3.2 m.

**TWIN Rotor Combine Harvester**
In 2005 we introduced our TWIN Rotor Combine, which is a combine based on axial flow threshing principles used in commercial machines.

Our TWIN Rotor machine is used for maize and rapeseed. With our TWIN machine we harvest 2 plots at one time, which provides us with a capacity of approx. 200 plots per hour. The working procedure is as ... follows:
2 Axial threshing cylinders, with a 450 mm. diameter, length of threshing unit 500 mm. separation unit 950 mm. Variable speed from 400 – 1,500 rpm. regulated from the driver’s seat.

Threshing unit: The concave wrap has a graduation of 100° degrees.
Separation unit: The concave wrap has a graduation of 90° degrees. The wire distance is 30/40 mm.

Two sieve boxes with adjustable Agri Broker Alfa CZ/4 chaffer and round holed bottom sieve each. The opposed reciprocating action of the chaffer relative to the bottom sieve provides a thorough cleaning of the sieve and makes the combine completely free of vibrations. That insures maximum accuracy of the weighing results. The total area is 2 x 1.4 m².

The TWIN Rotor for rapeseed can be equipped with the following headers:
2 x 1.250, 2 x 1.510, 2 x 1.740 and 2 x 2.045 mm.
For the maize harvest the machine has a 2 + 2 rows Geringhoff Rota Disc 475 header. Our Single Rotor is built after the same principles as the TWIN with the difference that it has only 1 axial cylinder.

TWIN Shaker

The latest novelty is stage two of a project which started in 2005 a traditional TWIN machine, at that time the machine wasn’t totally separated. In the winter 07/08 we finished this project and now build a totally separated machine: The Haldrup TWIN Shaker.

The machine is built as follows:

2 x concave, 2 x threshing drum and straw beater, 2 x PVC conveyor, 2 x 3-Strawwalkers and 2 x Sieves and boxes. The inside of the machine is totally separated.

The harvest capacity of the TWIN Shaker is about 200 plots per hour. Measurements of the machine are: width 2.5 m. and height 3.1 m. which makes it possible to transport the machine in Europe without any special permits.

All our combines are equipped with Deutz industrial diesel motors. Our 640 has a BF4L 2011 (55kW) turbo engine, our 850 & 850 STOR can be equipped with F4L 914 (50kW) industrial diesel engine or BF4L 914 turbo engine (67kW). Our TWIN combines are mounted with a 6 cylinder Deutz engine BF6L 914 turbo diesel engine (105kW).

All machines can be equipped with four-wheel-drive, furthermore all machines have can be mounted with cabin, weighing- and moisture system, different kind of bagging systems and NIRS.
Haldrup Grass Harvester

Since 1973 Haldrup has built Grass Harvesters, since then there have been sold almost 400 units all around the world. From the first machine to the machine which is here at the IAMFE symbolises the evolution the company Haldrup as well as the changes the mechanization has gone through. From simple cutting and weighing to direct analysis on the Grass Harvester.

The machine is mounted with a 1.510 mm. header, but can be delivered with a 1.230 mm. header.

Both headers have full width and large passage to the weighing hopper so the material will not be damaged – this is a great advantage when harvesting vegetables.

Our machine is equipped with double knives from ESM which are wear resisting and cuts everything. The knives are hydraulically operated with variable speed control from 800 – 1400 rpm. Two strong springs to relive the cutting table and reduce the ground pressure to about 50 kg.

The Grass Harvester is mounted with a Mettler IND 425 weighing system: Mettler IND 425 weighing display, rust, dust and waterproof according to IP65, RS232 data output. 1.200 litres weighing hopper on 4 bending weighing cells, of each 220 kg, which gives a capacity of 880 kg. Discharge to both sides and wind shields at each side to minimize the influence of wind on the weighing results.

There’s mounted a Lombardini 2204/T 2.2 litres turbo diesel engine, 42kW/2,600 rpm, at the back of the machine. Hydrostatic 4WD transmission with POCLAIN MSE03 and OMR200 steering motors. Optional there can be mounted a differential lock.

The Haldrup Grass Harvester can be mounted with cabin and NIRS for direct analysis of the harvested material. At present there has been built almost 400 Haldrup Grass Harvesters. The machine can also be adapted for the harvest of herbs.

Large crop dividers for separation of plots.

The reel is hydraulically driven with variable speed control 0-50 rpm. Reel diameter 1.000 mm. with 5 reel bars and 2 brushes for cleaning the knives. Lift above the fingers 0-400 mm.

Rotating brush to gather the material at one side to increase sample quantity. Especially an advantage when the crops aren’t so high.

Two different sizes of chopper: 140 or 270 mm. The chopper is delivered with hydraulically driven auger, and conveyor for transporting the sample to the platform. The quantity is regulated by the foot switch.
The first Swath Mower was produced in 1984, it is a user friendly machine with a small turning radius and large capacity, available with a 1.500, 1.750 and 2.000 mm. header.

The machine is standard delivered with 2 strong hydraulically rotating torpedoes. Optional are 2 extra torpedo’s in front and 2 under the machine. This guarantees an efficient separation of the plots, even with the most vigorous crops. The torpedoes have continuously variable speed control from 0-50 rpm.

Just by removing 4 screws the knife is dismounted and the machine can be used for separation or as a tool carrier.

Like on the Grass Harvester we have mounted a Lombardini engine on the Swath Mower, here we use a 2204 2.2 litres diesel engine, which gives 30kW/2600 rpm. Also here there can be mounted a 4 wheel-drive.

Haldrup is also producing Maize Harvester, both self-propelled and lift-mounted. Both machines are delivered with a Kemper Champion 1200 row independent chopper.

The self-propelled tractor unit with platform for driver and assistant, is powered by a Deutz BF4L 914 turbo diesel engine, 67kW, and 2-speed PO-CLAIN wheel hub motor. A front lift is fitted with category II linkage, capacity 3.100 kg.

