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FOREWORD

These Proceedings are the result of a happy cooperation between IAMFE (the International Association on the Mechanization of Field Experiments) and ICARDA (the International Center for Agricultural Research in the Dry Areas). The Regional Conference on the Mechanization of Field Experiments was held in ICARDA's new permanent buildings located on its principal research station at Tel Hadya, near Aleppo, Syria. Altogether there were 66 participants from 20 countries.

Both IAMFE and ICARDA recognize that mechanization improves the accuracy of field trials, and enables most operations to be completed more quickly. They welcomed the opportunity to hold this conference in West Asia, where the mechanization of cereal and legume trials is not as developed as it is in more temperate regions. The conference provided a forum for the presentation of new and modified equipment and the results of field tests, and for the identification of subjects for future research.

IAMFE was founded in 1964 with the objective to assist agronomists and plant breeders in the mechanization of field experiments and thus to improve the accuracy and capacity of their research work. The Association pays particular attention to the needs of researchers in developing countries and seeks to help them obtain access to appropriate equipment of high quality.

ICARDA was established in 1977; it conducts research in its own facilities and works with national agricultural research programs to improve agricultural production in dry regions, particularly those in West Asia and North Africa. It also has a strong interest in the management of experiments, both those at research stations and those carried out in cooperation with farmers on their own fields.

The coincidence in the interests of IAMFE and ICARDA was clearly manifested during the Conference, both in the papers that were delivered and in the visits that the participants made to the research plots on ICARDA's main farm and to the El Ghab Agricultural Research Station.

An exhibition of machinery was held in association with this Conference, and we offer particular thanks to the two manufacturers who sent their equipment and demonstrated it. A further benefit remains in that both manufacturers decided to leave their machines in Syria for one or two seasons, so that ICARDA may use and evaluate them.

At the end of the Conference, a seminar was organized to deal with a subject of considerable importance for agricultural production in the region. It concerned the mechanization of harvesting of lentil and chickpea, two crops of major importance for the diets of people in West Asia and North Africa. Although the subject was beyond the normal scope of a IAMFE Conference, the interesting papers presented at this seminar are included in a special section of these Proceedings.

IAMFE and ICARDA would like to take this opportunity to offer their thanks to the Norwegian Ministry of Foreign Affairs and the German Agency for Technical Cooperation (GTZ) of the Federal Republic of Germany, both of which provided funds to help ensure the presence of participants from developing countries.

The sponsors are confident that they are reflecting the view of all participants when they express appreciation for the untiring efforts of Dr. Juergen Diekmann of ICARDA. He coordinated all the preparations of the Conference and, with his colleagues, ensured its successful completion.

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National Strategies for Efficient Mechanization of Field Experiments

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Abstract

The national strategies of field plot mechanization are the same as in the industry, namely: To produce the result as fast and cheaply as possible, and with a better quality.

Mechanization of field experiments should be introduced in cases where mechanization can increase the capacity and reduce the experimental error, so that new, resistant, high-yielding varieties and cultural practices can be made available to the farmers in a shorter time. Experience has shown that mechanization is the most efficient way to ensure that the work can be done rapidly and safely.

To promote agricultural research, National IAMFE Committees on Mechanization of Field Experiments should be established in countries where such committees are not established thus far. These committees are very important in developing countries which cannot afford to waste money on research machinery and equipment that do not fit their local conditions.

Introduction

After the second world war, the impact of mechanized farm operations reached agricultural research institutions. The gap between mechanization of farming and mechanization of field experiments became clear and was recognized as a problem which needed attention. An

important reason for increased interest in mechanization of field experiments was also the shortage of manual labor encountered in many countries. These factors created the basis for a new science, "Mechanization of Field Experiments" and of specialized plot equipment manufacturers. Today the manufacturers of plot research equipment play an increasing role in the design and development of plot research equipment. However, the small demand for specialized machinery, equipment, and instruments has made it practical to develop strategies which can assist the scientists and the manufacturers.

National Committees on Mechanization of Field Experiments, acting as national IAMFE Committees, are established in several countries, i.e. Belgium, Denmark, France, Hungary, India, Netherlands, Norway, Sweden and West Germany. The national IAMFE committees are very important for securing funds for national research, development, testing, and information on plot research equipment.

Efficient National Strategies

In order to assure that national funds are used as efficiently as possible, national committees on mechanization of field experiments should be established. These committees should include bioscientists, engineers, and research administrators.

The national committees should initiate the following activities:

- Assess the current situation,
- Identify efficient machinery, equipment, and instruments for mechanization of field experiments,
- Adapt and improve existing machinery and equipment when necessary,
- Recommend appropriate new machinery and equipment,
- Provide manufacturers with requirements for the development of improved machinery for field experiments
- Establish a national stock of spare parts for imported equipment,
- Establish a national information service,
- Establish a national training program.

Further, the national committees should cooperate with IAMFE regarding proposals for:

- Plot size and shape in the cases where machinery and equipment are to be used on plots,
- Standardization requirements of research machinery and equipment,
- Improvement of research machinery and equipment,
- Testing of machinery and equipment.

A very important part of the strategy for securing rapid progress in the mechanization of field experiments should be to establish sections of plot mechanization at national institutes of agricultural engineering or at universities. These sections or centers should help and advise the national research institutions on their mechanization problems.

We know that variations in soils and plants as well as in slope, shape, and size of the fields may cause unexpected problems with new machinery and equipment. Ideally a mechanization program should not be started before similar mechanization programs in other countries under the same conditions have been investigated. On the basis of such investigations, the best machinery and equipment available should be purchased and tested and, if necessary, adapted to the local conditions.

Last, but not least, the national IAMFE committees are very useful when a country wishes to arrange national, international or regional IAMFE Conferences and Exhibitions.

Recommended Approach for Institutes

The most efficient use of research funds is to mechanize the "bottlenecks" and dramatically increase the research capacity with a given staff. As the quality of field experiments depends on high-quality research plots, it is very important that the plot drills and precision planters are self-cleaning and have high capacity and accuracy.

Another very important operation to mechanize is threshing. Good, self-cleaning threshers and shellers for single ears, single plants and small plots should be introduced in all plant breeding programs. As far as possible, small, self-cleaning plot combines should be introduced. The aims of each research institute should be to:

- Reduce the experimental error,
- Ensure completion of the work at the right time,
- Reduce the costs of manual labor,
- Increase the research capacity with a given staff,
- Attain the goals in a shorter time,
- Overcome the lack of qualified manual labor,
- Avoid the human errors in experiments carried out by hand labor,
- Achieve the control of accuracy which is impossible in programs carried out with a large input of manual labor.

We have many reports indicating that the research capacity has increased 10 to 100 times or more by mechanization and, at the same time, the experimental error has been reduced.

Supporting International Strategies

Rapid progress in any field is only possible by providing information about the advantages of new machinery, equipment, and instruments. The most efficient way of transferring knowledge is by the arrangement of conferences with the presentation of scientific papers and test reports as well as by demonstration of new or improved equipment. Participants in IAMFE Conferences and Exhibitions[1] have played very important roles in international cooperation and technology transfer since 1964.

The main strategies of IAMFE are to cooperate with national IAMFE committees as well as institutes,

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[1] Previous IAMFE Conferences are listed in the Appendix.

organizations, and authorities in arranging national, regional, and international conferences, exhibitions, and meetings on mechanization of field experiments, and to provide publications on the subject.

IAMFE offers the following publications to its members:

Proceedings/Papers of previous IAMFE Conferences,
The International Directory of Manufacturers of Machinery, Equipment and Instruments for Mechanization of Agricultural Research (The IAMFE Directory),
The IAMFE Journal and Newsletter.

Short-term IAMFE Fellowships are available for members who wish to arrange national, regional, or international IAMFE Conferences and Exhibitions.

Individual as well as state and private research institutes, universities, organizations, manufacturers, and countries are welcome to join IAMFE and to become partners in "The IAMFE Network". A membership in IAMFE is an important step to rapid progress in agricultural research.

Field Plot Techniques

Selection of an appropriate design is an important step in the planning of field experiments. Mechanical planting, pest control, and harvesting are possible with the randomized-complete-block and split-plot designs. Good management techniques are necessary to ensure uniformity within the trial and to minimize experimental error.

Common Designs and Field Plot Technique Used at ICARDA

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Abstract

The success of any experimental trial depends on selection of the appropriate design and experimental site. The most common designs used at ICARDA are Randomized Complete Block Design, Split-Plot Design, Lattice Design and Augmented Design. Good management of land preparation, planting, fertilization, weed control, irrigation, and harvesting operations can minimize environmental variation within a trial. Practical rules are given for research and demonstration trials.

Plot Designs

Field and laboratory trials are extensively used by the different research programs at ICARDA and in cooperative efforts with national program scientists in its region and around the world. The main objectives of these research trials are to obtain new information, improve the results of previous findings and test promising varieties, or demonstrate new practices and technology for tillage, weed control, and fertilizer application.

Research at ICARDA is devoted to different aspects of crop and livestock improvement such as breeding, crop management, pest control, quality, and crop-livestock farming systems. Different experimental designs and field plot techniques are used in the implementation of each type of field and laboratory research. The most common designs used by ICARDA are

Randomized Complete Block Design, Split-Plot Design, Lattice Design, and Augmented Design.

1. Randomized Complete Block Design (RCB)

The RCB is mainly used in evaluating promising varieties and lines tested in the different yield trials (initial, preliminary, advanced, and regional), variety verification and demonstration trials, cultural practices, quality evaluation, pest control, and feeding trials. The number of replicates and size of plots vary from one trial to another depending on the number of treatments, type of treatment, management practices, precision required, and available resources. One or more factors (variety, date of planting, fertilizer, or seed rate) can be tested in this design. If more than one factor is used, the trial is called "Factorial Experiment" where the main effects of each factor and the interaction between the different factors can be detected. Mechanical planting, weed and pest control as well as mechanical harvesting are used extensively in ICARDA research. Associate problems and advantages of using farm machinery in implementing this design vary from one nursery or trial to another depending on the nature and number of treatments, land preparation, irrigation systems, available machinery, and experience of personnel.

2. Split-Plot Designs

The family of split-plot designs is one group of experimental designs developed specifically for factorial experiments. It includes the split-plot design and its modifications (split-split-plot, split-split-split-plot, etc) and the split-block design (strip-plot design). A special feature of this family is that each design involves more than one plot size and each size is used for different factors.

The split-plot design has two plot sizes: the larger is called the main plot and the smaller the subplot. One factor is assigned to the main plot and another to the subplot. The relative size of the main

plot and the subplot depends on the number of levels of the second factor. For example, in a factorial experiment involving five varieties and four nitrogen rates carried out in split-plot design, and if nitrogen is assigned to the main plots and the varieties to the subplots, then the size of the main plot is five times larger than each subplot. Therefore each main plot contains five subplots.

In the split-block (strip-plot design), the levels of the second factor are laid out in strips (blocks) instead of being randomized independently within each main plot as in the split-plot design. This design is more appropriate for experiments in which both factors need relatively large plots, or where the interaction between the two factors is more important than the main effects of each factor. The strip-plot design sacrifices precision on the main effects of both factors but the interaction is measured more accurately than in the randomized complete block and the split-plot designs.

At ICARDA, the family of split-plot designs is used mainly in agronomy research trials such as varieties x dates of planting, varieties x nitrogen and/or phosphorus fertilizers, varieties x irrigation systems, dates of planting x fertilizers, and rotation x varieties. These designs are also commonly used in forage improvement, especially for cutting x varieties and varieties x fertilizer. Mechanization of split-plot designs is practiced at ICARDA. However, the success of mechanical planting, pest control, and harvesting depends on several factors similar to those encountered with the RCB.

3. Lattice Design

The lattice design is used when the number of treatments is large. In plant breeding, comparison among pairs of promising lines or varieties with equal precision is required and therefore replications could be split into smaller incomplete blocks. Since each block in an incomplete block design does not contain all treatments, they are usually called "incomplete blocks" and lattice design is the most common type.

In the lattice design, the number of treatments must be a perfect square, such as 25, 36, 49, 64, etc. This requirement is not difficult to satisfy. The size of an incomplete block or the number of plots in each incomplete block is equal to the square root of the total number of treatments. For example, 25 treatments require 5 plots in each incomplete block and 81 treatments require 9 plots in each incomplete block.

Lattice design is divided into two types:

a) The balanced lattice design in which every pair of treatments appears together once and only once in the same incomplete block, allowing equal precision in the comparison of all pairs of treatments in the trial. The major restriction of this design is that the number of replications required must be equal to one more than the square root of the number of treatments. In practice, this requirement is very difficult to afford.
b) The partially balanced lattice design in which any number of replications can be used, but some treatments will not appear together in the same incomplete block. Therefore, comparison among treatments that appear together in the same incomplete block will be more precise than among those that do not appear together. If two replicates are used, the design is known as the simple lattice design, and with three replications, the triple lattice, with four replications, the quadruple lattice, etc..

The balanced and partially balanced lattice designs are used in the ICARDA breeding programs and in the evaluation of a relatively large number of breeding germplasm. The main disadvantages of this design are it is difficult to construct and requires lengthy data analysis.

4. Augumented Designs

The main purpose of these designs is the screening and evaluation of a large number of new varieties, based on sound statistical analysis. The experimental area

should be divided into a number of blocks. Three or more check varieties should also be included within each block, while the remaining plots in each block are assigned to the new varieties under test. The new varieties are not replicated but assigned at random throughout the blocks. Yields of test varieties are adjusted for block differences, which are measured by the yields of the check varieties present in each block.

Block size can vary within the same trial, but with blocks of the same size, the trial is more efficient. Block size is determined by the number of blocks (b), the number of check varieties (c), and the number of new varieties (v). The minimum number of block (b) in this design is calculated as follows:

$$b > 10\ (c-1).$$

For example, with 3 check varieties, the minimum number of block (b) will be 5

$$b > 10/(3-1) = 5$$

In the layout of this design, the checks are randomly assigned to plots within each block. However, with a little less trial efficiency, one check variety could be systematically assigned to the first plot in each block and the other (c-1) check varieties could be assigned at random to (b-1) of the remaining plots in the block. The (v) new varieties are then assigned at random to the ($n=v/b$) remaining plots in the trial.

Augmented design is being adopted for germplasm screening, and statistical analysis is being carried out at ICARDA. The main advantages of this design are that it requires fewer seeds in the evaluation of early generation or introductions and is less expensive than the replicated trials. Efficiency of the design depends on several factors, including plot size, plot management, and statistical analysis.

Randomized Complete Block Design is the most common design used in the evaluation of different yield trials, disease nurseries, quality evaluation, cultural

practices, livestock nutrition trials, and variety verification trials. The family of split-plot designs and incomplete block design (lattice design) are used when more than one factor is tested with specific requirements such as large plot size, type of treatments, or availability of farm machinery. Augmented design is mainly used in the early evaluation of segregating populations of breeding programs, observation nurseries, and disease loss evaluation trials. It can also be used in demonstration and verification trials.

Field Plot Techniques and Error Control

The success of any experimental trial depends on selection of the appropriate design and site, trial management, data analysis, and the interpretation of results. The trial environment should also be as uniform as possible to allow for comparison between the different treatments. Some environmental variations can be partially controlled by good management. Therefore, to ensure accurate results and effective evaluation, operations such as land preparation, planting, fertilization, weed control, irrigation, and harvesting must be managed in such a way that environmental variation within a trial is minimized.

1. Site selection and land preparation

The experimental site should represent the area in which the results are intended to be applied and should be as uniform as possible in soil type and depth as well as topography. Soil-related conditions (salinity, high level of gypsum, variable fertility, soilborne diseases and pests), shallow spots, and old roads should be avoided as sites. Soils heavily infested with weeds or planted with the same crop in the previous growing season should not be selected. Sites close to trees and shrubs could be attacked by birds and should be avoided if possible.

Land levelling before planting may provide conditions that prevent the accumulation of water on parts of the site; however, soil fertility might be

affected by this operation. The land should be uniformly tilled with the appropriate machinery at the proper time. Fertilizer and herbicides should be applied as needed and recommended. Soil analysis and classification, and the climatic and socio-economic factors should also be considered in the selection of experimental sites.

2. Seed preparation

Before planting, seed should be thoroughly cleaned and sieved to avoid plugging problems in planting machines and broken seeds. Seeds should also be treated with fungicides and/or rhizobia when needed and put in paper envelopes on which the trial name, plot and run numbers are marked. The quantity of seeds per plot and the plot size vary depending on the type of trial. For yield trials, the seed rate must be adjusted for differences in seed weight to ensure that approximately the same number of seeds are planted per plot for all the test lines in the trial. This adjustment can be carried out by using simple procedures.

Seed germination and moisture content vary greatly from one line or variety to another, and therefore it may be desirable to conduct germination and moisture content tests before planting. The seed rate for each line can then be adjusted for variation in germination, moisture content, and seed weight. In many cases, seeds for yield trials and other experiments are calculated and measured on a volume basis using small cups or containers. This method is not as accurate as weighing out the seeds, but it may be acceptable if there are no large differences in kernel weight, seed germination, and moisture content.