A hydraulically, rotary sampler with variable speed control from 0-60 rpm, which takes one sample per second at 60 rpm. A 600 Litres weighing hopper with 3 bending weighing cells, capacity 660 kg. A Mettler IND 425 weighing display, rust- dust and waterproof, according IP65. A very powerful blower with feeding auger. The blowing time for 100 kg silage is about 10 seconds and the casting length up to 6 m. Revolutions PTO 1.000 rpm. Power consumption during blowing approx. 50kW and during harvest 2-3kW.

The tractor unit can be used as a tool-carrier, outside the harvest season.
Our lift-mounted unit has the same rotary sampler and weighing hopper as the self-propelled, but the in stead of the tractor unit an ordinary tractor is used, minimum demand is 100 hp.

Advantage is a lower investment, taking less space in the machine hall. Most research stations already have a tractor, which can be used for this purpose, so you’re only investing in a new sampling unit and a chopper.

The unit can delivered with wind-shield for the assistant, hydraulic unit on the sampler, so you’re not dependent on the hydraulics of the tractor.

The same sampling unit can also be adapted so it fits on a Unimog or Fendt Xylon.

**Haldrup Tool Carrier**

- Free height 800 – 1.200 mm.
- Chassis from high-strength steel
- Power transmission through chains
- Track width 2.200 – 3.500 mm.

**NIRS**

In 1998 Haldrup started a project together with the University of Braunschweig, Dr. Chr. Paul and Carl Zeiss Jena. The objective of the project was to make a direct analysis of the harvested material on the Haldrup Grass Harvester through Near Infra Red Spectroscopy. This was possible with the CORONA 45, which is adapted to operate on Combines etc. There has been produced a lot of prototypes, but now we can say that we have a system that works both for grass, grain and silage.

For grasses we work with a piston module, where the chopped grass is pressed in front of a windows, the CORONA is measuring through the window in a pendulous movement to increase the measuring area.

For grain the method is as follows the CORONA hangs over a conveyer which transports the grain from the pre hopper to the weighing bucket.

The adjustment of existing tractors, both new and used ones, to Tool Carriers is something Haldrup has done since 1998.
Silage maize is measured in the flow from the chopper to the rotary sampler. The CORONA is placed in a drum, which is mounted on the Kemper chopper.

On all systems there’s built an external black and white reference.

The NIRS system can be delivered for our Plot Combine Harvester, Grass Harvester, Silage Maize Harvester and as stationary systems for grasses and grain as well.
Weighing Systems and Field Research Software - Possibilities and Deployment

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Summary
Mobile weighing systems on plot combines are becoming more and more important. WINTERSTEIGER offers reliable and easy to use weighing systems together with a field PC (portable computer) and the appropriate software.

Article
WINTERSTEIGER offers amongst others, plot combines that fulfil all requirements for fast, 100% mix free harvesting, variety trials and seed increases. Mobile weighing systems on plot combines are becoming increasingly important, as they allow the collection of accurate and high quality data immediately after harvesting.

Automated collection of harvesting data covers the following parameters:
- Plot weight with maximum accuracy, up to a slope of 10%
- Moisture content of harvested crop
- Test weight

WINTERSTEIGER places great emphasis on developing and providing future-oriented solutions in the field of mobile data acquisition. Only state of the art systems are used in our harvesting machines, which have been specifically developed for agriculture research equipment. The system records the plot weight, percentage of grain moisture and test weight. The data collected is saved in the electronic field PC and printed out simultaneously on the field printer.

Data acquisition is carried out using an integrated weighing system. The measuring sensors determine the plot weight, test weight and moisture content. The built-in slope equalizer ensures maximum possible accuracy. The heart of the harvesting data acquisition system is a Windows compatible, hand-held PC. The harvesting data is stored and printed out simultaneously.

The following types of weighing systems manufactured by WINTERSTEIGER are commonly used:
- Harvest Master weighing system High Capacity Graingage
- Harvest Master weighing system

Weighing system “High Capacity Graingage”
Features:
- Single weigh bucket with two holding hoppers
- FRS (define) Harvest Software
- Grain level detection devices for strip harvest

Advantages:
- HM800 electronics with CAN eliminate bulky cables
- Highly accurate, repeatable measurement of moisture and test weight
- Weight measurements are compensated for movement of combine
- Single set of calibrations increases accuracy over double bucket systems
- Harvest two plots simultaneously
- Ability to harvest strip trials without stopping the combine

Weighing system “Graingage”
Features:
- Three different sized moisture chambers available for low yield crops
- Windows Mobile based FRS Harvest software
- Grain level detection device for strip harvest

Advantages:
- HM800 electronics with CAN eliminate bulky cables
Highly accurate, repeatable measurement of moisture and test weight
Weight measurement compensated for movement of combine
Ability to collect moisture and test weight on samples as small as 900 grams
Harvest strip trials or normal length plots without stopping the combine.

Field PC “Allegro”
The field PC Allegro has the following features:
- Full Color – TFT, Active Matrix
- MQ1178 Video Graphics accelerator for increased performance
- High screen contrast in all lighting conditions
- 320 * 240 pixel resolution
- Backlight to screen and key pad (please confirm)
- 128 MB RAM / 512 MB
- Bluetooth
- WIN CE

The Allegro can be connected to the Allegro PC as follows:
- Docking station: works with USB
- Serial interface

In connection with the weighing systems, WINTERSTEIGER uses the new Field Research Software (FRS) on the Allegro. The software has the following options:
- Field map Import / Export Agrobase, ARM (define) etc.
- Field map with traits to collect data.
- Export of Data as csv file
- Touch Screen or function key to select the activity
- Display 2D field map with collected and empty plots
- Windows CE based Application, Win XP as next step
- Database with interface to exchange data
- Available languages (German, English, French, Spanish, Italian).
If you have any further question, please contact our company:
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Development of Combined Peanut Planter

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Abstract
According to the requirements of the cultivation pattern and agricultural techniques for planting peanut in the north area of China, a new combined peanut planter has been developed. It consists of plastic-film-cover, spraying herbicide system, applying seed and fertilizer and building a soil ridge on the film right above the seed row etc. The key parameters of the planter were analyzed. Performance test results in the fields show that working performance of the sample machine is excellent and can increase the peanut yield about 20%, labor productivity increased by 30 times and cost of production was reduced by 50%.

1. Introduction
In North of China, there are two main methods of peanut cultivation, interplanting and summer sowing after the winter wheat is harvested. In the lower altitude areas where the effective accumulated temperature between post-wheat-harvesting and before the latest harvesting time of peanut is enough for the growth of peanut, post-wheat-harvest sowing (also called direct seeding) is applied. In this case, the techniques are not difficult and the mechanization can be easily applied. In the higher altitude areas, however, interplanting or planting peanut between wheat rows must be used. It is usually used as a way to fill the gaps between seedlings. Nevertheless, interplanting cannot be done easily using machines. The plastic-film-covered cultivation of summer sown peanut is beneficial in that it can increase the temperature, protect soil moisture and keep a good physical and chemical condition of the soil. According to the requirements of the agricultural techniques a new combined peanut planter was developed and experiment were conducted in the fields using the sample machine.

2. Operation items
The combined machine has to complete many operations simultaneously to meet the agricultural technique requirements. The structure of the combined machine is shown in Fig1. The operation items include the following:
1. Leveling and compacting soil
2. Furrowing
3. Fill water in the furrows
4. Place seed
5. Covering soil to enhance seed/soil contact
6. Spraying pesticide
7. Laying plastic film
8. Covering soil on the film right above the seed row.

3. Planter design
3.1 Frame
The frame was designed with tubular steel elements that resisted the horizontal, vertical and torsional forces imparted on them by openers. The hitch points were designed according to the standard 3-point hitches of matched tractor. The levering soil roller was fixed on the front of the frame. The device of laying plastic film and spreading soil device were fixed on the rear of the frame. The frame consists of two-section and the rear part can be winged up convenience for transport.
3.2 Leveling and compacting soil

Before sowing and laying plastic film, soil should be leveled and compacted. A roller was fixed in the front of the machine. The width of the roller is as same as that of covered plastic film \((B = 48\text{ cm})\). It can break small soil block and level plot. At the same time it drives the seeds metering device. It can support the machine and control the depth of the soil interacting tools. In order to run freely the diameter of the roller should be subjected to below equation

\[
R \geq \frac{\omega_r + \omega_p}{Q \times f}
\]

where
- \(\omega_r\) - the friction moment of the roller bearing \((\text{N.m})\)
- \(\omega_p\) - the resistance moment of driving the metering device \((\text{N.m})\)
- \(Q\) - the weight of roller \((\text{N})\)
- \(f\) - the friction coefficient of the roller and soil

The test results are \(\omega_r + \omega_p = 3.34, Q = 254\text{ N}, f = 0.2\). \(R \geq 0.07\text{ mm}\)

Considering the whole construction, \(R\) is 0.17m

3.4 Spraying system

The spraying system of the combined machine consists of herbicide box, assembly of nozzle etc. After sowing seed and before laying plastic film it is necessary to spread herbicide on the plot. The electronic controlled super-little spreading device was fixed in the middle of the machine and the herbicide box was mounted on the tractor. The switch is controlled by tractor driver. (If using herbicide coated film the spreading device can be removed.) The volume ratio of herbicide and water can be calculated by below equation.

\[
r = \frac{BVL}{1000Q}
\]

Where
- \(r\) - the volume ratio of herbicide and water
- \(B\) - the operational width \((\text{m})\)
- \(V\) - the working speed \((\text{m/s})\)
- \(L\) - the amount of spraying herbicide arranged \((\text{liter/hm}^2)\)
- \(Q\) - the spray nozzle flux \((\text{liter/h})\)
3.5 Laying plastic film and spreading soil device
The device of laying plastic film is consisted of plastic film dispenser, disc digger and film pressing wheel etc. In spreading the soil on the plastic film, it is necessary to spread the loose soil dense enough to prevent light but thick enough to enable the plumule to prick through the film without pushing it up. A soil transmitting basket is used in spreading the loose soil on the top of the plastic film for a more reliable.

3.6 Specifications of the sample machine
The sample machine is operated by 9~11 kW tractor. The specifications of the planter include the following
(1). Dimensions: 1880×960×730 mm
(2). Application of water from tank: 900~1800 l/ha
(3). Gross weight: 108 kg
(4). Volume of water tank: 105 l
(5). Operating speed: 3~5 km/h
(6). Capacity: 0.2~0.3 hm²/h
(7). Narrow spacing between rows: 28 cm
(8). Wide spacing between rows: 48~50 cm

4. Field experiment
4.1 The planting quality
Working performance of the sample machine was tested in the fields. The results of test in the experimental field were shown in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test plots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of soil ridge on the plastic film/mm</td>
<td>52 53 46 53 65 55 60 52 60 50 55</td>
</tr>
<tr>
<td>Depth of planting/mm</td>
<td>42 42 60 49 40 52 49 38 41 63 47.6</td>
</tr>
<tr>
<td>Offset/mm</td>
<td>15 12 5 4 3 12 7 6 10 5 8</td>
</tr>
<tr>
<td>Row spacing/mm</td>
<td>280 280 280 280 280 280 280 280 280 280 280</td>
</tr>
<tr>
<td>Width of covering plastic film/mm</td>
<td>485 480 480 470 480 470 482 485 480 470 478</td>
</tr>
</tbody>
</table>

Table 1. The planting quality.

<table>
<thead>
<tr>
<th>Planting ways</th>
<th>pod yield/kg/hm²</th>
<th>main stem height/mm</th>
<th>side stem length/mm</th>
<th>all stems /number/plant</th>
<th>double seed ratio/%</th>
<th>The number of seeds per kilogram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine planting</td>
<td>4363.5</td>
<td>266</td>
<td>345</td>
<td>10.7</td>
<td>64.9</td>
<td>844.0</td>
</tr>
<tr>
<td>Manual planting</td>
<td>4420.5</td>
<td>256</td>
<td>339</td>
<td>10.5</td>
<td>58.4</td>
<td>890.9</td>
</tr>
</tbody>
</table>

Table 2. Pod yield and plant growth.