3. Planting

Seeds can be planted in dry or moist soils. Irrigation must be applied after planting in dry soils if immediate germination is desired as in date of planting trials. In dry soils, care should be taken that the seed is not damaged or picked by birds or other pests

before irrigation or rain. Inadequate or sparse rainfall on dry soils after planting may lead to seed germination but may not be sufficient to support the seedlings. Therefore all the germinating seeds die. It is always advisable to have access to irrigation facilities in areas where low rainfall may cause this problem.

The start and the end of each trial should be marked at planting time with the name of the trial and plot number. Date of planting should be recorded and field maps prepared for all trials. It is also very important to plant the whole trial in the same day, and under adverse conditions such as rains during planting time, a whole block should be completed in one day.

For hand planting, furrows can be opened by animal or tractor-drawn implements set for the correct row width. Manual opening with a hoe can also be used if animal or tractor power is not available. Seed should be evenly distributed in the furrows and covered with 3-5 cm of soil. Care should be taken when covering furrows not to mix seeds from different treatments.

The most common experimental planters are cone planters which allow even distribution of the seed throughout the length of the plot. Envelopes should be arranged in "runs" according to the planting plans. The run number and the plot number or serial number within the run should also be indicated on each envelope. While planting, frequent checks should be made to ensure that the planter is not plugged and the planting depth and length are correct.

4. Fertilization and irrigation

Variability in soil fertility can be a major source of variation within a trial. Therefore, special care should always be taken to ensure an accurate and uniform application of necessary fertilizer. In addition to the pre-planting and pre-germination fertilization, top dressing of nitrogen and other fertilizers may be necessary during the growing season. Special care should also be taken in the distribution of these fertilizers.

In irrigated crops, special care should be taken to ensure a uniform and sufficient application. Lack or excess of water in the field may cause severe damage to the trial. All trials of the same nature should be treated with the same irrigation system as far as possible because the time and method of irrigation could greatly effect the data.

5. Pests and weed control

Pests and weeds can be a great problem to research trials, and their control is necessary. Appropriate pesticides and herbicides should be applied uniformly at recommended rates. Traps, poison baits, or fumigation may be useful for control of rats and mice. Birds are often a problem, particularly for early-maturing lines, and netting can be very effective, but is difficult and expensive to use over a large area. Mechanical noisemakers may also be useful if available. Birds can be better controlled in the early morning and before sunset if guards can be hired.

Cultural and chemical weed control are useful in reducing experimental error. The method used in controlling weeds depends on the local practices and the availability of equipment, herbicides, and labor. The manual, mechanical, or chemical control of weeds should take place in the early stages before the weeds compete with cultivated plants.

6. Field books and collection of data

Field books for the recording of data should be prepared before planting. For variety trials, field books usually list the variety name or cross and pedigree, the plot number, and the source of seeds. Entry and plot number should also be listed in the replicated trials. For example, in a replicated yield trial with 24 lines and 4 replications, the entry numbers would be from 1-24 and the plot numbers would be from 1-96. Each page should have enough columns for the necessary field and laboratory data. The book should be checked and corrected before planting. The size and format should be convenient for use in the field and for the statistical analysis.

The collected data may serve as selection criteria. Poorly taken notes may in fact be worse than no notes at all and can lead to false or unscientific conclusions. All conditions which may cause a bias in the observations should be accurately recorded. For example, if a part of the trial is dry due to shallow soil, it should be noted since the problem will effect other observations such as days to maturity, plant height, grain yield, and 1000-kernel weight.

Notetaking may at times become tedious and difficult, but it is important to complete data recording for the whole trial or at least for a complete block at once. It is also advisable to record data directly in the field book and avoid transcription or transferring data from separate papers or books. Opportunities for errors in copying data are then minimized.

7. Harvesting

With hand or mechanical harvesting and threshing operations, precautions must be taken to avoid seed loss, mixing, or breakage. Each trial should be harvested at the appropriate maturity or harvesting time; harvesting of the trial should be completed on the same day if possible. The whole plot or representative samples should be harvested and the yield calculated. In variety yield trials, some lines mature earlier than others. Therefore yields may vary greatly because seed are shattered and grain moisture content is lost during harvesting. Homogeneous lines should be grouped in one or more trials whenever possible.

Practical Rules for Research and Demonstration Trials

1. Keep the trial simple. (Even simple trials are complex and time-consuming.)
2. Do not undertake an experiment unless you are absolutely sure of the availability and continuity of adequate labor, equipment, management, and other necessary input. An experiment which is

inadequately performed or maintained is worse than no experiment at all. In addition to giving unreliable results, a poorly conducted trial is an eyesore that reflects poorly on the researcher and the organization.

3. Use a proper design and obtain qualified help if necessary in designing and analyzing the results.
4. Check that the equipment used in the experiments are appropriate, properly adjusted, and in satisfactory operating condition.
5. Weigh and measure all quantities accurately. A small weighing error on a small plot may cause a large error when converted to kilograms or tons per hectare.
6. Draw a detailed map of the experiment and keep accurate records for all operations performed.
7. Apply all management practices (except those being compared) to each block and replication as uniformly as possible. Plant and harvest each block at one time. If you have to finish before the whole trial is completed, finish at least a block.
8. Visit and observe the experiment frequently for any change or problem that might introduce bias such as disease, insect, drought, or damage. Keep accurate notes on these changes and apply appropriate control measures over the entire trial.
9. Remember that statistics and statistical analysis do not prove anything and that there is always a probability that your conclusions may be wrong. Do not jump to a conclusion, even though it is statistically significant if it appears out of line with previously established facts. In this case, investigate the matter further.

Soil Tillage and Seedbed Preparation

Local modifications of primary soil tillage implements are reported from Egypt. A chisel plough and two subsurface ploughs performed well under test conditions.

At the Gezira Scheme in central Sudan, deep blading and deep ploughing tillage systems are used to control weeds. In the primary tillage of land for the preparation of seedbeds, offset and disc harrows are used.

The preparation of homogeneous fields for a two-crop rotation of cereals and legumes is an objective of soil tillage operations at ICARDA. The primary soil tillage concept is based on an inverting soil tillage after cereal crops followed by a non-inverting soil tillage after legume crops.

Improved Chisel and Subsurface Ploughs in Egypt

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Abstract

A modified locally manufactured chisel plough and two subsurface plough were tested in field experiments at the Sakha Experimental Station. Distribution of soil draft per meter were functions of the type of implement and the ploughing speed. The subsurface ploughs required less soil draft per meter than the chisel plough. Although no significant differences were measured in the ability of the three ploughs to break up soil clods, the subsurface ploughs performed the tillage in one pass as compared to two or three passes required by the chisel plough.

Introduction

In Egypt, a locally manufactured chisel plough is used to till the soil at depths from 10 to 15 cm. The tillage operation requires two or three passes over the soil surface. The ability of the chisel plough to break up soil clods is insufficient to kill all weeds in the soil. The chisel plough also leaves an unploughed area between the tines.

Therefore, modifications of the chisel plough are desirable for better results under diverse Egyptian conditions such as scant precipitation, wind erosion near the desert, and the heavy clay soil of the Delta and Southern Egypt.

The objective of the present study was to develop and construct a modified chisel plough and two subsurface ploughs. The performance of the three

ploughs was evaluated by comparing the effect of the forward ploughing speed on soil draft and on the surface area of soil clods.

The Ploughs

Three different types of ploughs were designed and constructed for the present study. They were a modified chisel plough, a subsurface sweep flat plough, and a subsurface wing plough.

The chisel plough was manufactured by the Behera Company. It had nine tines arranged in two rows (four in the front row and five in the rear row). The ploughing width was 2 m.

Both subsurface ploughs were constructed at the Alexandria Tractor Test Station. These plows had a common plowing width of 1.6 m. The subsurface cutting width of the blades was 53 cm.

The design of the subsurface sweep flat plough by the author rests on the theoretical basis in the work of Bernacki et al. 1972. The plough has three large cutting width blades arranged in two rows (one blade in the front row jointed at the center line of the plough frame and two in the rear row). Each cutting width blade has two parts. The front part has a peaked shape which tends to deform the soil. The rear part has a large-sweep, flat shape which tends to cut soil layers. Two triangular cutting plates on the blade increase the degree of pulverization and loosening of the soil. Contact with the soil is only across the wings to minimize the friction forces.

Field Tests

Field tests of the three ploughs took place at the Sakha Experimental Station on some of the most heavy clays in the Delta Area. All tests were performed at a plowing depth of 13 cm.

Soil samples from depths of 10, 20, and 30 cm were analyzed for bulk density and moisture content. The

soil draft was measured several times for each ploughing operation to obtain an average value. The three ploughs were operated at ploughing speeds of 3.4, 6.4, and 8.8 km/h on a random distribution of the test plots.

Results and Discussion

Comparison of the performance of the ploughs included measurements of the soil surface before ploughing and the size of the large soil clods after ploughing. The average measured moisture content and soil bulk density values before ploughing were as follows:

Depth (cm)	Moisture content (%)	Soil bulk density (g/cm^3)
0-10	7.7	1.44
10-20	21.0	1.31
20-30	25.4	1.30

The ploughing width of the ploughs varied. Therefore, all soil draft data calculations were based on one meter width of ploughing to permit direct comparison. The results of the average soil draft per meter for the ploughs are presented in Fig. 1.

The distribution levels of soil draft are functions of both the type of plough and ploughing speed. Maximum soil draft occurs with the Behera chisel plough at the high ploughing speed of 8.8 km/h. Minimum soil draft occurs with the subsurface wing plough at the low ploughing speed of 3.4 km/h. The soil draft of all three ploughs increases with an increase in ploughing speed.

The soil draft for the subsurface wing plough was least. At ploughing speeds of 3.4, 6.4, and 8.8 km/h, it required 61.14, 59.63, and 59.20% of the soil draft

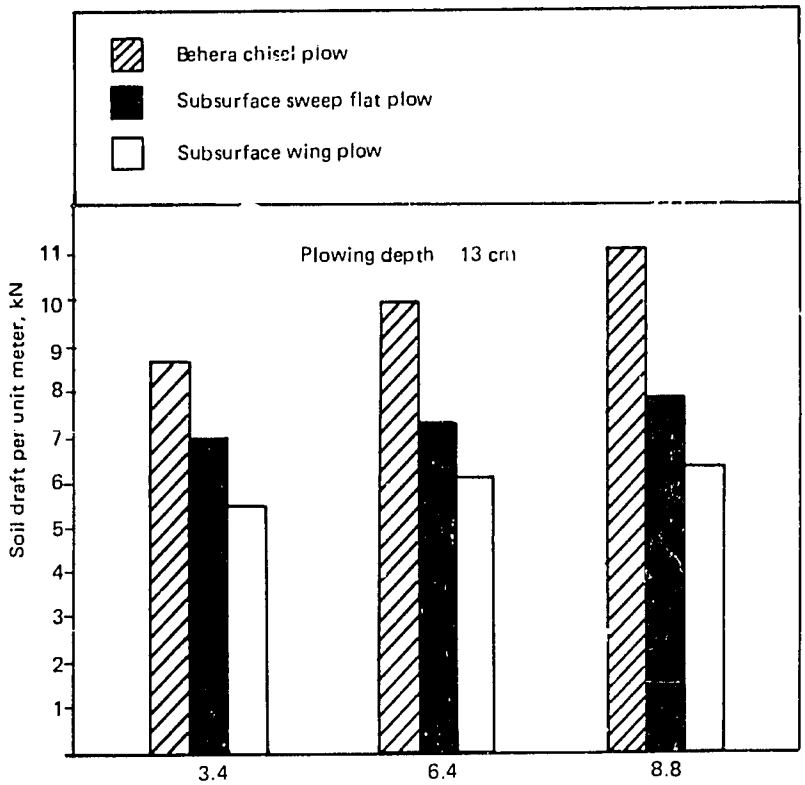

Fig. 1: Distribution levels of average soil draft per unit meter for three different types of plows as affected by plowing speed.

required by the Behera chisel plough. The soil draft for the subsurface sweep flat plough was 78.65, 72.01, and 70.26% of the soil draft required by the Behera chisel plough at the same ploughing speeds.

Fig. 2 shows little difference in the soil break up by the two subsurface ploughs (85.5-88.0%), especially at ploughing speeds of 6.4 and 8.8 km/h. The soil break up by the Behera chisel plough was 82.5% at the same ploughing speeds.

The three ploughs caused the same degree of soil pulverization. The experimental results agree with earlier work of Abou El-Kheir 1986.

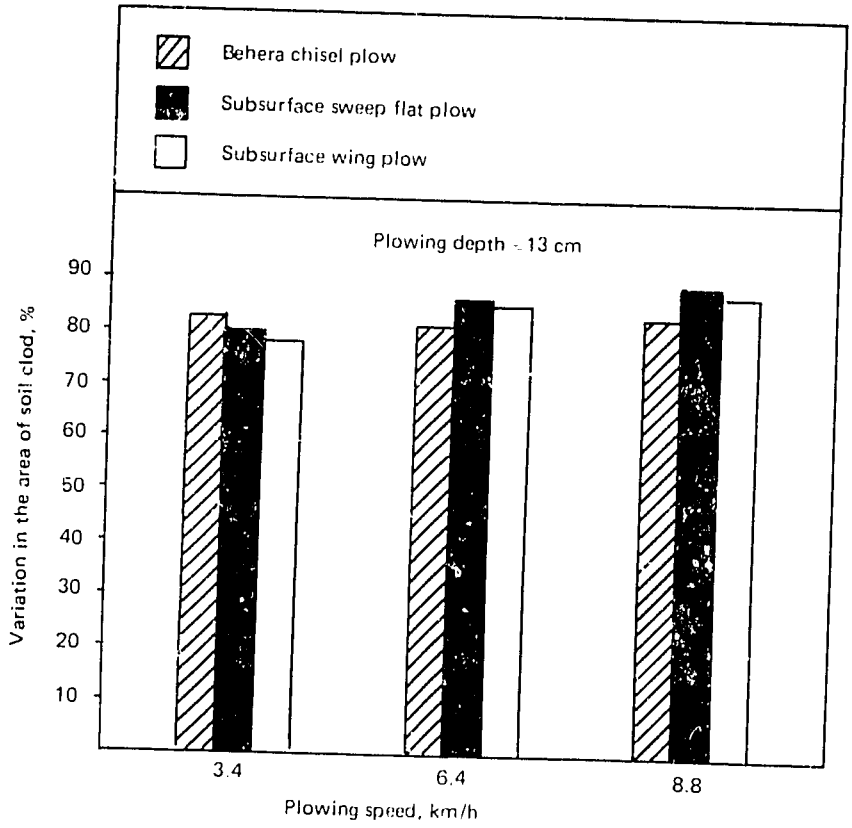

Fig. 2: Distribution levels of the variation in the area of soil clod for three different types of plows as affected plowing speed.

Summary and Conclusion

1. Subsurface sweep and wing ploughs provide appropriate technology for primary tillage in the dry areas because they loosen and mix soil without inversion.
2. The soil draft of the subsurface sweep and wing ploughs is less than the soil draft of the Behera chisel plough.
3. The soil draft of all three ploughs at a constant ploughing depth is affected by the ploughing speed.
4. The ability to break up soil clods was common to the three ploughs.

5. The soil draft and variation of the surface area of soil clods indicate that the subsurface ploughs are suitable for ploughing speeds of 5-7 km/h.
6. The subsurface ploughs break up the soil surface with one pass and with less soil draft. Therefore, further developments are promising for tillage in dry areas.

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Tillage Systems in the Gezira Scheme

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Abstract

The tillage systems practiced in the Gezira Scheme are deep blading, deep ploughing, and shallow tillage. Deep blading, at 30-40 cm depth, is mainly used to control deep rooted and rhizomous weeds. Deep ploughing (20-30 cm) is mainly used to control deep rooted weeds and to disturb and manipulate the soil. In the shallow tillage system, offset and tandem disc harrows are used in some areas and lister ridging machines in other areas for basic operations. Future research programs are suggested to solve some of the tillage problems facing the Scheme.

Introduction

The Gezira Scheme is located on the central clay plains of the Sudan between the Blue and White Nile Rivers south of Khartoum. Most of Sudan's cultivated land lies in these central clay plains which make up 9% of the geographical area of Sudan.

The area under cultivation in the Gezira-Managil Scheme is about 882 thousand hectares. The land is owned by the government, but it is farmed under a tenancy arrangement. Tenants cultivate between 6-15 ha with an average of 8.5 ha per tenant. The main crops produced in the Gezira-Managil Scheme are cotton (long and medium staple), wheat, groundnuts, and sorghum. The Scheme is irrigated by gravity from the Blue Nile River through a network of irrigation canals.

The cotton black soils of Gezira are of relatively uniform parent material. The major physical limitations of Gezira soils arise from their high clay content, structural development, soil moisture characteristics and their low hydraulic conductivities. Soil consistency states are such that the soils are plastic when too moist or hard and cloddy when dry. Therefore, the moisture range in which the soil can be worked under optimum conditions is rather narrow.