4.1 Pod yield and plant growth
The pod yield and plant growth were tested in the experimental fields and it was compared with manual planting at the same fields. The test results were shown in Table 2.

5. Conclusion and recommendation
1. The new planting peanut technology can increase the peanut yield about 20% and save the seed used approximately 25% than traditional planting methods. It is necessary to develop the new technology by the machines because it is a very complex one. The combined machine developed according to the requirements of the new planting technology can accomplish all the working procedure. Satisfactory results have obtained through a lot of field experiments.
2. Single-seed sowing is applied with 225000~255000 plants per hectare. Then covered with plastic film and a ridge is built above the line of sowing row. The ridge is 50~60 mm high. It is necessary to spread the loose soil dense enough to prevent light but think enough to enable the plumule to prick through the film without pushing it up. Field experiment results showed that labor productivity increased by 30 times and cost of production was reduced by 50%.
3. When the moisture content of the upper 100 mm of the soil is less than 10 percent, the rate of water use during planting should be about 2600 l/ha for a regular growth, hence increasing yield of the crop.

4. The plastic-film-covered cultivation of sown peanut is beneficial in that it can increase the temperature, protect soil moisture and keep a good physical and chemical condition of the soil.

5. Peanut planter is a key implement for the mechanized sowing peanut. To achieve the reliable planter, considerable further mechanical research is required.

References


Flexiseeder air assisted delivery and distribution module: An overview including technical specifications

Authors: Flexi Technical Note - 003

Summary
Air assisted delivery and distribution systems are more versatile for integration into plot seeders than gravity feed and mechanical distribution and delivery systems. This applies to a wide range of particulates when open-plan coulter layouts are used to improve residue passage during zero tillage and reduced tillage as well as for close row spacing on cultivated ground. It is a key component for upgrading older seeders in affordable and efficient ways to the multi-purpose Flexiseeder system, without substantially re-designing and re-building the original chassis. Likewise, it applies when you wish to broadcast fertilizers or other dry, granular materials, and also for operating at wider working widths than plot trials, including commercial agricultural and other operations. Smallaire, an Australian company already supplying large scale commercial agriculture, joined the Flexiseeder Project two years ago to help develop and supply “scaled down” air delivery and distribution equipment in modular form, for small and medium-sized farm, horticulture, viticulture and plot seeders. These modules are introduced and described in this technical note, including technical specifications.

Acknowledgements
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Introduction
Air delivery and distribution systems have been used for many years on commercial agricultural seeders and broadcasters, powered either by PTO or (increasingly) hydraulic or electric motors. Historically, these units have been “broadacre” (suited to more than 3m sowing width), unaffordable for plot seeders compared with gravity / mechanical distribution, too bulky (over specified) to accommodate on compact plot seeder frames, and (the fan) too noisy for plot seeder operator safety and comfort. Originally (1970s and 80s) air distribution systems were inherently less reliable than the original Oyjord distributor / gravity feed system both in their distribution patterns and clean out. A coefficient of variation (CV) of 5% can be achieved with the best mechanical distributors and with individual fluted feeders. A CV of up to 15% can often be acceptable where row distances are moderate - up to 25 cm. In these cases, the crop is often able to compensate almost all of this variation. Such high CVs are not acceptable with narrow row spacing, and in small plots.

The design and manufacture of air delivery systems has improved substantially over the past 20 years, particularly their distributor heads. With modern well designed and manufactured equipment CVs of between 5-15% can be expected on level / flat
ground, depending on how the equipment is managed / materials sown / sowing (application) rates etc. The design of some distributor heads have been reported to be more successful than others, in respect of clean-out functions plus the evenness and repeatability of product partitioning between distributor ports. In all cases, for research work it is important to check / calibrate machines (as you would a spray rig) using the actual product being sown, while running the machine as it is going to be used (Kumar and Divaker Durairaj, 2000).

The performance of even the best equipment can vary substantially over a relatively small range of operating / operator conditions. Once a satisfactory range for operation has been determined, it is important to stay within this range, particularly where there are requirements to minimize CVs. Performance drops off very quickly as equipment is moved from flat to sloping / undulating ground and / or if it is overloaded, as with mechanical distributors of the type used on many plot seeders (Oyjord, for example).

The spatial design of traditional integrated air units made it virtually impossible to routinely set up and run dual delivery and distribution systems in parallel, as required for interfacing two determined / independent cell wheels used for metering seed and fertilizer / different particulates independently of each other. Over the past year however, by using assistance provided by Smallaire coupled with additional strategic input from Norway, Sweden and New Zealand viable solutions have been found under the Flexiseeder project which are both affordable and efficient for use on plot seeders and other small-scale equipment, reported in this technical note. This technical note is one of six listed in the attachments prepared as technical background to Leuchovius et.al. (2008) and Stevens et al. (2008) (Covering the evolution and development of modular components of the Flexiseeder project, under the IAMFE / IAU Seed and Seed Drilling Help Group formed at IAMFE 2004 in St Petersburg.).

**Background**

Smallaire P/L - air movement specialists of Horsham Australia have been designing, developing and manufacturing fans and other air seeder components for 30 years, supplying a number of air seeder manufacturers in Australia and globally. Their core products cover ventures, primary heads, secondary heads, splitters, blowers, riser pipes plus a range of other components and accessories. They also custom make practically any thing to do with air assisted farm machinery. A photo-composite of the factory is presented in Plate 1.

Over the years Smallaire have developed a computer program that calculates the optimum pipe sizes for any machine module which they design and fabricate, allowing the resulting device to function at its optimum working capability without seed damage. During the past three decades they have built up a vast pool of knowledge and experience in fitting out machines from plot seeders to 80 foot air seeders. Smallaire is one of the largest seeder component manufacturers in Australia.

During December of 2005, Smallaire was approached by, and agreed to work with the Flexiseeder Project to help develop and supply air system modules for plot seeders and other small to medium scale equipment. As a result, a special purpose high pressure blower, a new style venturi system and self cleaning distribution heads were developed, and with the assistance of Norway, Sweden and New Zealand refined to the point of proving them to be an accurate and efficient system module under level conditions, for research as well as other small-scale and medium-scale uses. Chris Roberts in New Zealand was contracted under the Flexiseeder Project to draft these components in CAD for Smallaire. It remains for self levelling devices to be developed and incorporated.

Plate 1. Photo-composite of Smallaire factory and key facilities.
During 2007, the New Zealand section of the Flexiseeder project identified and moved ahead with Skellerup Industries Ltd in Christchurch to produce a standard Flexiseeder line of thick walled (9 mm wall x 28 mm ID) natural rubber seed hose according to European specifications. This was essential to withstand the intense vibration of S tyne coulters on Flexiseeders (their key feature in producing a fine tilth under hard conditions, as an ideal seed bed) while direct seeding into hard ground, under conditions where all other traditional sources / types of flexible air and other hose had failed.

Module components

High Pressure Blowers

The 19 and 22 series notation refers to the diameter (in inches / imperial measure) of the impeller. There are several different impeller combinations for each size. So far, blowers used on Flexi-plot seeders have been of the 19 series type with straight blades and a three inch (75 mm) outlet. Normally these units are capable of servicing 30 x 32mm distributor ports (outlets). On the Norway Flexi-plot seeder it services 24 distributor ports. While this may be considered “over kill” both Flexiseeder and Smale prefer

Smallaire components - 19 series blower (150 mm and 75 mm outlet)

Smallaire components including venturii (lower right) – note slim line of blower on plot machine – centre top blower has 150 mm outlet while the others have 75 mm outlets.
to have excess air capacity so that the blower can be run at a slower (and quieter) speed. The 19 series straight bladed blower with a six inch (150 mm) outlet is capable of feeding up to 75 x 32 mm ports. The 22 series turbo blower fitted with six inch outlet shown below (Plate 3) and above in Plate 2 (lower left, Smale equipment) can supply enough air for 130 x 32 mm ports.

Main features of Smallaire high pressure blowers include:
- Strong pressed steel casing and well balanced aluminium fan;
- Easily mounted in any of a number of positions;
- Mesh guard inlet (after-market diversion kit available to deflect intake away from operator);
- Quiet – particularly so when diversion kit fitted;
- Magnetic rev pick up bracket;
- Durable powder coated finish;
- Choice of hydraulic, belt or petrol / diesel drives;
- Custom built to suit specific needs – components documented in CAD for repeat supply / consistent product specifications; and
- Manometer (60 mbar) adaption for calibration and repeat settings – developed by Norway.

Plate 2. Air Module components.

Three examples of larger machines fitted with Smallaire technologies which overlap with the Flexiseeder modules. Note the hydraulic drive on fans. The two machines on the left, built by Smale (www.smale.com.au) in Australia are fitted with 22 series blowers and the Horwood Bagshaw (www.horwoodbagshaw.com.au) machine on right is fitted with a 19 series blower. Both have 150 mm blower outlets.

S&N heavy-duty natural rubber seed hose, made in New Zealand – released after drill sent to Norway.

Norway Flexi-Plot Machine – modified distributor insert (Norway Cone), manometer and free-flow distributor.
Computer Programme

The Smallaire computerised program can be used to determine the correct sizes of hoses, primary and secondary heads and also the correct fan and venturi or pressurised box system.

This computer program takes the guess work out of design / up-grades. It is a key factor contributing to trouble free systems with seeders working at their optimum air speed to minimize blockages, limit seed bounce, and reduce pipe wear.

Field usage and up-grades

Norway

Test data generated by Norway using their Smallaire system is presented in Tables 1 and 2. Two problems were encountered initially with distributor heads; (i) poor clean out and (ii) un-even distribution between ports. Two modified distributors were provided free of cost by Smallaire as replacements (shown in Plate 1). These were installed and re-tested. Clean out was improved by the new design, but variation in delivery between individual distributor ports was still unacceptable. A plastic cone (shown in Plate 1) was machined and inserted with excellent results, developed around concepts for distributor modifications / operation suggested by Kumar and Divaker Durairaj (2000). By using this modification, acceptable CVs of 10% and less (down to 3.7%) were recorded. Results are given in Table 2.

Sample size, seed / particulate size and density plus air pressure are but a few of the variables known to impact significantly on the performance of air distribution systems including distributor heads. Although it cannot be explained at present, there seem to be an optimal rotational position for the distributor in its location on top of the riser pipe. A number of positions should therefore be tested while setting up and adjusting the system. Modified heads which clean out combined with the use of plastic cone inserts are recommended. More work is required to evaluate and if necessary modify the air riser line and distributor head for use on sloping ground, steeper than 10 to 15 degrees. It is important that individual machines are regularly calibrated for samples / materials being sown. For this, the manometer fitted (0 to 60 mbar) proved invaluable as a simple, affordable and reliable adjunct for quantifying the operating speed of the fan in terms of delivery air pressure in the system.

Diffuser cups / cyclone relief vents may be needed to prevent seed bounce within the row. This has yet to be established. Besides the Smallaire diffusers, an additional source has been identified on-line at www.d-cupdiffuser.com, yet to be evaluated.

Sweden

Good progress made in Norway during 2007 for up-grading their air delivery system prompted Sweden to adopt the same system for its MacTrac project. The object of the Swedish project is to make a drill module for the MacTrac tool carrier. It is a co-project between the Applied Field Research group at the Swedish University of Agricultural Sciences (SLU), Mapro Systems AB (producer of MacTrac) and the Agricultural Society of Halland (user of the drill).
The main part of the component costs are paid by the end user while SLU and Mapro have taken development costs. Besides the Flexiseeder – Smallaire module, portion feeder, digital drive, and tool bar / tyne / tip modules are being used from the New Zealand / Australia arm of the Flexiseeder project.