Tillage Methods

The objectives of tillage in the Gezira Scheme are to:

- Develop a desirable soil structure for a seedbed
- Control weeds
- Manage plant residues
- Establish a specific surface configuration for planting, irrigation, and drainage.

Tillage operations for seedbed preparation are often classified as primary or secondary although the distinction is not always clear. A primary tillage operation constitutes the working of undisturbed soil to loosen it to the required depth. Secondary tillage is the working of the previously loosened soil into the required clod size and distribution for the correct degree of compaction to give good soil contact with the seed or plant.

Before the best cultivation treatment can be selected, the required soil condition must be defined. Then the best way to transform the soil from its present state into the desired state must be determined. An implement of suitable shape and weight for use in the prevailing soil moisture and consistency conditions must be selected. For each basic cultivation operation, an optimum consistency state exists in which the operation should be performed (if possible). If work is done outside the optimum ideal soil condition, extensive soil damage or a poor result can be expected. The moisture range over which the soil can be worked under optimum conditions in the Gezira Scheme is relatively narrow.

Tillage Systems in the Gezira Scheme

The main factors governing the selection of tillage systems in the Gezira Scheme are the particular crop to be grown and the type of weed and degree of infestation.

On the basis of crop, the land is classified as cotton land (about 200 thousand hectares annually) and other crops (includes sorghum, wheat, and groundnut areas).

The cotton land is prepared by the agricultural engineering section of the Gezira Scheme. The other crop areas are prepared by the private sector. On the basis of the type of weed and the degree of infestation, the land is classified into four categories.

Category (1)

This category includes cotton land which is moderately infested with weeds mainly Cynodon dactylon (Bermuda grass) and Ischarmum afrum (Ankog - local name). The primary tillage system adopted for this category is deep ploughing (30-40 cm). The implements used are the Felico blade, disc plough, and chisel plough.

The Felico blade was designed and developed by the Agricultural Section of the Gezira Scheme in the early sixties. It is a long wide blade with sharp pointed rods in the leading part to assist penetration. The blade is made from high-quality heat-treated steel. It is bolted to two shanks carried on a heavy-duty toolbar. The blade is mounted at the rear of a crawler tractor.

Three-and five-furrow heavy duty disc ploughs are mounted on the three point-linkage of a wheeled tractor. They are usually used in areas with relatively light weed infestation.

The heavy duty chisel plough is used in limited areas. This implement is recommended to replace the blade.

Category (2)

This category includes cotton land which is heavily infested with noxious weeds. The dominant weed is Cyperus rotundus (nut grass). These areas are treated with the Felico blade at 30-40 cm depth.

Category (3)

This category represents the fallow land which is intended to be planted with cotton in the following season. This land is deeply ploughed with the Felico blade. The aim is to cut the weed roots-mainly Cyperus rotundus, Cynodon dactylon and Ischarmum afrum and expose them to dry during the hot summer period.

Category (4)

This category includes the other crop areas (groundnut, wheat, and sorghum). These areas receive minimum soil manipulation depending on the degree of weed infestation. Some areas are treated with shallow harrowing; others are ridged with a lister ridging machine (dry ridging). Immediately prior to planting, the ridges are split with the same machine oriented to build the new ridge on the old furrow.

Large soil clods result from the primary tillage of cotton land (categories 1-3). Offset and tandem disc harrows are used as secondary tillage implements to break these clods into fine soil particles which are formed into ridges by the lister ridging machine. Prior to cotton planting, the ridges are split as described above.

Advantages and Disadvantages of Deep Ploughing

The depth of tillage is an important factor in the disturbance and mixing of soil and in the cutting of weed roots. Deep ploughing helps in burial of saline and alkali concentrations on the soil surface. It also helps in burial of disease-carrying roots to a depth where they are inaccessible for new root growth. Deep ploughing helps to change the water absorption characteristics of soils.

There are a number of limitations to the value of deep ploughing. In many soil profiles, the subsoil contains little plant food. Ploughing deeply in these areas may be objectionable as it places the good soil where it is less accessible to the plant roots.

Although the basic aim of deep ploughing in the Gezira Scheme was to control weeds, development in chemical weed control has now advanced to a point where it is possible, though not necessarily most economical, to control most weeds by spraying rather than by cultivation. Almost all cotton area in the Gezira Scheme is sprayed annually by weed killers. Thus the aim of weed control by deep ploughing is no longer justifiable in Gezira Scheme.

The energy requirement of soil tillage depends on the plough depth, the speed of ploughing, the shape of the implement, and the characteristics and moisture content of the soil being ploughed. The energy requirement of deep ploughing in the Gezira Scheme is considerable.

The Felico blade is a wide tine which requires high draught when working at 30-40 cm depth. The blade cuts the soil at depth and raises the cut soil upwards with little disturbance. As the blade moves away, the cut soil returns to its original position. The harrowing operation following the blading requires more energy than the operation following disc ploughing for it disturbs the soil and breaks the big clods into fine particles as well.

Problem of Soil Compaction in the Gezira Scheme

Due to the current use of heavy and powerful tractors and harvesting machines in the Gezira Scheme, signs of soil compaction are reported, although no scientific work has been conducted to analyze these observations. Trials of subsoiling were run in a limited area in the central part of the Scheme in 1986 to support the belief that soil pans exist in some areas.

The basic aim with subsoiling is to loosen compacted areas within the soil profile and thus permit

the free vertical movement of water and the growth of plant roots. Unless there is a restricting horizon within the soil profile, no response can be expected from subsoiling. The depth of subsoiling is determined by the position of the impeding layer within the profile. To obtain maximum lifting and the displacement of the layer, the subsoiling shoes should be set at 7-10 cm below the compacted layer. The moisture content at the time of subsoiling greatly affects its effectiveness. Subsoiling should only be carried out when the soil is dry to obtain the maximum lifting and shattering effect.

The Role of Research

Farm machinery research is a major component of any mechanization strategy. In Sudan, the research in this area was neglected in the past. At present, promising and well-planned research is in progress. For the Gezira Scheme, tillage operations constitute an urgent problem. The economics of mechanization must be assessed in relation to the short- and long-term response of the soil to crops. Then research can be relevant for field practices.

Research work is needed to answer the following questions:

1. Is the deep ploughing practiced in the Gezira Scheme economically justifiable? If not, what is the most economical tillage system for the Scheme?
2. Does soil compaction occur in Gezira soils? If so, does it have an economic effect on crop growth and yield? Can compaction be avoided or reduced by suitable changes in design and use of machinery? What remedial action is appropriate if compaction is unavoidable?

Seedbed Preparation on Heavy Clays in Semi-Arid Areas

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Abstract

The two-crop rotation of cereals and legumes provides the framework for a tillage concept of combined inverting and non-inverting primary soil tillage. Dry mouldboard ploughing after cereals controls volunteers and gives the cleanest possible seedbed. Non-inverting soil tillage after legumes is performed by a tine implement at depths less than 12-15 cm. The choice of implements for seedbed preparation is dependent on the hardness and roughness of the soil. The rotary harrow works best on hard, cloddy soil. After 15-30 mm of precipitation, a light ducksfoot cultivator with wire cage roller can be used. Disc ploughs and disc harrows are not used in this concept.

Introduction

Soil tillage usually has objectives such as weed control, restoration of good soil structure in the arable layer, removal of plant residues, and preparation of soil for the seedbed. Commercial farming in semi-arid areas has the additional target of water savings and good water storage. On heavy clays, the consideration of energy consumption may eliminate many options. To keep soil compaction and energy consumption as low as possible, the target is a minimum number of passages. Then the choice often is between a tine cultivator and a plough. If the soil tillage is intended for the preparation of homogeneous, clean, healthy fields with well-levelled surfaces for experimental use, you will have to consider a few more points in fitting your tillage concept together.

ICARDA has a good collection of most available soil tillage implements for heavy soils. The inventory of primary soil tillage equipment includes: reversible and non-reversible mouldboard ploughs, disc ploughs, disc harrows, ducksfoot cultivators, sweeps, and chisel cultivators, single-pass machines such as combined cultivator-fertilizer-spreader-seeder, as well as seedbed preparation equipment such as light cultivators, spike tooth harrows with and without wire cage rollers, power harrows, and, last but not least, rollers of the Cambridge or Crosskill type.

Part of the ICARDA Tel Hadya station is used for experiments involving soil tillage as practiced by the farmer and other parts are used for rotational experiments which also include comparison of tillage methods. In the remaining fields at the Tel Hadya station, experiments dealing with plant breeding and crop improvement research are conducted. Therefore, we must constantly keep our fields clean of volunteers. Summer irrigation is necessary because the chemical control of volunteers is difficult and costly ($100 per ha). Some problems with summer irrigation under our conditions are:

1. Not all volunteers will germinate immediately after harvest with the prevailing high temperatures around 37-40°C during July-September.
2. The water required to ensure even germination is not less than 60 mm (sometimes more). This quantity of water will not evaporate in our heavy clays until after soil tillage for the coming season.
3. Prior to irrigation, we perform a very shallow soil tillage of no more than 5 cm depth so that volunteer seeds can germinate. This tillage ensures the availability of food for rodents from harvest to the time of deep soil tillage in September/October.

Problem 3 leads to a further requirement for soil tillage in an experimental station: control of (soilborne) pests, parasites, and diseases.

Under our conditions of a basically two-crop rotation of cereals - legumes, I therefore propose a concept of combined inverting and non-inverting primary soil tillage.

Inverting Soil Tillage After Cereals

Dry mouldboard ploughing of our heavy clays (55-65% clay content) seems possible using modern, strong ploughs with stone security. This ploughing eliminates all problems with summer irrigation as mentioned above, but could result in slightly increased stress for plough and tractor. Dry mouldboard ploughing is best applied after cereals, because it controls volunteers at least as efficiently as with previous irrigation and germination of the volunteer crop, which could also result in a mediocre ploughing performance. It would also give the cleanest possible seedbed which is important if a precision planter is to be used, i.e. for chickpea or faba bean. It is less risky after cereals because most likely a good rainfed barley or wheat crop exhausts the available water more than some of the legumes, especially vetches cut in early April for hay or lentil ripening by mid-May.

Dry mouldboard ploughing will hopefully take care of rodent control without bait and poison distribution on these fields. We also hope that the exposure of the soil after ploughing during August/September would have a positive influence on soil hygiene (i.e. nematode populations). To achieve these targets, the working depth must be no less than 28 cm. This depth is also important if we look at the options in the second year for soil tillage after the legume crop.

Non-Inverting Soil Tillage After Legumes

The primary reason inverting soil tillage cannot be employed after legumes is that it would definitely turn up to the surface volunteers of the last year's cereals that are still able to germinate. These volunteers would have an even worse effect in the Tel Hadya station than having them in the legume crop. As an example, the rotation could be barley segregation population, lentil yield trials, and wheat increases.

The problem of cereals in cereals can be avoided by leaving the previous cereal volunteers as long as possible in the deeper layers (15-30 cm) where they hopefully will rot before being turned up to the surface. This is possible if no ploughing occurs every second year. It remains to be seen whether ploughing in the third year would still turn up healthy cereal volunteer seeds that could emerge in a legume crop. The tillage concept of alternate inverting and non-inverting soil tillage is shown schematically in Fig. 1.

The suitable machine for primary soil tillage would therefore be a tine implement, like a sweep, ducksfoot,

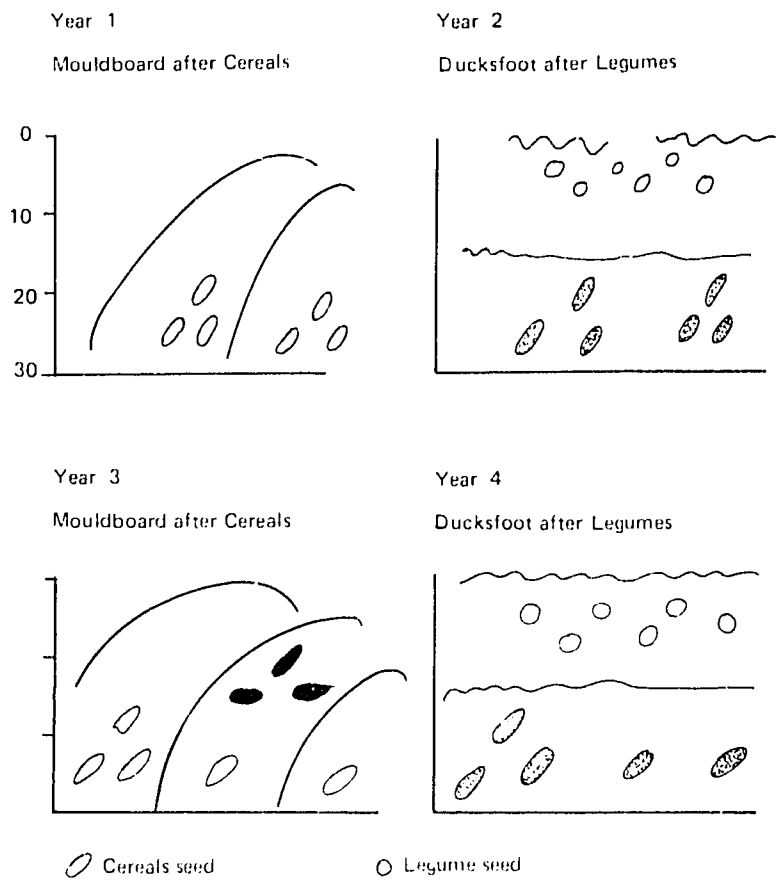

Fig. 1. Effect of alternating deep mouldboard ploughing and shallow ducksfoot cultivation on cereal seeds in a two-course rotation

or chisel, not working deeper than 12-15 cm. This working depth prevents volunteer seeds from being turned up; the soil is not stirred too much in case there is water in the 15-30 cm layer that could be available for the coming crop. This method may require more attention to rodent control in fields after legumes, because the tine implements leave plant residues on the surface.

Two widely used implements not considered very useful in this concept are the disc plough and the disc harrow. The disc plough would work similar to the mouldboard plough, but not as clean. In addition, a reversible version is either unavailable or expensive and difficult to operate. Furthermore, the disc plough has the disadvantage of a very uneven surface, including deep furrows and dams in the working direction.

The disc harrow would perhaps be an alternative to a tine implement, but it would only be recommendable for the incorporation of large quantities of plant material, i.e. faba bean straw. The main disadvantages would be the partial pulverization of the soil and the difficulties in adjusting the machine for an even working surface. (Adjustments would be much easier with a tine implement.)

Seedbed preparation is essential for small plot work. The choice of implements is dependent on the hardness and roughness of the soil. The longer we wait after the first rains, the larger the choice of efficient implements will be. The choice is very often a theoretical one because we must start in September or October although the first safe rains do not occur before November or December.

Our experience is that the rotary harrow works best and most efficient for seedbed preparation of the hard cloddy clay soil in September or October. Options for the hard cloddy soil would be several passages with a disc harrow with 200-300 rpm of the rotors, whereas well-structured soil (dried at the end of the previous season without traffic over it) would be prepared with one passage.

The advantages of the rotary harrow are adjustable impact on the soil, good depth control, very even surface, and the possibility for combination with a seeder (saving one passage when a commercial seeder can be used). The disadvantages are costs and stones, if the model is not robust.

If the conditions are easier, i.e. after a rain of 15-30 mm, a light ducksfoot cultivator with wire cage rollers is an option. The ducksfoot cultivator may leave a relatively loose seedbed, thus creating problems for plot equipment.

The spike tooth harrows alone may not level the surface enough. Spike tooth or spring harrows with wire cage rollers come closer to the quality of a rotary harrow but are not as precise in depth control and levelling of the surface. Furthermore, they tend to clog in wet clays. For all seedbed preparation or other passages after primary soil tillage, i.e. N-fertilizer spreading, we try to fit twin wheels as far as possible. If you want to minimize the number of passages required, you can fit an additional roller on the inner strip between the tractor wheels and choose your twin wheels to match the working width of the rotary harrow. This would leave a seedbed for planting in a perpendicular direction with a plot planter without any problems.

Last, but not least, the roller after seeding has to be mentioned. Pressing stones below the surface of heavy clays after planting under dry conditions can improve germination conditions, plant establishment, and surface levelling which is important to achieve low cutting heights for the following crops: lentil, hay, and lodging crops for seed (e.g. barley and vetches.)

The above concept will now be applied for the second season in some ICARDA fields, and for the first season in slightly more than one-half of our cultivated area. We are still in the early stage of observations. We have noticed that full mechanization of several crops depends very much on the attention given to soil tillage.

Plot Planting Equipment

Recently developed planting equipment being tested include a three-cone planter, a faba bean planter, and a device to test seed drills.

Some commercially available planting equipment and optional accessories are described by two manufacturers.

Mid-Mounted Three-Cone Planter

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Abstract

A three-cone mid-mounted planter has been designed and fabricated at ICARDA, in combination with commercially available Oyjord cone distributors. Three plots were planted simultaneously in 1986. The plot width was 1.50 m; the working width was 4.5 m. The following requirements were satisfied: adequate soil penetration, depth regulation, seed-furrow closure, and row tracking. This planter has the capability to plant all types of cereal, lentil, chickpea, and similar seeds.