**New Zealand**

At the same time as the Flexiseeder – Smallaire module was being evaluated and up-graded, aftermarket modifications were being made in Christchurch, to a “Farmall” plot seeder built locally seven years ago. It included a locally manufactured Oyjord-type mechanical distributor. The distributor was powered by a 1/8 hp, 12 volt electric motor of the type used in car heaters. While operating adequately for small- and medium-sized seeds and small plots, it proved unreliable for larger seeds and longer plots (20 m). The motor was under powered. It ran at 2,800 RPM while not under load, but lacked torque to maintain speed settings under load. It was replaced with a modified ¼ hp vehicle generator (dynamo) used as a motor, direct coupled to an inverse fabrication of the traditional Oyjord impellor. Powered in this way, at full speed, the distributor ran at 800 rpm. Six settings were built into a control system, equally spaced between 400 and 800 RPM using a resistor.

Data generated using this equipment while sowing 250 gm samples (presented in Table 3) was comparable to that obtained in Norway while evaluating the Flexiseeder – Smallaire distributor fitted with the replacement head (full clean out model used on flat ground) and no cone inserted. Once the cone was inserted, the Smallaire distributor gave more even distribution. Attempting to use this mechanical distributor to sow 500 gms of wheat seed while traveling at 3 km/hr appeared to be too fast, judging from the higher CVs. This emphasized the need for operators to routinely calibrate their equipment before sowing using representative samples and adjust sowing and impellor speeds accordingly.

Recommended operating speeds for impellors of this type vary between: 600 rpm for big beans, 750 rpm for soya and peas and 900 rpm for grain, oilseeds, etc. Fertilizer requires at least 900 rpm. Therefore ranges of working speeds are required between 500 and 1500 rpm or at some fixed speeds 600/750/900/1050/1200. These impellor speeds cannot be obtained using the above modification. The project is therefore working with John Brooks Ltd to develop and promote an alternative 12 / 24 volt drive of 180 / 250 watt and 1500 and 2000 rpm capacity coupled with an in-line mechanical variator (see Fraser et.al. 2008 and Plate 5).

Plate 3. MacTrac (www.mactrac.se ) use of Flexiseeder - Smallaire module on its new prototype modular plot seeder, under construction.

Plate 4. Mechanical distributor with direct-coupled electric drive and replaceable slip ring inserts for altering number of rows sown.

Before – note slip ring insert for altering number of rows sown

After – note slide for dropping motor away from distributor housing to change slip rings easily.
Discussion and conclusions

Cross over with Farmer Equipment

There is much to be gained from linking farm machinery with research equipment through overlapping modules. Thirty years of experience gained by Smallaire, mostly on large sized machines was put to good use under the Flexiseeder Project by its members in designing and providing a range of equipment air modules suitable for plot seeders and other small-scale users, thereby confirming the role which farm machinery can have in helping research. In return, Smallaire gained experience and other input from the plot seeder project which helped them further refine their products, not only for small-scale but also “broad acre” machines.

Natural rubber seed hose identified for the project by S&N International as a suitable replacement for a much stiffer plastic hose used on farm machines also proved successful for plot seeders. Because of this overlap, hose was purchased in bulk for both classes of machines, with considerable savings. This reduced the cost of purchasing hose for plot seeders by 75% compared with purchasing this same material otherwise.

Air Distribution Systems

Significant advances were made in the adaptation, evaluation and use of air distribution systems on plot seeders, including (i) minimizing the risk for residues left in the system, (ii) using over-sized blower for silent operation with enough spare capacity, (iii) and design, manufacture and use of slim, exchangeable, distributor heads with a range of outlet ports. By using air compared with gravity feed, the transport time for product from cell wheel to coulter is very short - fractions of a second. By using air, operator(s) and equipment can be placed in any of a number of positions on seeders without concern for low spots in hoses, etc.

Mechanical Distribution Systems

The historic use of vehicle dynamos for driving mechanical distributors was revisited and evaluated. On the basis of this, more versatile electrically driven / direct coupled 12 / 24 volt option was identified for driving the impellors using modern technologies which cost approximately the same amount installed. By having more accurate seed and fertilizer distribution to your coulters, higher germination rates may

Table 3. Distribution of 500 and 250 gm samples of wheat sown with Farmall tractor at approximately 3 km/hr over 20m plot length. Data supplied by Plant Research (NZ) Ltd (www.plantresearchnz.co.nz)

<table>
<thead>
<tr>
<th>Wheat 500 gms Coulter</th>
<th>Delivery of Seed (gms) per Coulter x Variation</th>
<th>Wheat 250 gms Coulter</th>
<th>Delivery of Seed (gms) per Coulter x Variation</th>
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<tbody>
<tr>
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<td>Rep 1</td>
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<td>Rep 3</td>
</tr>
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<td>53</td>
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</tr>
<tr>
<td>Total</td>
<td>512</td>
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<tr>
<td>CV%</td>
<td>17.7</td>
<td>22.2</td>
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</table>
be expected. With air systems users must take care to plumb the system so there are no dead patches and remain aware of the potential risk of seed bounce at the soil – coulter interface which is able to be eliminated using micro cyclone "add-ons".

Comparative Evaluation of Distribution Systems

Based on the observed CVs of seed delivered through each port on distributors under the conditions tested, the performance of mechanical distribution systems and of the Smallaire system fitted with a self cleaning distributor were comparable, provided they are operated within their limitations for loading and slope. Air delivery was superior where a Norwegian cone was fitted to the self cleaning Smal-laire distributor. The importance of operators regularly calibrating and adjusting their systems as they use them is emphasised.

Common Problems

The need remains to design and incorporate self levelling devices on hilly / sloping land for both systems.

Where Next?