Introduction

Conventional planters have limitations when a number of plots are to be planted simultaneously. Single-plot planters are more frequently required and used in the field than multi-plot planters.

To meet the need for multi-plot planters, a three-cone mid-mounted planter was designed and fabricated by the ICARDA Engineering Services. It is mounted on the smallest conventional toolcarrier. Whenever this multi-purpose tractor is required for other farm services, the planting unit can be easily dismounted.

Design

The planter incorporates three Oyjord units (cone feeder and rotating distributor), three commercially

available seeding units, a gear box and three sets of shares, according to the required number of rows (each set having a maximum allowable plot width of 1.5 m). The elements are integrated within an appropriate frame to be mid-mounted on the smallest toolcarrier (Fendt 231GT tractor). The three Oyjord units provide the capacity to plant three plots either simultaneously or individually according to the requirement.

The 60 cluster gear unit is powered by a cogwheel directly driven by the front ground-pto (rpm directly proportional to the forward velocity). The distance between grains can be varied from 2 to 40 cm, independent of tractor speed because the ground-pto is mechanically coupled to the rear-wheel transmission. The total transmission of the cluster gear is divided into three speed ranges. Within each range, 20 rotation clusters are available. This system allows a maximum plot length of 15.5 m. The rotating distributors are driven by three heavy-duty, 12-V electric motors, thus providing a uniform distribution of the seeds. The distance between the rows is variable. The minimum width is 10 cm, and the overall working plot width is 4.5 m.

The entire load (including three operators) of the implement is concentrated on the symmetrical center and distributed along the middle beam. Therefore, the load is not concentrated on a single point.

Operation

The amount of seed for a particular plot length is fed into the funnel. At the beginning of the plots, the three funnels are lifted simultaneously and grains fall into the distributor cones. While the machine travels the length of the plot, the cones rotate 360°. The falling seeds are guided by the run-off jets into the rotating distributors. The grains fall through the holes of the distributor into the individual drill shares. Thus the exact amount of seed is distributed without any remaining seed at the end of the plot.

Observation and Conclusion

During the first trial in 1986, the planter performed well. The distribution was very good and resulted in equal row lengths. Therefore, the observations and comparisons between different rows were enhanced. The reproducibility of planting was within allowable tolerances.

The planter can be used to drill head rows, as well as small and large selection plots, increases, and large multiplication plots.

Faba Bean Plot Planter

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Abstract

A faba bean planter was developed from the Hege 95 machine on the basis of a commercial Nodet Gaugit corn planter. The rear-mounted unit is designed in a 4 row/45 cm row spacing configuration. The system is pneumatically operated to overcome problems presented by the size and irregular shape of faba bean kernels. After use of the planter in the 1986/87 season, operational problems have been identified and corrected. The experience indicates the need for a 100% safe control mechanism so that breeders can use the planter.

Discussion

Approximately 22 ha of faba bean are planted by hand at the ICARDA main station every year. The main reasons for mechanizing attempts were not so much the costs of hand planting ($ 4.00 - 9.00 per laborer daily) but the possibilities for accuracy in planting, mechanical weed control, and better conditions for mechanized harvesting.

In mechanized planting of large-seeded legumes, we started with chickpea, which was easy in comparison to faba bean. The additional difficulties with faba bean come from its size (diameters ranging from 12 to 33 mm) and irregular shape (oval/flat, concave/convex). We needed a pneumatically operated system because the mechanical system would have required much more calibration for the various seed sizes.

We began to look for a suitable faba bean plot planter in 1983. The Wintersteiger precision seeder was too small in all dimensions of the row unit to handle faba bean, especially Vicia faba major. The Hege Company developed the faba bean plot planter from the Hege 95 machine based on a commercial Nodet Gaugit corn planter. The rear-mounted unit was made in a 4 row/45 cm row spacing configuration with central as well as individual row-filling options.

The vacuum system is used for selecting the kernels out of the seed container and keeping them on the singling-out disc as well as for cleaning the surplus seed out of the seed containers. Switching the vacuum flow as well as the filling and emptying flaps are controlled and operated by a pneumatic system. The alleyway length and the cleaning cycle are also pneumatically controlled. The seed distance in the row is adjustable by a sprocket-chain system to about 10 cm. This relatively large distance is a result of the large size of the beans; only 12 holes are left on a disc which usually has 24 openings.

Problems encountered were clogging at the emptying cycle, more than one seed on the disc hole, and irregular starting of the plot cycle.

The clogging occurred when beans repeatedly did not pass through the cleaning outlet of the row unit, but fell back into the seed reservoir of the row unit after switching the vacuum again to planting position. This problem must be solved, otherwise breeders cannot operate such a machine.

The problem of several seeds on the disc hole results from the odd shape of a faba bean that does not allow a scraper to ensure only single occupancy of any hole at the singling-out disc. This creates increasing difficulties with increasing kernel distance in the row, because relatively few kernels are planted per plot row.

The irregular starting of the plot cycle was caused by temperature-sensitive parts in the control system.

During the 1986/87 season, an 8 ha seed increase field was planted with the machine.

Our comments now are:

- A 100% safe control mechanism, i.e. a sensor indicating clogging at the emptying cycle, is required to make the machine safe for use by breeders.
- The largest possible diameters are required for passage of all faba bean kernels to reduce operating interruptions.

We are very interested in extending the use of a precision planter for faba bean to all our breeding work, because complete mechanization of weed control and higher accuracy in planting depth and longitudinal row distribution are possible.

We appreciate the manufacturer's efforts to further develop the present model despite the limited market.

A Simple Apparatus for Field or Laboratory Testing of Seed Drills

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Abstract

A simple apparatus for testing seed drills can be mounted on coulters of seed drills and planters. The metered seeds are fixed to a transparent adhesive tape. The tape and seeds are immediately covered by a paper so the seeds remain fixed and can be studied in the field and at any later time. The device can be used by agricultural engineers and plant scientists as well as commercial growers.

Introduction

Three simple apparatuses for studies of the distribution of seed drills, precision planters, and fertilizer spreaders have been designed by Oyjord, 1984. These devices have the limitation that they are not handy for studies in the field. An apparatus which can be used in the field as well as in the laboratory was invented in 1986. Two field testing apparatuses have been constructed. Preliminary tests have shown that such devices can be valuable for scientists as well as for growers.

Description

The simple design consists of two side walls shaped as a boat (see Fig. 1). Between these sides, a roll of transparent adhesive tape turns on a shaft A through a point B over the bottom C, which is between the two

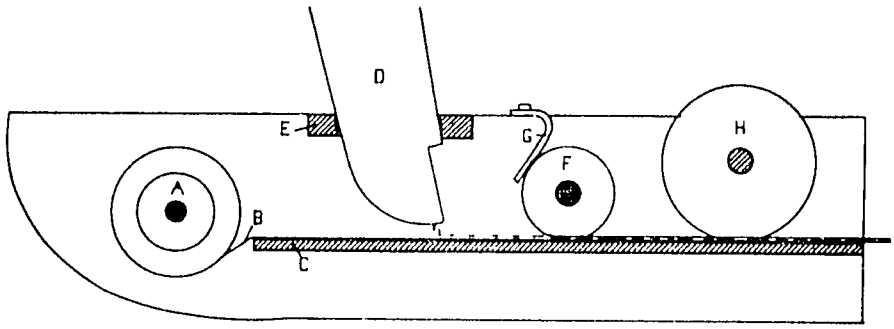

Fig. 1. The principle of Oyjord field testing apparatus for seed drills.

outer walls. The coulter of the drill D pushes the apparatus along the ground, pressing against a piece of wood or metal E. A roll of paper F on a shaft rolls over the tape with the seeds. The roll is braked with a piece of rubber G. A roll of plastic foam H rolls over the paper so the seeds are firmly "stored" between the tape and the covering paper. The end of the tape with the covering paper must be held fixed during a test. The analysis of the tape is the same as described by Oyjord 1984.

An application for patent of the system has been filed. The device will be produced under licence by one or more manufacturers. Orders are welcome.

Reference

Oyjord, E. 1984. Three simple apparatuses for studies of the distribution of seed drills, precision planters and fertilizer spreaders. Pages 116-119 in Proceedings, Sixth International Conference on Mechanisation of Field Experiments (Ward, S.M., ed.). The Institution of Engineers of Ireland and The International Association on Mechanization of Field Experiments. 8-13 July 1984. Dublin, Ireland. The Institution of Engineers of Ireland, Dublin, Ireland.

Plot Planting Equipment of the Hege Company

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Abstract

Three types of planters are included in the Hege line: plot planters, single-row planters, and pneumatic precision drills. They are all self-cleaning, permit seed exchange in the alleys, and provide a high hourly rate of planted plots. The Hege 80 belt cone planter incorporates a modified Oyjord system of cone feeder and rotating distributor. The Hege 90 single-row planter is very versatile with single, small cones feeding each row. The Hege 95B pneumatic precison seeder was developed especially for research work. These planters can be mounted on a tractor or on the Hege 75 toolcarrier. A hand-pushed one-row seeder is also available (Hege 90/1).

Introduction

The planting of agricultural research trials often requires a unique approach. Different crops and experiments can require adaptations of planters.

The available Hege planters are: plot planters, single-row planters, and pneumatic precision planters. They satisfy the following conditions:

Complete self-cleaning after each plot,
Highest possible precision in drilling,
High capacity in plot planting.

Seed exchange in the three types of planters is made within the pathways; it is not necessary to stop between plots. The Hege planters are suitable for sowing seeds ranging from very small to large-sized. The precision in distribution is highly developed.

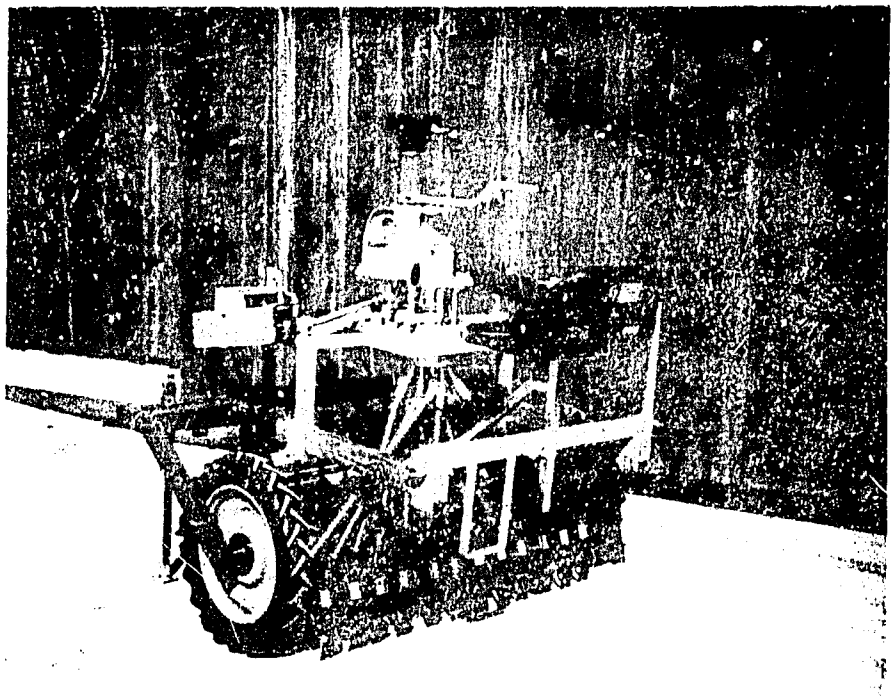

Fig. 1: Hege 80 belt cone planters

The Hege 80 Belt Cone Planter

This planter uses the Oyjord system of cone feeder and rotating distributor. However, the Hege 80 is modified in both respects (see Fig. 1). A belt cone feeder with chrome surface precisely feeds any size or type of seed at high or low rates. The rotoseed distributor (System Weihenstephan) gives high quality distribution of all seeds. Even microgranules can be distributed by the cone feeder and the rotoseed distributor. A range of easily exchangeable feeding funnels allows an optimal predistribution around the belt cone. The flat belt around the cone has a V-belt on the reverse, leading it and allowing it to run without adjustment problems for years. The advantage of belt cones is that there is no rubbing effect between seed and plate, as in cell cones, and they will not carry seed over the exit, either when bigger seeds are used, or when highly loaded.

Additional options are available for automatic feeding systems with magazines or a fluted feeder for continuous drilling. A horizontal levelling system allows absolute precision also on sloping land. Different distribution heads, easily exchangeable from underneath, allow row numbers from 2 - 14. Different coulter types are available, such as shoe openers, double disc openers, and hoe openers, with special depth control systems. Planters are available as tractor-mounted models or in combination with the Hege toolcarriers. Plot widths up to 1.80 m or double units up to 3 m are available. Plot lengths are adjustable by gearbox transmission in various steps between 2 and 20 m or larger. The cone feeder and distributor can also be used as a broadcasting unit for fertilizers.

Stepless adjustment of 10 cm and wider interrow distances can be made. Combinations of two-cone units with a distributor system allow planting with one unit and individual fertilization of each plot with one passage. If microgranules are to be used, it is possible to feed the seeds and with the second feeding the microgranules by the same cone unit. It is also possible to use a small belt cone or a microgranule feeder in addition to the standard cone equipment.

Depending on field conditions, operators, and plot lengths, a capacity between 400 - 800 plots per hour may be reached. A very high standard in precision and multifunction has thus been reached by this belt cone planter with rotoseed distributor.

Hege 90 Single-Row Planter

This type of planter is very popular due to its versatility and open, precise design. The machine has single, small cone units separately feeding each row (see Fig. 2). The cones can plant all kinds of seeds. The options are to feed each row with a different variety or all with the same variety from a magazine or by handfeeding. The Hege 90 planter is suitable for headrow planting as well as for plot drilling. Different additional outfits are available for feeding by an automatic feeding system that is individually and

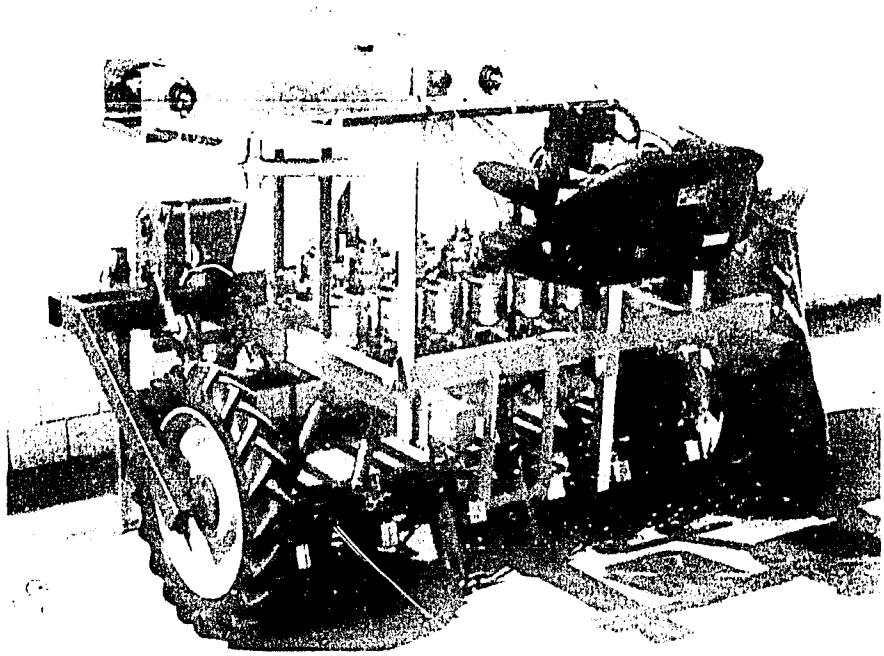

Fig. 2: Hege 90 single-row planters

easily programmable by a station. Mechanical transmission is combined with an electric program unit, which can hold up to three stored programs. An electronic program unit is also available. It eliminates the influence of ground slip on plot lengths and can be easily programmed locally.

The distribution of the Hege 90 machine has proven to be very good. Rows have the same length, which is helpful for interrow observations and comparisons. However, the distribution is not as even as that given by pneumatic precision planters.

Hege 95B Pheumatic Precision Seeder

This pneumatic planter was developed in cooperation with ITCF/France. It is especially adapted for research work and is a further development of the Nodet pneumatic system which has proved highly successful throughout the world.