We have not explored so far, whether there is something to be gained by adding electrically driven mechanical impellors (of the kind described by Fraser et.al. 2008) into the Smallaire and other air distributor heads used under very hilly conditions (especially if the slope is more than 15 degrees).

References


### Table 1. Distribution of Seed - FlexiSeeder Air Delivery Module: Part I - Test of variation in grain delivery between ports (22.02.2008)

<table>
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<tr>
<th>Material</th>
<th>Air Pressure</th>
<th>Delivery Time</th>
<th>Distributor Head</th>
<th>Terrain</th>
<th>Unit</th>
<th>Couler Number x Delivery of Seed per Couler x Variation</th>
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<tr>
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<td>Million</td>
<td>Sec</td>
<td>Type</td>
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* Horizontal machine = 0 degrees
## Table 2. Distribution of Seed - Flexiboothes Air Delivery: Part II - Test of variation in grain delivery relative to position of distributor head (new type) on riser pipe (11.01.2009)

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<th>Delivery Time</th>
<th>Distributor Head</th>
<th>Tensile Angle°</th>
<th>Collection Position</th>
<th>Unit Grams</th>
<th>Coulter Number x Delivery of Seed per Coulter x Variation</th>
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<th>4</th>
<th>5</th>
<th>6</th>
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* Horizontal machine = 0 degrees
* Cone inserted
FLEXISEEDER DRIVE MODULES: AN OVERVIEW INCLUDING TECHNICAL SPECIFICATIONS

Flexi Technical Note - 001

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Summary (Abstract)

Drive systems are a pivotal component of plot and farm seeders as well as many other pieces of agricultural equipment. Drive modules which can be easily adapted, adopted and shared across a wide range of equipment, both for research and production, have considerable application for increasing efficiency and saving costs without compromising quality. This technical note introduces and provides technical specifications for two new Flexiseeder drive modules released at this conference, a digital gearbox and an electrically powered, “vari-speed” mechanical drive, developed jointly by John Brooks, S&N International, SLU and BACD under the Flexiseeder Project, (www.flexiseeder.com). A voluntary user-group project of the Seed and Seed Drilling Technology Help Group: International Association for the Mechanization of Field Experiments / Global Institute and Agricultural University Internet Hub (IAU Trust.) and launched for use into the public domain.
FLEXISEEDER "CONTINUOUS-RUN" SEED AND FERTILIZER MODULES FOR SMALL-SCALE USERS

Flexi Technical Note - 002

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- M. Bakkegard, Bioforsk Arable Crops Division, Apelsvoll, N-2849 Kapp, Norway.

Summary (Abstract)
Small-scale continuous-run seed and fertilizer modules are an essential adjunct to cell wheels on plot drills, used also for metering and applying other particulates. For these technologies, there are excellent opportunities for cross-over with commercial systems, to develop multi-purpose affordable and efficient modules. Thian Agri joined the Flexiseeder project (www.flexiseeder.com, A voluntary user-group project of the Seed and Seed Drilling Technology Help Group: International Association for the Mechanization of Field Experiments / Global Institute and Agricultural University Internet Hub (IAU Trust).) two years ago and since then by working together with S&N International, SLU and BACD, has contributed two modules to the Flexiseeder project, as described in this technical note. These modules are easily and simply incorporated into a wide range of custom built small-scale gravity fed boxes, hoppers and/or air delivery systems, as well as Oyjord-type distributors. They match up well with the Thian gearbox, Zero Max Y2 gearbox (with torque delimiter attached) and probably, after further programming and testing, with the Brooks-S&N digital gearbox and the Brooks-S&N electric “varispeed” unit fitted with an Oyjord-S&N impellor. Individual seeders and other componentry are available commercially, because they are already registered and part of a larger commercial operation, they could not be put into the public domain.
Air assisted delivery and distribution systems are more versatile than gravity feed and mechanical distribution and delivery systems for integration into plot seeders. This applies to a wide range of particulates when open-plan coulter layouts are used to improve residue passage during zero tillage and reduced tillage, as well as for close row spacing on cultivated ground. This is a key component for upgrading older seeders to the multipurpose Flexiseeder system, without the costs of substantially redesigning and re-building the original chassis. It also applies for broadcasting fertilizers or other dry, granular materials, and for greater working widths. Smallaire, an Australian company already supplying large scale commercial agriculture, joined the Flexiseeder Project (www.flexiseeder.com.au) two years ago and began working with S&N International, SLU and BACD to develop and supply “scaled down” air delivery and distribution equipment in modular form, for small and medium-sized seeders. These modules, including technical specifications, are introduced and described in this technical note. Components are available commercially, because they are already registered and part of a larger commercial operation, they could not be put into the public domain.
Summary (Abstract)
Air assisted delivery and distribution systems are more versatile than gravity feed and mechanical distribution and delivery systems for integration into plot seeders. This applies to a wide range of particulates when open-plan coulter layouts are used to improve residue passage during zero tillage and reduced tillage, as well as for close row spacing on cultivated ground. This is a key component for upgrading older seeders to the multipurpose Flexiseeder system, without the costs of substantially redesigning and re-building the original chassis. It also applies for broadcasting fertilizers or other dry, granular materials, and for greater working widths. Smallaire, an Australian company already supplying large scale commercial agriculture, joined the Flexiseeder Project (www.flexiseeder.com). A voluntary user-group project of the Seed and Seed Drilling Technology Help Group: International Association for the Mechanization of Field Experiments / Global Institute and Agricultural University Internet Hub (IAU Trust;) two years ago and began working with S&N International, SLU (Swedish University of Agricultural Sciences (SLU), VPE/FÄrilt Forsk, Uppsala, Sweden), and BACD (Bioforsk Arable Crops Division, Apelsvoll, N-2849 Kapp, Norway).
FLEXISEEDER CELL WHEEL AND DISTRIBUTOR MODULE: AN OVERVIEW INCLUDING TECHNICAL SPECIFICATIONS