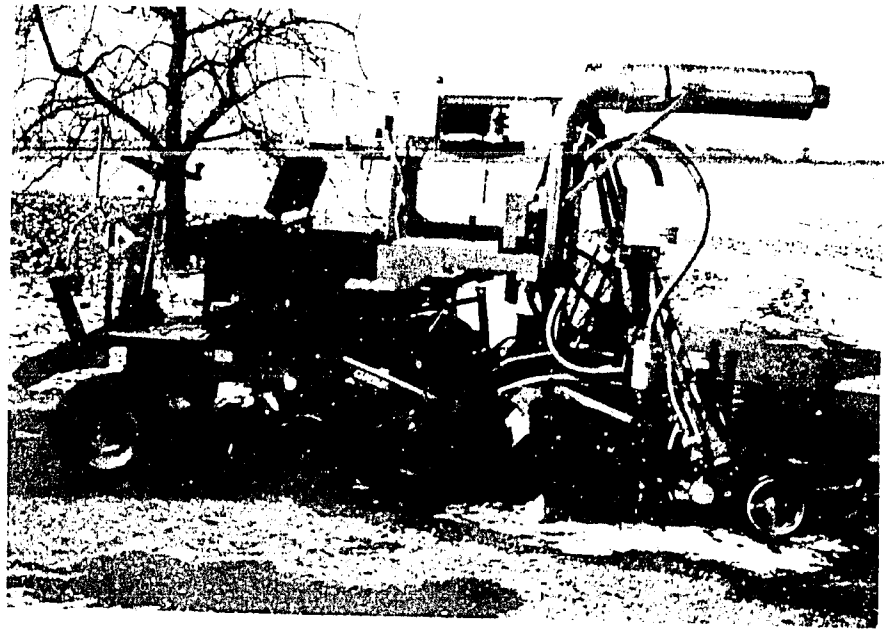

Fig. 3. Hege 95B pneumatic precision seeder on a Hege 75 toolcarrier

The Hege 95 pneumatic planter combines a very high precision in drilling with an immediate and complete seed exchange without stopping while travelling along normal pathways of 50 cm width or wider. Seeds ranging from very fine to large beans with 800 g 1000-kernel weight can be drilled at the rate of 200-500 plots/h. (Heavier 1000-kernel weights can be handled by special models.) Grain spacing between 2 and 40 cm can be selected; row distances of 16 cm and wider can be selected. Depending on the program, the planting speed is 1.5 - 4 km/h. (See Fig. 3).

The seed exchange is governed by a pneumatic register that is adjustable in its time relations. It is shifted as a manual command by pressing a button or shifted automatically by an electric or electronic program unit. The system is based on discs with holes and an air vacuum. The hole sizes and numbers of holes in the discs depend on the grain size and the required grain spacing. Together with an adjustable mechanical transmission shift in 2 x 50 steps, all desirable grain spaces can be reached. Although the last grain can be

taken from the seed chambers, there should be about 5 - 15 extra kernels per row to be sucked off at the end of each plot. The seed exchange is completed within 1 - 2 seconds.

The seed feeding is done either manually or automatically by magazines. Different size magazines are available. Each row can be fed with an extra variety or a central feeder-divider may be used. The installation of central feeding together with individual feeding is possible. Two or three rows can be fed together as a group. The universal type coulters ensure good ground penetration. Different shoes enable deeper or shallower positioning of the grains.

The depth control system is standard equipment. Different press wheels are available. Combination with an applicator for microgranules to each row or with extra shoes for fertilizer application is available. The vacuum for the pneumatic elements and the compressed air for the seed exchange process is serially installed and driven from the pto shaft. A very silent fan results in low noise during the operation. The same machine can be used for different crops by only changing the discs. Little work is required to modify row distances.

The Hege 95 B pneumatic precision drill is available as a tractor-mounted type (up to 12 rows) as well as on the Hege 75 toolcarrier (up to 4 or 6 rows), thus becoming a self-riding unit.

Hege 90/1 Hand-Pushed One-Row Seeder

This hand-pushed seeder uses a small belt cone unit (see Fig. 4). The machine can perform the drilling work for a large range of crops in different row lengths with very high precision. The manual feeding of seed for each row is a simple operation carried out by one worker. A special accessory allows easy conversion for continuous drilling with this type of planter. It is useful as a planter for special research programs.

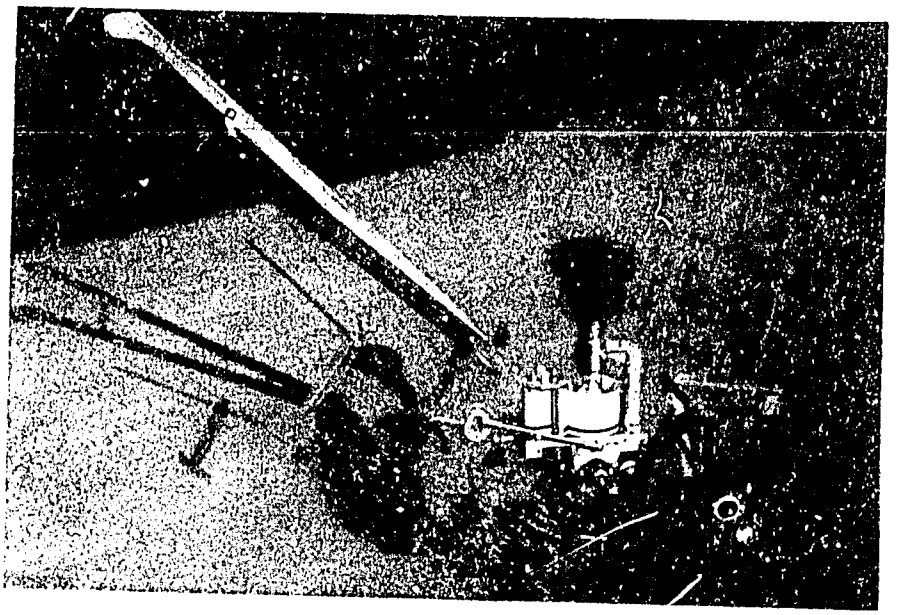

Fig. 4: Hege 90/1 one-row seeder

The Hege 75 Toolcarrier

This medium-size machine is specially designed for multipurpose use in research work. It is equipped with an 18 hp gasoline engine or 20 hp diesel engine. It can transport weights up to 400 - 500 kg between the rear wheels. All Hege planters can easily be mounted to this machine. The Hege 33 fertilizer distributor system, spraying systems, and cultivators can also be used with this carrier.

Standard widths between 1.25 m - 1.50 m or larger widths up to 2.50 m are available. Hydraulic or pneumatic systems are integrated to lift the tools. A pto shaft with 400 - 700 rpm regulated by the motor speed (shifted on or off separately) is integrated.

This toolcarrier is a very simple design, extremely maneuverable, handy, and strong. Special versions with high clearance (ca. 80 cm) or equipped with low pressure tires are available. Speed monitor and monitor for pto shaft can be supplied. Single wheel brakes and a mechanical drive system with six gears forward and two gears backward are integrated.

Precision in Plot Planting Equipment

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Abstract

Precision spaced planters plant a single seed with exact, predetermined intrarow spacing. Wintersteiger models include precision spaced planters and modified Oyjord cone planters. Different meanings of the term "precision" in plot planters are discussed. Guidelines are given for the evaluation of plot-planting equipment by potential buyers in developing countries.

Introduction

All agricultural machinery used in plot operations must be precise. However, precision must be understood as a function of certain design features, operating methods, and the results which are expected from or achieved by the planter. There is also a time factor to be considered. Under certain conditions this factor correlates inversely to the degree of precision. Hence, both factors have a bearing on the price of the equipment.

Misinterpretation of the concept of "precision" may lead to the purchase of equipment which does not fulfill expectations or which could have been purchased at a lower price. Such cases occur frequently in developing countries due to the lack of expertise or information. This paper is intended to contribute to a better understanding of the relevant criteria and to enable the user to better judge potential investments.

To clarify some of the common confusion about the meaning of "precision", the presentation of Wintersteiger plot planters is followed by a discussion of the different meanings of "precision" in plot-planting technology.

Precision spaced planters are designed to plant only one seed at a time, with exact, pre-determinable intrarow spacing. Precision refers to the distribution and the placement of the seeds in each row and the fact that they are individually planted. The number of seeds must be exactly the same in each row. Their position across the width of the plot should also form straight lines. A better name for such a planter would be numeric planter. All of these planters work on the vacuum principle.

The modular precision spaced planter mounted on a diesel-powered, Plotspider chassis is shown in Fig. 1. It is a self-propelled unit. Since the technical function of a precision spaced planter is to pick and place only one seed at a time, its performance is defined by the number of seeds it is able to handle in a unit of time. The Wintersteiger precision spaced planter plants up to 20 seeds/sec and is the fastest planter on the market today.

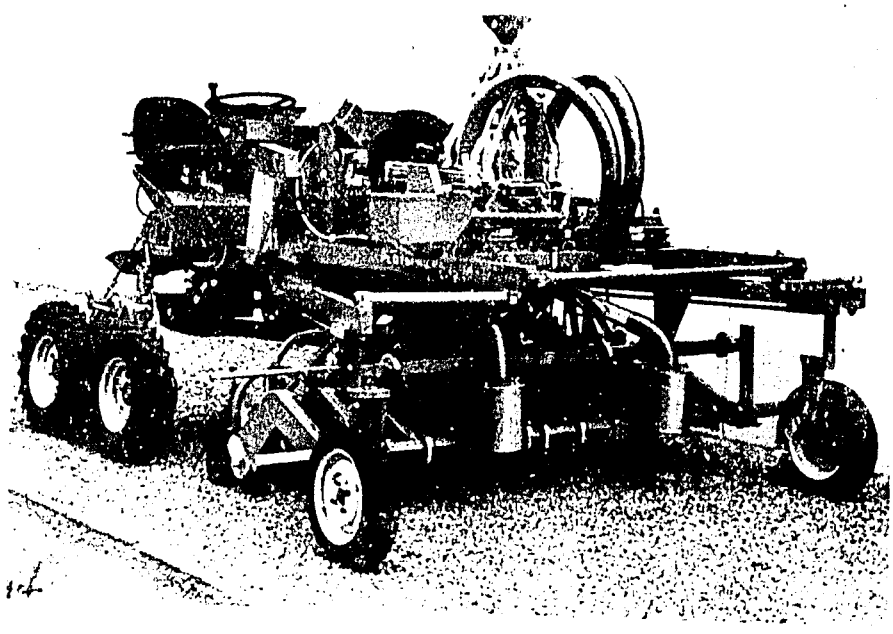

Fig. 1. Modular precision spaced planter for six rows of cereals

However, this does not mean that the ground speed must also be high. When 20 seeds/sec are placed at 3 cm distance, the ground speed is only 1.08 km/h. The operational speed of a precision spaced planter is related to the physical nature of the seeds as well as to the pre-selected intrarow distance. The planting speed is usually slow.

Whereas the seed sample is prepared by weighing or the approximate counting of the seeds into a small container or envelope, the number of required seeds are placed exactly because the planter counts the seeds out one by one.

Depending on the design, all such ordinary space planters are more or less modified systems of normal farm units where sophisticated shutter or trap systems must be added to the metering unit, but which are still sensitive to the rather wide variations in size, weight, and shape of the seeds, e.g. with breeding material. The only unique and new construction where the combination of two discs allows a much greater variation in seeds is offered by Wintersteiger Company. The planters may operate in a stop - go mode when the plant spacings are very small and the alleys between plots are not wide, or in a nonstop mode when the intrarow distances between the plants are larger, the alleys are wider, and the plots are shorter.

A very simple version of this planter is designed for use in small operations or in developing countries. It is offered as a self-propelled planter, either as a module for the tractor-mounting frame or for the small-chassis Plotman. All the unique features of this patented system are incorporated into the machine, yet arranged in a way that is very simple and easy to understand and for a price which is no higher than for a normal plot planter such as the Oyjord cone planter.

A normal plot planter like the Oyjord cone planter may also be described as a precision planter, but here precision refers to the precise distribution of a defined number of seeds within the given area (plot) in adjustable seed rows. The number of rows may be selected, but it is related to the plot width and the

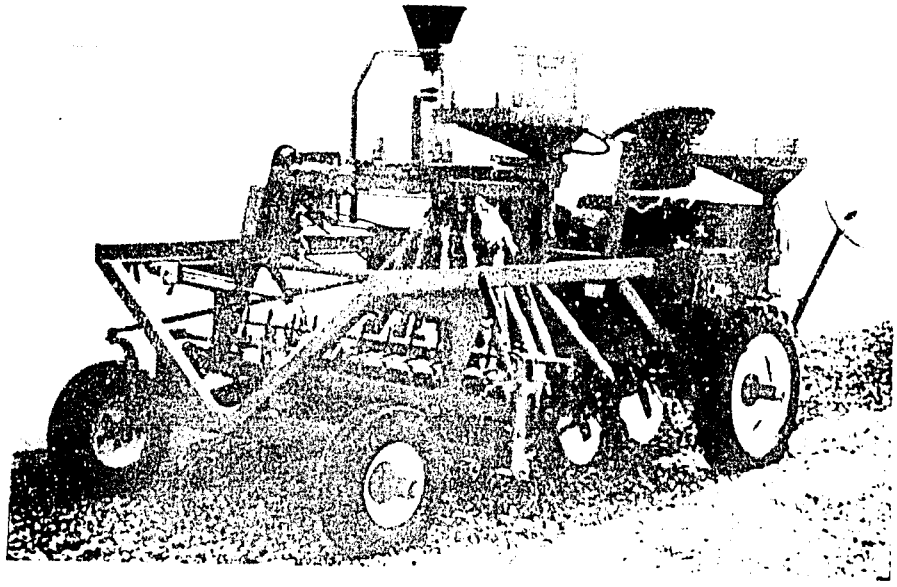

Fig. 2. Modular Oyjord cone planter for 12 rows

interrow distance. Precision here refers to the plant population. The number of seeds within one row may be different from that of another row. The distance between the plants is random. Due to the technological characteristics of systems which use cone distribution, the spacing of the single seeds must be variable from 0 to a random maximum. A better description for such a planter would then be "Randomized Planter".

The modular Oyjord cone planter mounted on a diesel-powered Plotman chassis is shown in Fig. 2. It is a self-propelled unit.

A cone planter uses gravity and centrifugal force only. Its performance is limited by the maximum speed with which it can be driven over the field, and by the speed with which the planter operator is able to refill the planter with the next sample before the next plot starts. The operational speed of a cone planter is neither related to the physical nature of the seeds nor to their intrarow distance (density). The planting speed is usually very high.

The cone as the metering unit is followed by a spinner distribution system. The function of this system is to distribute the seeds from the discharge opening into the relevant seed tubes and thus into the corresponding furrows. Spinners are of different designs; every producer claims that his design performs with the best efficiency. All spinners share a common feature: the faster the rotation, the more uniform the distribution.

To avoid damage to the embryo from the impact when the seeds fall into the spinner, the Oyjord cone planter has a dynamically shaped spinner, which was empirically developed to handle the seeds gently and allow for a higher spinner speed at the same time. The seeds are transferred from the spinner to the seed tubes and the furrow openers. The slide angle of the latter must remain as steep as possible (to ensure that the seeds fall as quickly as possible). Therefore, the height of the cone distributor above the seed furrow must not fall below the critical level.

When a single cone serves for one row, the diameter of this cone is limited by the minimum interrow distance. A certain height is also necessary; otherwise the slide angle of the seed tubes will again not be sufficiently steep.

Discussion

Several implications of the term "precision" with plot planters are now discussed. Precision within the plots as far as seed distribution is concerned may be divided into three categories, namely:

at the start of the plot,
in the main area,
at the end of the plot.

At the start of the plot, a precision spaced planter will produce a precise, uniform stand. If the design of the metering units allows it to be adjusted and synchronized as with the Wintersteiger precision spaced planter, the plot will start with a lateral line

of plants, regardless of whether the planter is working in a stop-go or nonstop mode.

With a cone planter, the start of a plot will be different. Such a planter normally only operates in a nonstop mode. The Oyjord cone planter has lamellae which hold the seeds after they have been released from the funnel and distributed evenly over the case of the cone. At this moment, some seed will immediately fall through the discharge opening into the spinner and down into the seed furrows.

With a belted cone, seeds will also fall directly through as soon as the funnel is lifted. This is a basic effect with both systems. With both types of cones, deflectors above the discharge opening may prevent the direct fall of seed, but they add the deflected seeds to the start or the end of the plots, thereby increasing the seed density.

Therefore, the seed density at the start or the end of the plot is distorted. The effect of the density distortion with the Oyjord cone planter is a fixed ratio of 4.1% of the plot length with the large cone or 6.25% with the small cone for any amount of seed. This effect with the belted cone where the seeds may slip sideways into the discharge opening with an amount of e.g. 0.3 dm^3 for plots of 12 - 16 m length or densities of more than 200 seeds/m^2 is added to the basic one and will distort up to 8.4% of the plot length. However, with small amounts of seeds of e.g. 0.1 m^3 for plots of 4 m length or densities of less than 200 seeds/m^2, not more than 5.5% of the plot length will be affected.

The density distortion is the reason that belted cones are commonly used in shorter plots only, while Oyjord cones are used for all plot lengths even up to 23 m. When the diameter of the cone decreases, these errors will increase by the same correlation factor in both systems. No influence is manifested on the population of the plot but the plant density at the start of the plots is slightly different.

The different lengths of the seed tubes which feed the outer rows and those which feed the center rows

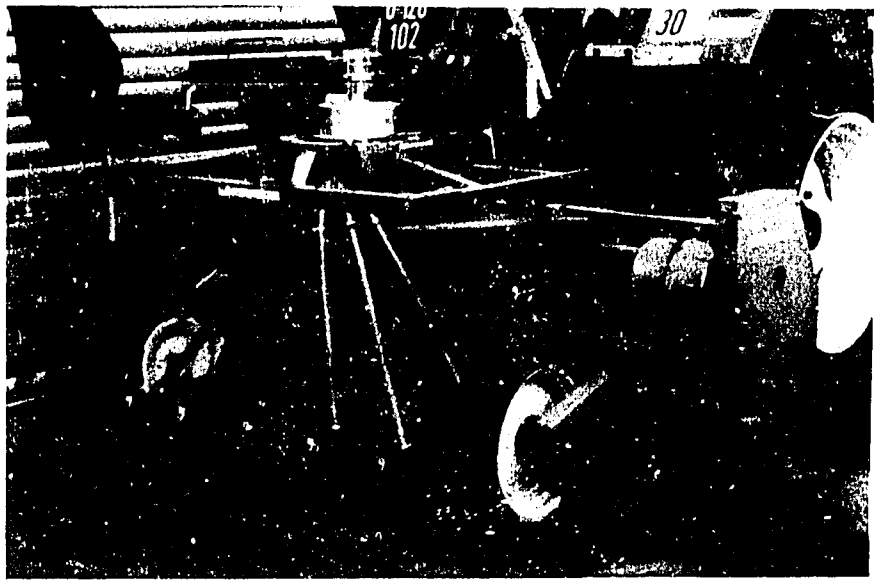

Fig. 3. Modular 10 row. Oyjord cone planter on TRM chassis

introduce some error from virtually all cone planters. Seeds travel down the almost vertical center feed tubes faster than they travel in the outer tubes with their flatter inclination. This peculiarity causes a flat-wedged shape at the start of the plot. The higher the planting speed, the more distinct the wedge, because the seeds arrive earlier at the center rows than in the rows at the side of the plot. This effect occurs only at the start and end of a plot and at the alley. (See Fig. 3.)

A high degree of precision is reached with belted cones when they are filled to a height less than 15 - 20 mm. With normal populations, this corresponds to a high degree of precision in plot lengths up to 4 m.

A high degree of precision is reached with Oyjord cones when they are filled to a height less than 10 mm, which corresponds to 0.7 dm^3 with the large cone and 0.55 dm^3 with the small cone. This corresponds to a high degree of precision in plot lengths up to 16.5 m with the large Oyjord cone and 7 m with the small one. (See Figs. 4 and 5.)

Fig. 4. Belted cone shows dispersed plot end

Fig. 5. Oyjord cone shows delimination at the plot end

In the main area of the plot, the precision spaced planter will perform the numerical and synchronized placement of seeds in the same way as at the start. The precision with which a cone planter plants the plot depends on the performance of the spinner system to which the seeds are conveyed after they have been discharged through the opening in one sector of the circumference of the cone. In a belted cone, this opening is merely a segment where the belt is lifted off the cone. However, the opening at the bottom of the loop of the Oyjord cone (with its lamellae) must have a reniform shape. With this shape, the opening reaches up to three lamellae simultaneously, and thus the seeds are fed uniformly into the spinner system.

This is the case even when very small quantities of seed are planted. The seed then gather on one side of each cell at the wall of the lamella but also discharge uniformly and evenly due to the reniform shape of the opening.

The modular precision spaced planter shown in Fig. 6 is semiautomatic with manual filling. It is mounted on a TRM tractor chassis.

Uniformity of precision at the start, middle, and end of the plot is maintained with the precision spaced planter and the Oyjord cone planter because the seeds are positively discharged. However with the belted cone, the same degree of error as described under "start of the plot" must also be expected at the end of the plot.

With all types of cone seeders, the wedge shape at the start of the plot occurs again at the end where the wedge now points the other way but has exactly the same shape.

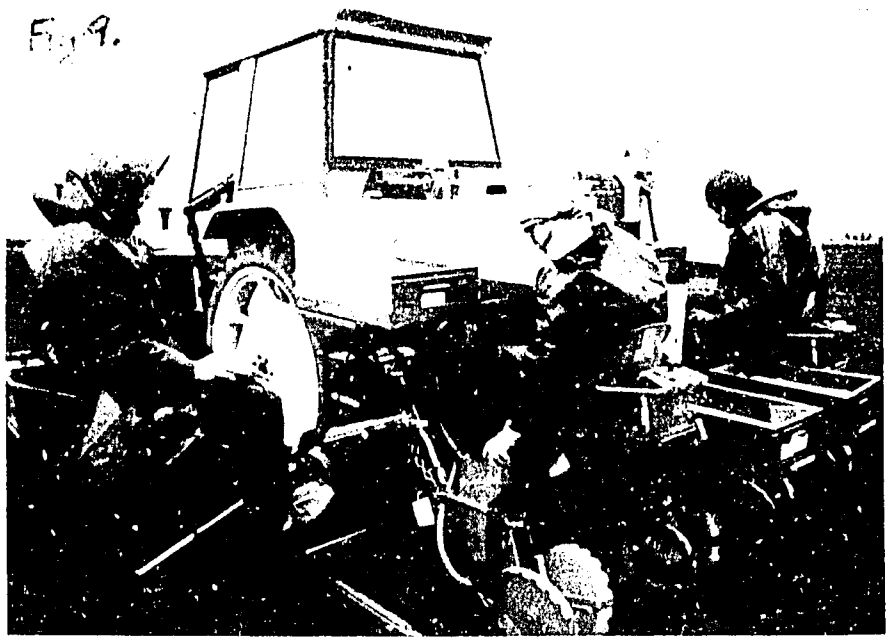

Fig. 6. Modular, four-row precision spaced planter

Precision between two consecutive plots is related to interplot contamination (carryover). Two effects here are a technical effect related to the design, and a human effect related to the operator of the planter.

The technical effect

A precision spaced planter performs the necessary operations like cleaning, refilling, and preparing the first seed for the start of the next plot in the alley between plots. The earlier models dumped the remaining seeds after each plot in the alley. Now the remaining seeds are evacuated from the metering units and collected in a small container to avoid displacement. Depending on the available alley width, the precision spaced planter must either be able to stop in the alley, as is necessary when very short alleys (e.g. 30 - 50 cm) are requested (stop - go mode), or move over the alley at planting speed (nonstop mode) for the planting of traditionally wider spaced crops, e.g. corn. If the operation is large enough to require a fully automatic planter and the required high performance justifies the high investment costs, then for the first mode a self-propelled planter with a hydrostatic drive, such as the diesel-powered Plotspider, would be necessary. Otherwise, the small, inexpensive, but rather slow, manually operated Plotman would be preferable. For the nonstop mode, the precision spaced planter mounted on a standard farm tractor with an independent pto shaft and a three-point linkage would be a good choice.

The Oyjord cone planter functions on the principle that the planter has been adjusted in such a way that the cone has completed one full revolution by the end of the plot. The last seeds which have fallen out define the end of the plot. The alley between the plots is achieved, when the empty cone keeps turning for a part of one revolution, which defines the length of the alley. Therefore the cone planter is completely empty at the end of the plot simply due to the force of gravity. The wedge shape at the start and the end of the plots is the reason a few plants grow in the alley, where they are eliminated as a result of mechanical

operations or by the application of chemicals to clean the alley.

The human effect

Precision among consecutive plots or interplot contamination not only depends on the equipment but on the operators. During a long day's planting by manual operation, the repetitive movements of the hands result in lapses in concentration of the operator due to tiredness. The shorter the plots, the greater the probability of operator error, such as feeding the wrong sample, feeding too soon or too late, starting the plot in the wrong place or not at all. These errors may be avoided by automating:

The filling operation (semi-automatic),
Measuring plot lengths and alley widths (semi-automatic),
All functions (fully automatic).

Automation of the filling operations is achieved by the Wintersteiger Seedmatic magazine system. When planting is organized in this way, the layout of the experimental area, the planning of blocks, repetitions, etc. must be fixed well ahead of planting and may not be altered, enlarged, reduced, or reorganized either shortly before or during planting time. Automation of the filling operation is not reasonable unless an automatic length-measuring system is also used.

The following telemetric systems can be used in automated measurements of plot lengths and alley widths:

Wheels with a mechanical drive connection to their control,
Wheels with an electronic pulse generator,
Cable systems.

Special wheels for metering purposes must be positioned in the tracks of the big wheels of either the planter or the tractor to find as smooth and even a surface as possible, because clods or stones significantly distort

the accuracy of the measurements. The use of big supporting wheels on a tractor-mounted planter for metering purposes is a stopgap solution because the weight of the planter causes the wheels to form tracks as they more or less uniformly compact the soil. The same applies to the driven wheels of a self-propelled planter used for this purpose. Here the distortion would be even worse, since the uncontrollable and variable wheel slippage which inevitably occurs as a result of differing soil types, will clearly exacerbate the measuring errors. The error coefficient from the use of supporting or driven wheels varies between 5 and 10% and is unacceptable for the measurement of subsequent plot lengths for precision spaced planters or cone planters. However, it is adequate for the measurement (and control) of the intrarow distances between the single plants of a precision spaced planter when it is used as a module on the Plotman toolcarrier.

The special wheels for measuring purposes which are mechanically linked to the controls of the planter by shafts and chains with cams are outdated. Modern planter systems use an electronic pulse generator located in the hub of special metering wheels which do not operate on the principle of friction but use an electronic device to convert the signal into the mechanical movement of the relevant part of the planter. The electronic control device, as provided with the toolcarrier Plotspider for the Wintersteiger precision spaced planter, allows up to 10 different programs for automatically repeated plot lengths and alley widths.

Cable measurement systems are widely used in the United States and France. They are superior to special measuring wheels because greater precision is achieved when the length of one planted area exceeds 200 m. Check markings should be placed every 50 -60 m across the field. When special metering wheels are used, the expenditure for the additional labor increases the costs. However, as cable systems use cams to trigger the control functions of the planter, they can only provide one type of signal and may therefore only be used in planters where the alley length is set and controlled by the planter itself, as is the case with

the Wintersteiger Oyjord planter and tractor-mounted precision spaced planter. Cables may have any length. Minor deviations up to a maximum of 3% are automatically compensated for over the total planting distance along one length of the cable.

The precision of the precision spaced planter may be increased by installing a planter monitor. This device monitors the regular and precise placing of the seeds in the seed furrow. In the event of no planting of seeds or clogging of the cleaner, the monitor would indicate the source of the trouble.

The total automation of all planter functions requires automatic filling and automatic measurement. Total automation is only possible when the planter continuously indicates which steps are being performed to permit the operator to recognize and correct irregularities at once. Totally automated planters represent the latest and most advanced type of planter if the manufacturer has selected the components according to the above criteria. Optimum precision is reached only when all possible errors (mechanical and human) have been minimized or eliminated. However, the importance and size of the operation, the degree of available service, maintenance, and repair facilities as well as a highly competent technical staff, must be carefully considered if such an investment is to be justified.

Summary and Recommendations

Major consideration must be given to the agronomical requirements, the size of the operation, the current conditions, and human factors in the evaluation of plant-breeding equipment. Recommendations are given to provide guidelines for potential buyers in developing countries.

1. Criteria related to the agronomical requirements and the demands which will be placed on the new planter:
   * interrow distance,
   * intrarow spacing (seeds per meter),

* planting depth,
* crops, described according to species, 1000-kernel weight (test weight) and deviations,
* plot lengths,
* plot widths (number of rows multiplied by the interrow distance),
* alley width between two subsequent plots,
* separation of neighboring plots (number of rows or distance between adjacent plots),
* number of rows which form a plot (one to the maximum),
* description of soils,
* seedbed preparation (good, normal, rough or reduced tillage),
* application of fertilizer between, on, or sideways under the seeds (lay-by fertilizing),
* application of micrograules.

2. Data concerning the size of the operation to be performed and how it can best be achieved by the new planter:
   * total number of plots,
   * number of plots per experimental field,
   * number of working days per planting season,
   * number of qualified staff available for planting.

3. The current agrotechnical conditions at the investor's facility:
   * tractors for plot work,
   * self-propelled equipment,
   * repair and maintenance,
   * compatibility with equipment currently owned,
   * installation of a new spare parts store or extension of an existing one.

4. Human factors and the educational level degree of the staff:
   * extent of experience in operation and maintenance of similar equipment,
   * estimate of training requirements.

5. Spacing of the plants:

Individually placed seeds (numerical) require a precision spaced planter only. Thinly scattered plants (at random) may be achieved by a normal plot planter (e.g. an Oyjord cone planter) much faster and less costly.

If both normal plots and individually placed plants are to be planted, then one chassis with a precision spaced planter module and a cone planter module is recommended. However, if the total operation is large, investment in two separate planters might be considered. To facilitate operations and service, it is advisable to purchase planters with the same chassis (the basic unit). The planter modules attached to the chassis would be interchangeable. But this significant technical advantage should not affect the operational performance of the planter, ease and clarity of operation, serviceability, and the centrally placed mounting of the planter module between the front and rear axle of the planter, which are equally important factors.

6. Type of travel gear

Although every farm has a tractor, the suitability of a tractor for planting operations is limited. The interrow distances must be wider than the width of the rear wheels plus a 10% safety margin. A plausible reason for selecting an existing tractor would be limited funds, service, or maintenance.

Since voice communications between the planter operator and the tractor driver is not possible, optical and/or acoustic signals must be provided. When the tractor is used with a precision spaced planter, attention must be paid to the ground speed in first gear. The tractor must have a gear slow enough to let the pto work on its standard speed to ensure good functioning of the blower. It is not possible to reduce the ground speed by throttling back because then the pto shaft would also rotate more slowly and the vacuum blower would not produce enough suction. This would subsequently lead to

the malfunction of the planter. Wider intrarow distances allow higher planting speeds which illustrate the better suitability of tractors for the traditionally wide-spaced crops. If a stop - go planting mode is required, a tractor is not advisable, because its mechanical clutch is not built for frequent stops and would soon wear out. For this mode, only tractors with hydrostatic drive are suitable.

Hence, a self-propelled planter represents the ideal solution in every respect (see Fig. 7). A travel gear with a hydrostatic drive as is fitted to the Plotspider offers many advantages: easier adjustment with regard to distance between plants, plot width, planting speed, soil condition, traction, ease of handling for the operators, and last, but not least, automation. The higher degree of sophistication, however, must be complemented by an after-sales service organized jointly by the supplier and the investor. The only real limitation is the relatively high investment costs.

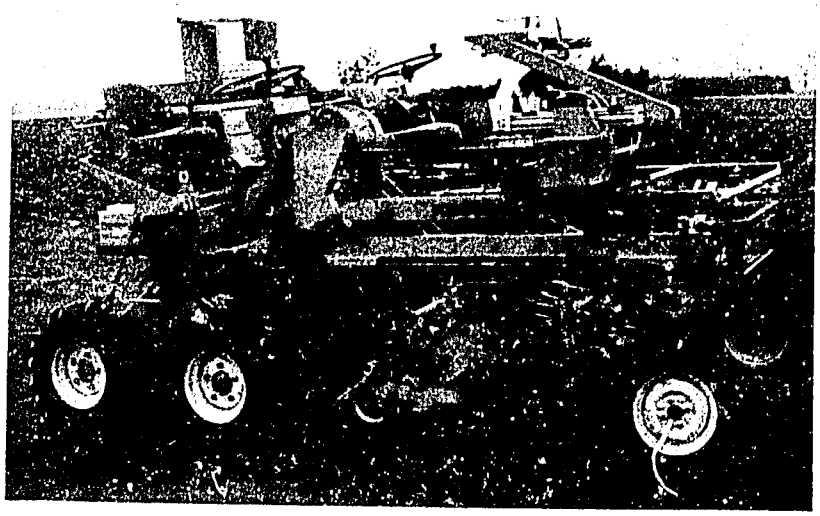

Fig. 7. Modular precision spaced planter

One possibility for smaller operations or for a simpler level of agrotechnical technology is the Plotman as a simple travel gear with mechanical drive. The functional performances of the precision spaced planter and the Oyjord cone planter are the same. However, the planting capacity is lower with the precision spaced planter module on the Plotman, due to the lower number of rows, the reduced power of the smaller gasoline or diesel engine, and because this combination allows a stop - go mode only. However, when a Plotman is used with an Oyjord cone planter, the planting capacity is only slightly less than of a Plotspider with an Oyjord cone planter, because the top speed of the Oyjord system is only limited by the condition of the seedbed.

Last but not least, consider the degree of automation for it contributes considerably to precision. Automation does not aim to set people free, although this may sometimes be a very welcome side effect.

Automation primarily concerns telemetric systems. Depending on plot lengths and planting speed, it removes the need for markings and for an operator to trigger the planter in a split second at the marking. As a technical device, it also makes the start and end of the plots more precise.

On the other hand, the operators have a mere 5 -6 sec to grab the next sample, open it, and dump it into the proper funnel.