Summary (Abstract)
Hundreds of Oyjord and “Oyjord-like” cell wheels and mechanical distributors remain in use globally, some more than 40 years old. Spare parts, new units and upgrades are included. These include cell wheels of different sizes and lamellae spacing cast with different numbers, as well as deeper than normal lamellae, (suited to metering larger than normal seeds / fertilizer and other particles / sizes of samples) and distributor impellers of clockwise and counter-clockwise rotation. Such specialized units have been fabricated at additional cost rather than being cast routinely, for want of improved pattern making and casting ideas and procedures as developed recently under the Flexiseeder Project (www.flexiseeder.com). A voluntary user-group project of the Seed and Seed Drilling Technology Help Group: International Association for the Mechanization of Field Experiments / Global Institute and Agricultural University Internet Hub (IAU Trust) by S&N International Ltd in association with SLU (Swedish University of Agricultural Sciences, VPE/Fält Forsk, Uppsala, Sweden), BACD (Bioforsk Arable Crops Division, Apelsvoll, N-2849 Kapp, Norway), The Casting Shop, Collins Patterns and Geoff Gray Ltd. These improved Flexiseeder technologies including an improved cell wheel / portion feeder assembly are introduced and described in this technical note together with details of two modern hard-wearing, low-friction materials that are being used in combination with traditional materials to improve efficiency and to reduce costs. These technologies have been put into the public domain.
FLEXISEEDER FRAME MODULE: AN OVERVIEW INCLUDING TECHNICAL SPECIFICATIONS

Flexi Technical Note - 006

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Summary (Abstract)
Conceptualizing and designing frame modules within strict dimensional and weight limitations is the most challenging part of building multi-purpose plot seeders that are equally suited to zero tillage, reduced tillage and cultivated ground. Because this is a relatively new area of application, there is only limited history and accumulated experience to draw on, mainly from scaled down versions of farmer / horticulture / viticulture machines which seldom meet the immediate dictates of plot seeders and have to be modified / re-built to suit individual needs. This is time consuming and expensive. To save costs and increase efficiency a, two-way cross-over modular approach has been developed by the Flexiseeder Project (www.flexiseeder.com). A voluntary user-group project of the Seed and Seed Drilling Technology Help Group: International Association for the Mechanization of Field Experiments / Global Institute and Agricultural University Internet Hub (IAU Trust.) under the combined leadership of S&N International Ltd, SLU (Swedish University of Agricultural Sciences (SLU), VPE/Fält Forsk, Uppsala, Sweden) and BACD (Bioforsk Arable Crops Division, Apelsvoll, N-2849 Kapp, Norway), which (a) takes on board relevant technologies from large-scale commercial production lines and (b) systematically matches these with specialized research components / modules in ways that are interchangeable and reciprocal. It is upon this underlying philosophy that the applied Flexiseeder Project is built. Practical examples are introduced and described in this technical note. Resulting developments have been put into the public domain.
REFERENCES


FODDER OATS: www.fodderoats.net – A successful project spawned by the Seed and Seed Technology Help Group of IAMFE / IAU

Flexi Technical Note - 007

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Summary (ABSTRACT)
Oats (Avena sativa (as implied by the literal use of “oats” in this article)) are an important, yet under utilized source of forage and fodder in developing countries, used variously for milk and meat production and feeding draft animals. It may be fed green, dried and used as oaten hay, or wilted and made into silage / balage. Multiple cuts are usually taken, after which part or all of the crop may be saved for seed. So far, this crop has been passed over by globally coordinated crop improvement programmes of the CGIAR. Instead, global leadership in the developing world has come from domestic crop improvement programmes within temperate and continental regions of developed countries. Made possible, by the high degree of agro-ecological overlap between crop improvement programmes in these areas and cool season / winter lowland climates plus summer highland climates in sub-tropical and tropical ecologies.

In these activities, the New Zealand oat programme has emerged as a leader, closely linked with North America and Europe where oats have been grown for grain since the early centuries of the Christian era. Oats were introduced into the Indian sub-continent during the British imperial era. New Zealand broad leaf oat cultivars were introduced to the Himalayan Hindu Kush region thirty years ago. Since then field testing and evaluation has shown that “broad leaved” cultivars originating from New Zealand perform well along the full length of the Himalayan Hindu Kush chain stretching from Afghanistan to Myanmar and into China as well as into the adjacent lowlands. The same cultivars have also proven widely adapted in Central and South America and Africa.

New Zealand broad leaved fodder oats are pivotal in Nepalese environmental conservation and rehabilitation projects for enabling farmers to change from free grazing to stall feeding / zero grazing including moving away from goats, cows and yaks (including cow/yak and visa versa hybrids) to buffalo which are more efficient when stall feed and the meat can be eaten within a Hindu society. During 2000 in support of this work, a group of Nepali and New Zealand scientists got together and started a cool-season fodder oat network (www.fodderoats.net) under SEMEC (the New Zealand / Australian Branch of IAMFE) and then the IAMFE / IAU Seed and Seed Technology Help Group, encouraged by an Austrian colleague from Wintersteiger, who was supplying / servicing the New Zealand Oat programme’s Oyjord plot equipment (which included an Oyjord-Schou planter that reached New Zealand in 1975).

Firstly, a global paper was prepared and presented at the 6th International Oat Conference held at Lincoln University (New Zealand) in 2000 to launch the idea
(Stevens et al. 2000). This led to an invitation from the FAO for one of the group to attend a FAO conference in Bhutan (Armstrong 2002a,b) and then for the group to draft two major articles for a FAO global position paper on fodder oats (Stevens et al. 2004 and Armstrong et al. 2004). Out of which, the Himalayan – Hindu Kush fodder oat network based in Nepal was started. The Nepalese part has subsequently been taken over, and is to be continued by the New Zealand Aid Programme (from 2007 inward) as described in this poster.

This shows in a practical way, how IAMFE can function as a spawning ground for invaluable projects which reach far beyond its basic mandate for assisting with the mechanization of field experimentation.

References


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