Wintersteiger introduced the fully automatic Elite Planter Seedmatic, developed by the "Bayerische Landessaatzuchtanstalt Weihenstephan". Like the Oyjord cone planter, it is a breakthrough in the mechanization of plot-planting operations due to its magazine system. If the seeds are organized in magazines before the planting season, the planting itself may be accomplished in the shortest possible time. However, the organization and planning requires a methodical approach.

Telemetric and magazine systems represent the highest degree of automation and sophistication. A planter is a wise investment, if it is matched to the given operational, technical, and human requirements. However, the understanding of "precision in planting" is the first and most important basic requirement.

Harvesting Equipment

Development is reported of a straw and chaff collector to provide material for analysis of the grain-straw ratio.

Plot combines are described by three manufacturers.

Compact Straw and Chaff Collector

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Abstract

A compact straw collector has been developed at ICARDA to provide an efficient device for the analytical study of the grain-straw ratio (yield factor) by cereal scientists. It can easily be fitted to any plot combine and does not require any additional mechanical propulsion. The kinetic energy of the main airstream generated by the combine blower is utilized for the entire collecting process.

Introduction

Cereal scientists require an efficient device to collect material for analysis of the grain-straw ratio (yield factor). Neither commercially available straw collectors nor a simple box-type collector is suitable for this experimental purpose. Therefore, a compact straw collector was designed at ICARDA to obtain the best performance at a relative low cost with easy operation. It can be fitted to a piot combine harvester.

The objective is to collect all straw and chaff without affecting the existing separation of grain from chaff. The simple operation of the collector does not require skilled labor.

Principle of Collection

The principle of collection is based on the separation of the non-grain matter from the airstream by applying

aerodynamic principles. The gravitational forces and the inertia of solids (straw, chaff, and plant rest) separate these particles from the airstream using streamlined obstacles. The principle is illustrated schematically in Fig. 1.

When an airstream carrying solid particles flows over an obstacle, it is deviated, whereas the solid particle continues in the path, due to its own inertia, and strikes the obstacle. Due to this impact on a series of carefully distributed obstacles, the particles are separated; a gradual dissipation of the kinetic energy is also achieved. With the optimum gaps between the obstacles to allow a free flow of the airstream, efficient separation can be obtained.

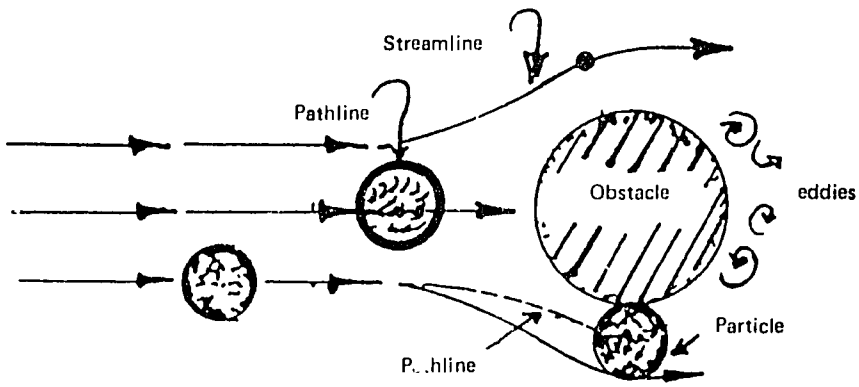


Fig. 1. Particles of three different sizes carried by the airstream.

Prototype

Generally, back pressure takes place in the transition area, if the airstream is prevented from flowing freely. Fig. 2 illustrates the principle of separation. Fig. 3 shows the sectional side elevation of the straw collector with two sets of grille louvres (the obstacles for the solid particles).

The first set of aerodynamically formed aluminum grille louvres diverts the main airstream and also provides the straw collector with a dissipation chamber

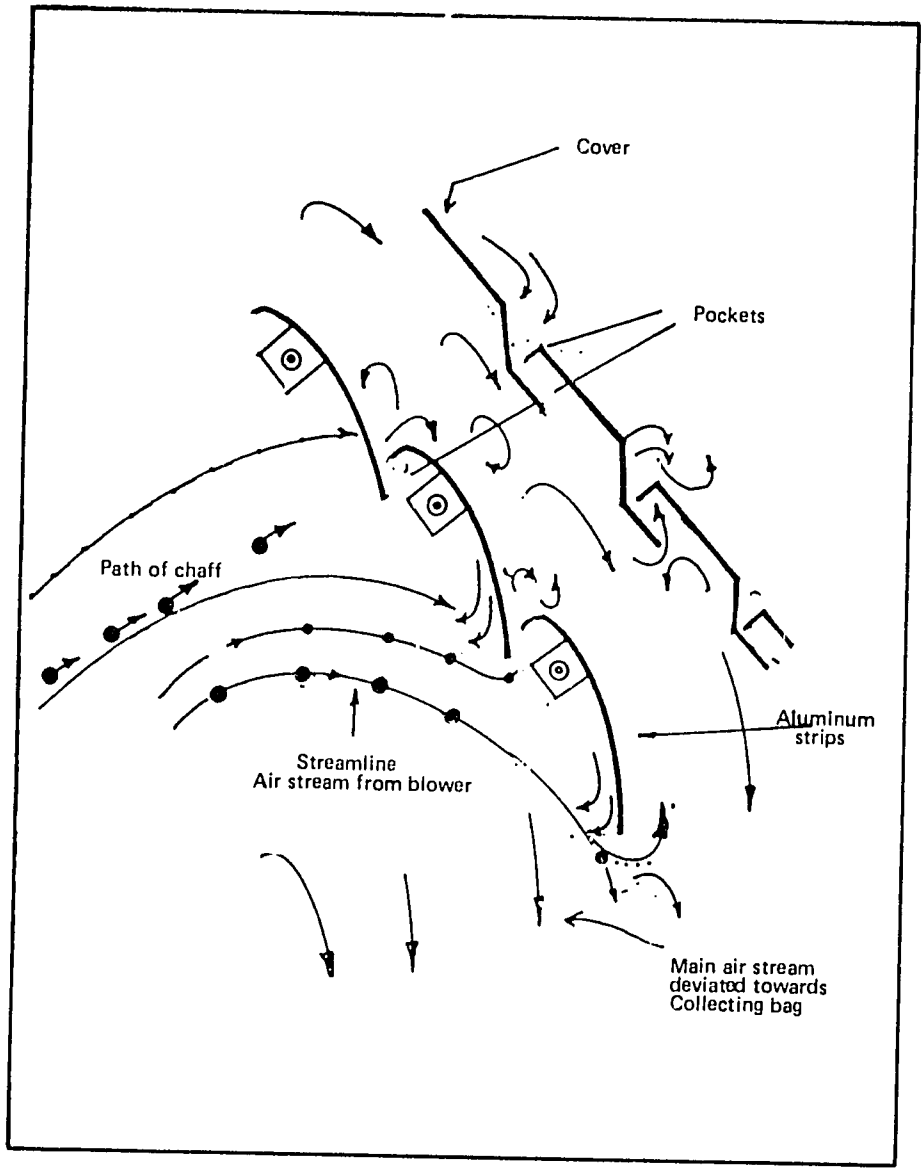
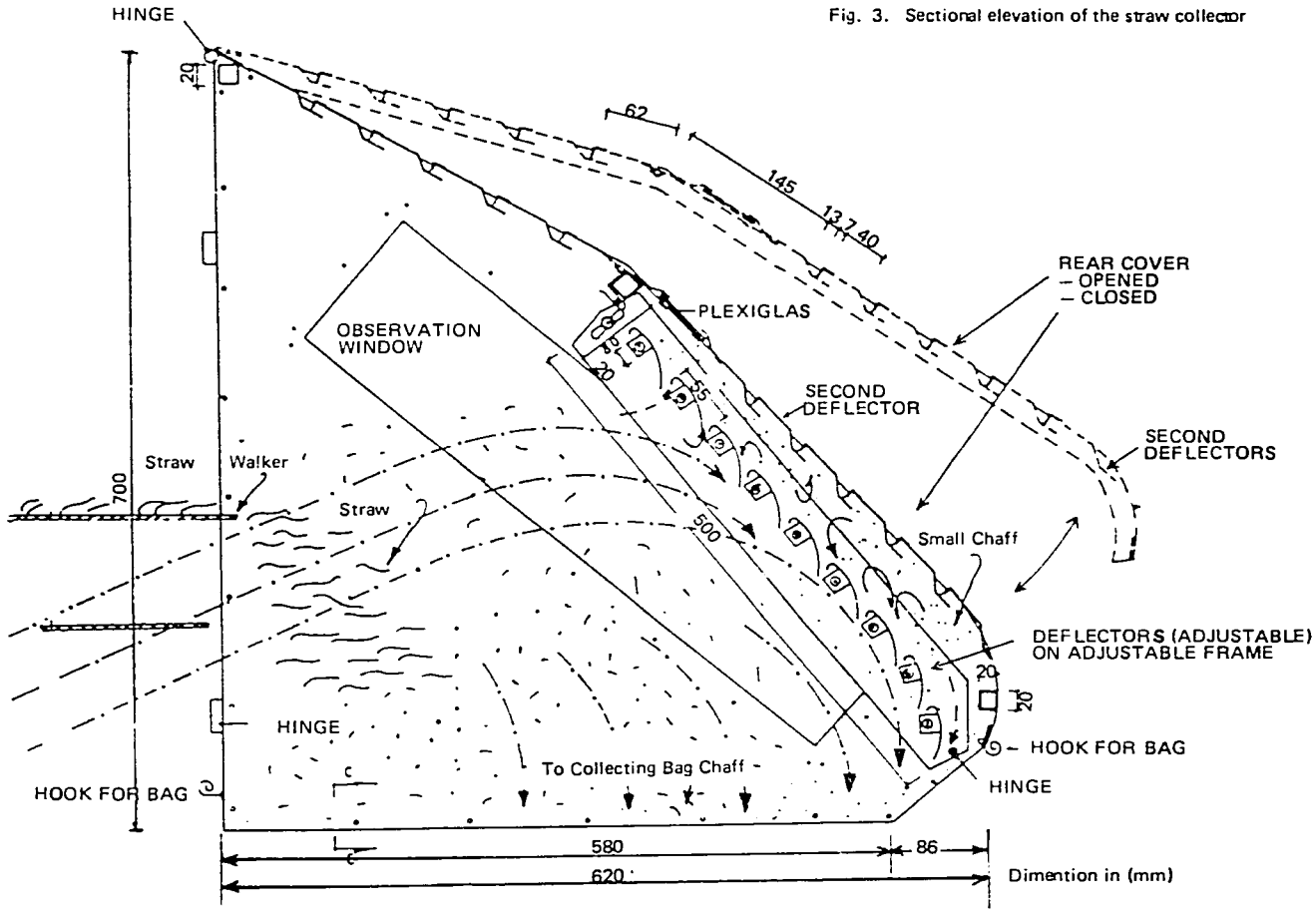


Fig. 2. A schematic illustration of first and second set of . aluminum deflectors.

(the second set of aluminum grille louvres hinged to the rear of the straw collector).

The first set of aluminum obstacles is designed as aerofoils in an appropriate aerodynamic form to perform the following functions:

Fig. 3. Sectional elevation of the straw collector



- deviate the main airstream transporting the chaff into the collection bag and into the dissipation chamber,
- direct the bulk straw into the collecting bag;
- serve as obstacles for the impact of chaff and dissipate its kinetic energy,
- isolate a part of the main airstream into the second compartment (the dissipation chamber) to prevent stagnation and back pressure;
- initiate turbulent flow inside the dissipation chamber;
- provide structural reinforcement to the straw collector.

The aluminum foils forming the rear cover have different aerodynamic forms to:

- trap the smaller chaff (achieved with the sharp bend at the top end),
- change the direction of the airstream thus creating eddies in the dissipation chamber and developing a turbulent flow;
- direct the flow of trapped fine chaff into the collecting bag.

The rear cover is hinged to the rear frame of the straw collector; it provides access to the rear of the combine for inspection. The cotton collecting bag allows the passage of the filtered airstream.

Process of Collection

The collection of bulk straw, chaff, and fine chaff are shown in Fig. 3. The bulk straw moves along the straw walker of the combine and falls directly into the collecting bag due to its own gravity and the main airstream.

The position of the louvres permit changes in the direction and magnitude of the air. The optimum gap between the louvres allows part of the airstream to flow through them, without creating obstacles to the sliding bulk straw.

All straw and chaff are transported into the collecting bag. The straw and chaff can be weighed in the field with a spring balance fixed to the combine.

The Flow Pattern

The flow pattern in the first compartment consists of streamlines which are either curving in the space or converging and subsequently diverging into the dissipation chamber. The eddies and vortices created in the dissipation chamber constitute an internal turbulent flow and thereby prevent the buildup of back pressure. Since the velocity of the continuous airstream in the first compartment is greater than the velocity of the airstream near the rear panel, all particles in the dissipation chamber flow into the collecting bag. (See Fig. 4.)

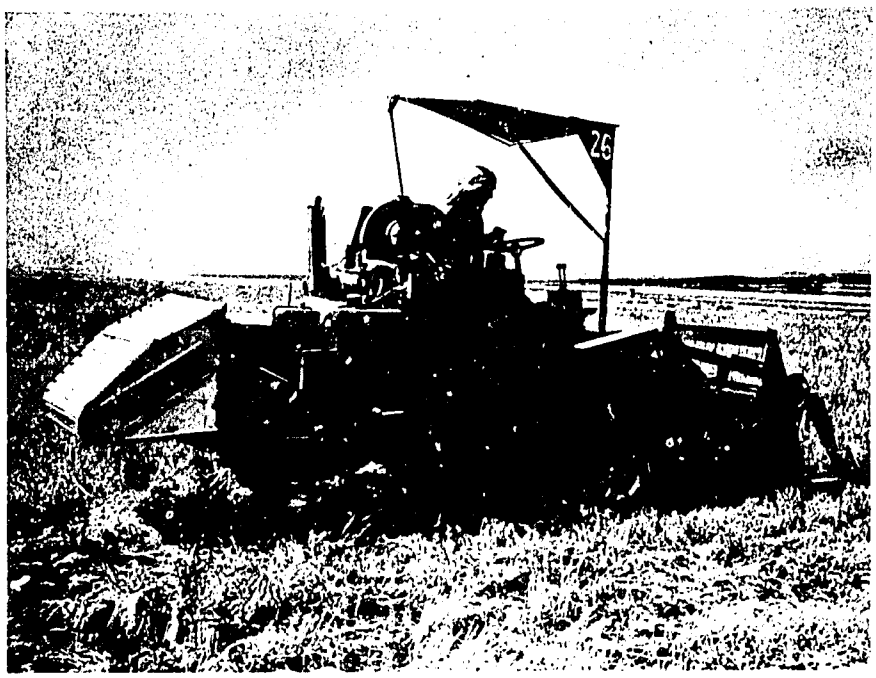


Fig. 4: Harvesting and collection of straw and chaff.

Results

During the 1985 harvesting season, a prototype was first tried at ICARDA. Its compact design and optimum form allowed good visibility as well as easy operation and good maneuverability. The atmospheric wind or its direction did not affect the harvesting process. Furthermore, the environment was free from dust.

The collector fits any plot combine since no additional mechanical propulsion is required, and the kinetic energy of the main airstream generated by the combine blower is utilized for the entire collecting process. The main airstream which provides initial separation of much of the chaff from the threshed grain is deviated into a bag, which filters the airstream. Thus retaining even the finest chaff inside the collecting bag for evaluation. The collecting capacity is up to 10 kg.

Technical Specification

The straw collector weights about 20 kg with dimensions of 68 cm x 85 cm x 65 cm. It fits into the rear opening (65 cm x 85 cm) of the plot combine.

The collecting bag hooked to the bottom opening of the straw collector has the dimensions 80 cm x 70 cm x 55 cm, large enough to hold the 10 kg of straw and chaff. The bag is made from a woven material to allow passage of the airstream.

Wintersteiger Models

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Abstract

Evolutionary product development has resulted in the production of the Nurserymaster and Seedmaster plot combine harvesters. Their sturdy construction and range of optional equipment are very advantageous for harvesting field trials.

Introduction

The development of plot combine harvesters by the Wintersteiger Company has been a long evolutionary process. The first Pam harvesters designed by the Wintersteiger Company in the early sixties were intended for plant breeding conditions in Central Europe. In 1970, the Seedmatic Universal was introduced. It was a sturdy machine with a special feature to rapidly change the header between wide and narrow cutting widths with minimum effort. The bagging system was pneumatically operated; the seeds were collected under the sieves and delivered to a mechanical airlock. They were then conveyed by air to a cyclone with a bag holder. A new hydrostatic drive system increased the comfort of the operator and provided the correct technical solution to the problem of frequent stops. This model was used for harvesting cereals and other crops.

Nurserymaster Hydrostatic Combine

The design of the Nurserymaster hydrostatic combine was based on the earlier prototype (see Fig. 1). It became an ideal complement to the Seedmaster Universal. The

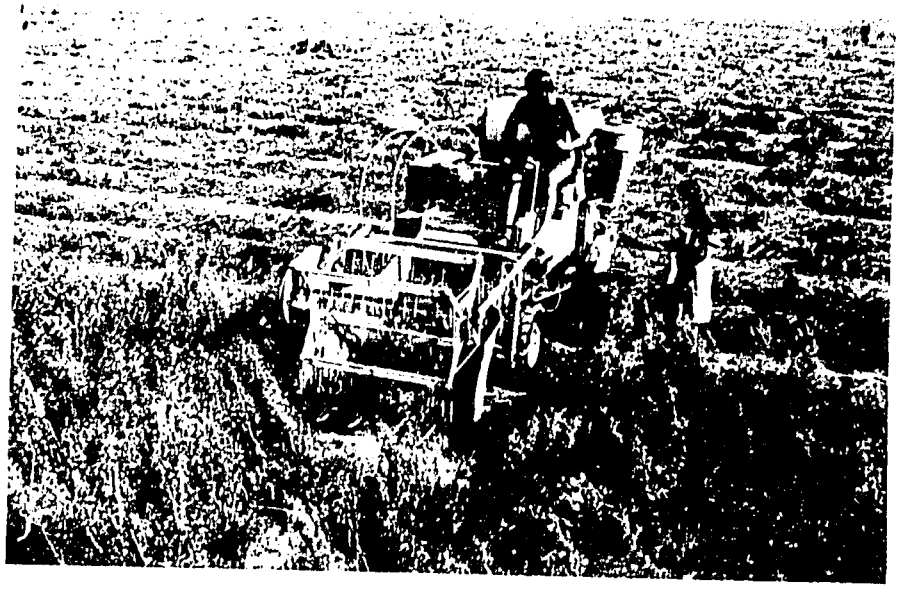

Fig. 1: Nurserymaster hydrostatic

very efficient pneumatic seed delivery system was significantly improved by the addition of a unique injection-type airlock to it. This made possible a completely reliable cleaning between plots within a few seconds, regardless of whether the bag-filling unit or the seed drawer is used. Tried-and-tested features such as the reliable hydrostatic drive system were retained, as well as the easy control over the opening between the concave and the drum, indicated by two pointers on scales (in mm), and the ergonomically designed driving position. All control levers are within easy reach of the driver. However, one of the most important new features was that the concave could be changed for another crop within 20 minutes. Special attention was given to clearly arranged belt and chain drives, to good maintenance and service access, and in particular to better organization and supply of spare parts, with particular emphasis on the developing countries[1].

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[1] See pages 113-132 of these Proceeding for papers presented on the supply of spare parts in developing countries.

Throughout this period, the Seedmaster Universal was still on the production line. Yet, it was not sufficiently flexible for use in sunflower, pulses, and tall maize plants.

Nurserymaster Elite Combine

To satisfy these requirements, the smaller plot combine was upgraded to an advanced version; the Nurserymaster Elite (see Figs. 2 and 3). Its shape was altered and the chassis reinforced to carry a grain bin with a discharge system onto a farm trailer, a two-row corn-cob picking head, and various weighing systems. More comfort was added for the convenience of the operator. The cleaning system was again improved and adapted to the increasing stress factors. The most attractive improvement was a patented cassette system which allows the concave to be pulled out sideways. The changeover for another crop was easily accomplished within a few minutes.

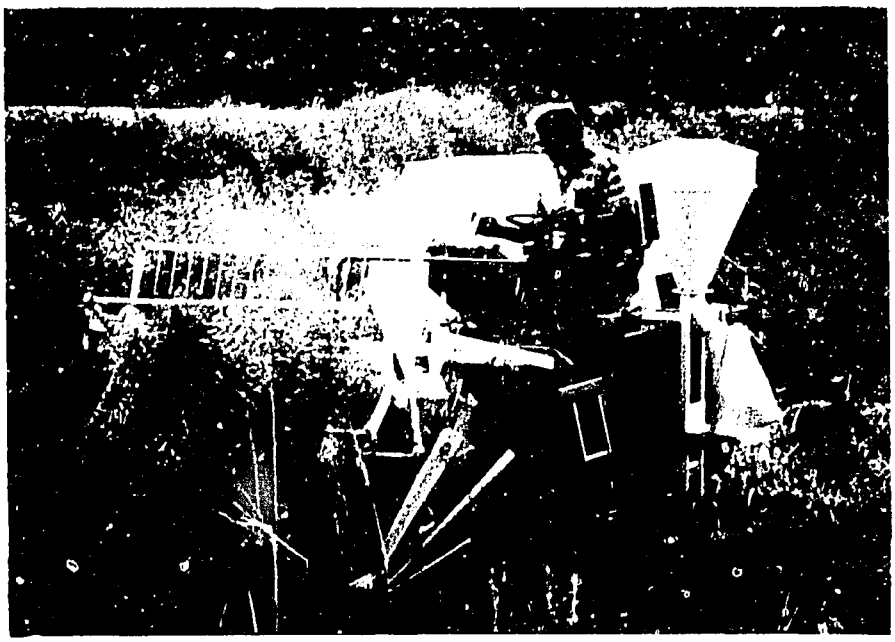

Fig. 2: Nurserymaster elite

Seedmaster Advance Plot Harvester

The Seedmaster Advance plot harvester is the result of Wintersteiger research (see Figs. 4 and 5). It combines high performance with an automatic cleaning system. The Seedmaster Advance offers the following features for plant breeding and seed production operations:

Narrow track width,
Safe and complete cleaning within a few minutes,
Large grain bin,
Large platform where bags may be filled,
Optional accessories, e.g. weighing system and moisture meter.

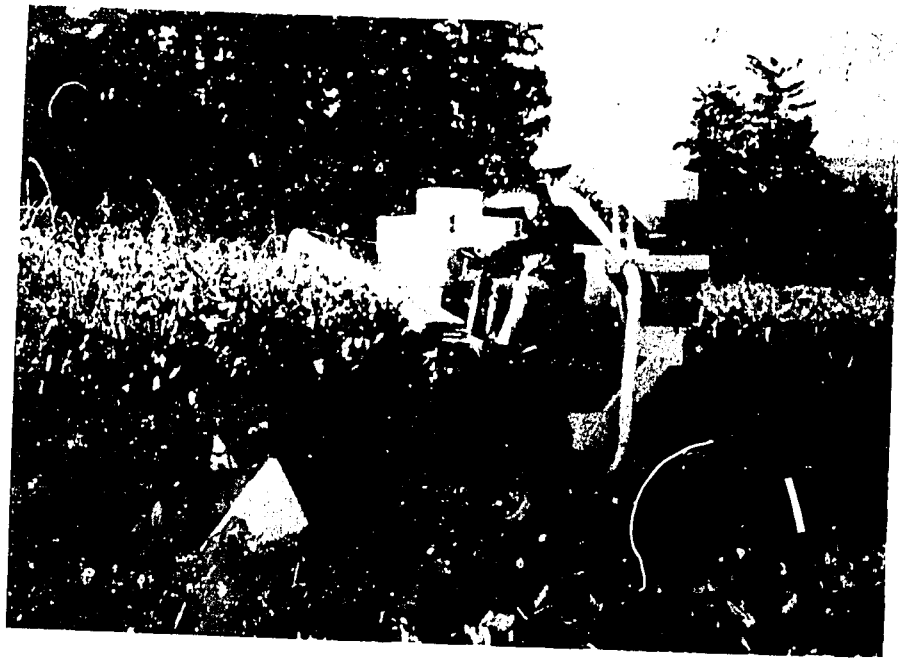

Fig. 3: Nurserymaster elite.

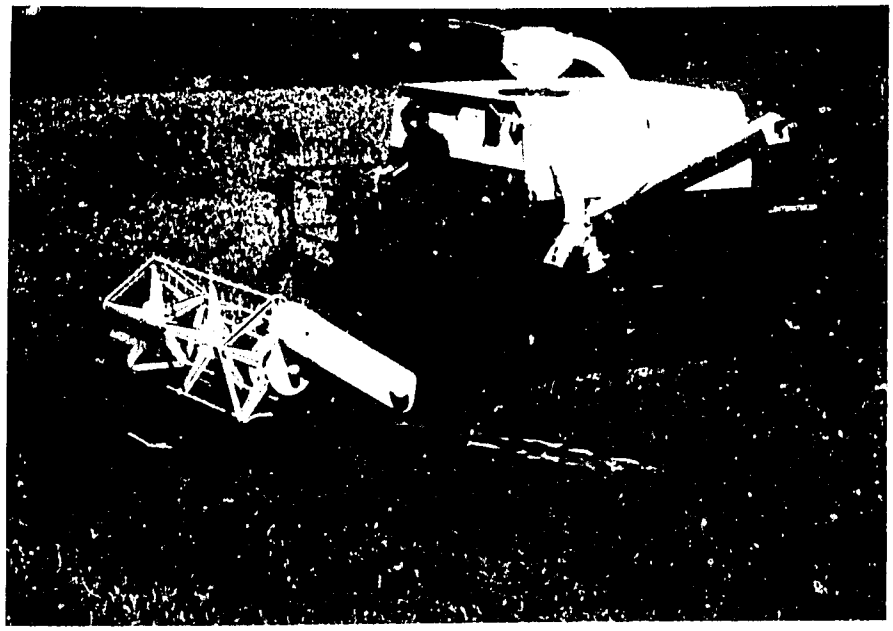

Fig. 4: Seedmaster advanced

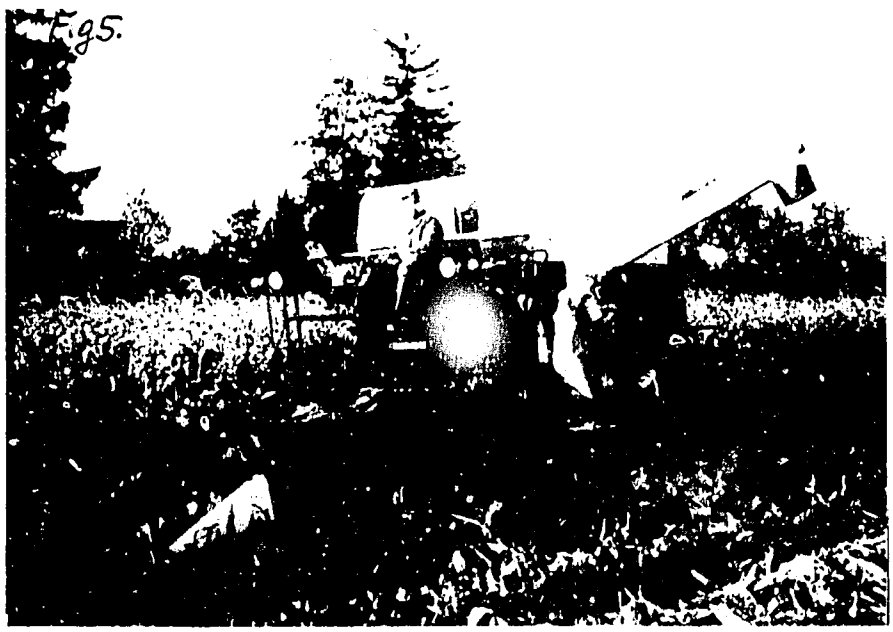

Fig. 5: Seedmaster advanced.

Hege Models

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Abstract

Third-generation Hege plot combines are now available for breeding and research. They are the results of continuous development. The Hege 125C plot combine is ideal for nurseries and test plots. The larger Hege 140 model is a double-task machine for harvesting plots and seed multiplications. The stationary plot thresher Hege 122C can be used on a wide range of crops.

Introduction

Agricultural research stations have used Hege harvesting equipment for a number of years. Continuous improvement has led to the development of the third generation of Hege plot combines. A short overview of these plot combines indicates the modifications and optional equipment currently available for different crops.

The Hege 125C Plot Combine

The machine is easy to maintain and operate. The Hege 125C plot combine is a good plot thresher for nurseries (even for single plants and spikes) and for test plots of any size (see Fig. 1). Many parts are interchangeable with parts of the older Hege 125A and 125B models. Thus, the supply and storage of spare parts are rational and economical. The construction and simple design of the thresher permit local repair in most cases.

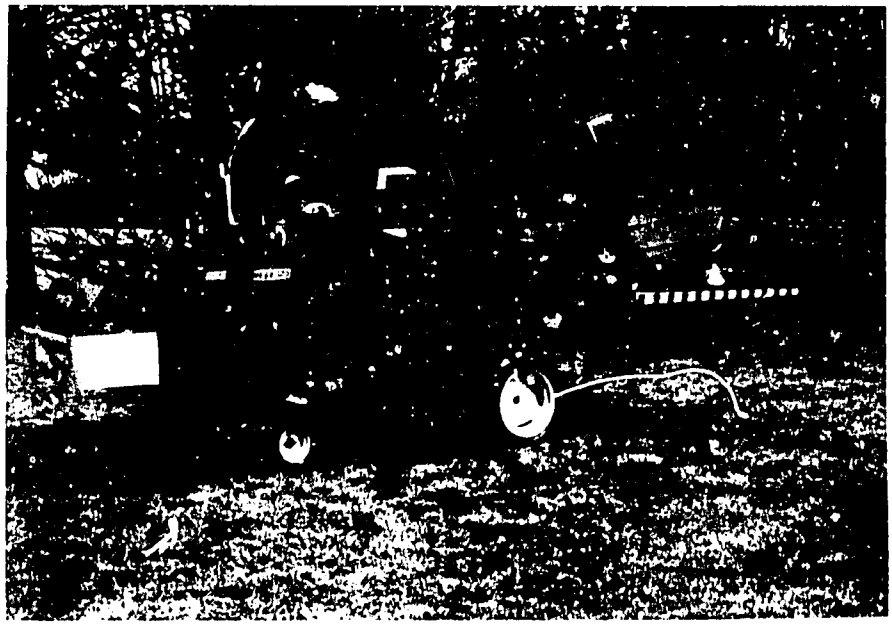

Fig. 1: Hege 125 C plot combine.

The technical principle of the Hege 125C plot combine is the same as in earlier Hege plot combines, e.g. a rolling machine base of conveyor belts. The machine is self-cleaning without additional blowing equipment. The time required for cleaning is 5 - 15 sec, depending on the crop and other conditions.

The Hege 125C plot combine has an increased threshing capacity because of an adjustable shaker, a high-power variator drive system, and a new design of the cutting table incorporating a high precision double-knife cutter bar. Adjustments of the shaker include shaking speed, duration of shaking per strike, and position. The design permits easy change to other shaker sizes. The high-power variator drive system for the drum, together with a digital monitor for drum speed, the straw beater, and concave are located in a specially formed housing. Other improvements include modifications to the cleaning and bagging systems.

Several optional equipment are available for use in various crops. Simple adjustment of the fan by a quick

change of the cleaning sieve permits the basic equipment to be used in many crops. Special attachments are available for harvesting rapeseed, sunflower, maize, and other crops. A double-knife mowing system is available instead of the finger-mowing system for special needs. Different bagging systems are also available. The standard equipment provides side bagging with a separate blowing out of the remaining chaff and awns. Dust in the air during bagging is not a nuisance to the operator. The impeller type conveyor is soft for the seeds, operates quickly, and empties completely. Seed delivery is also possible from the driver's platform for one-man operation. A pneumatic blower is another option.

Different tire sizes for the drive wheels and two different track widths for the rear axle are offered. The available engines are two Volkswagen gasoline engines with air cooling, a Volkswagen diesel with water cooling, and a Volkswagen-Audi gasoline model. A mechanical drive system with a newly designed and proven wide-range variator drive (three gears forward and one gear reverse) is simple to operate and maintain. Hydrostatic drive is available for a foot-and-hand-lever system.

Control of the internal machine functions and cleaning are easy operations. Many adjustments can be made from the driver's seat. The installation of disawners is simple. The concave clearance can be quickly changed. The feeding conveyor belt can be lowered for threshing large maize or sunflower. The standard cutting widths are 1.25 and 1.5 m. Other widths are available.

Newly designed, efficient crop dividers can be quickly adjusted. In the 1.5 m version, the tops of the crop dividers can be adjusted to 1.25 m for different plot widths. The following optional equipment are available: ear lifters, another feeding roller on the table for bulky material, different concave sizes, cleaning sieves, and shakers, a vertical cutting system, devices for harvesting sunflower in rows, a spike drum and concave for rice threshing, and a unit with two threshing drums for special crops.

Working lights, power steering, and straw collectors are also offered.

The Hege 140 Plot Combine

This combine is the big brother of the Hege 125C plot combine (see Fig. 2). It is a double-task machine for harvesting plots and seed multiplications. The technical principle is the same as mentioned above.

The Hege 140 plot combine has an increased threshing capacity and can thresh seed multiplication trials in spite of its relatively small size. Modifications in the threshing area concern the space for straw walking. Other modifications concern the cleaning system, grain conveyor, bagging or the use of a grain tank.

This machine is a perfect plot thresher for nurseries and test plots or for inbred lines without compromise in the working speed of 80 - 140 plots/hour.

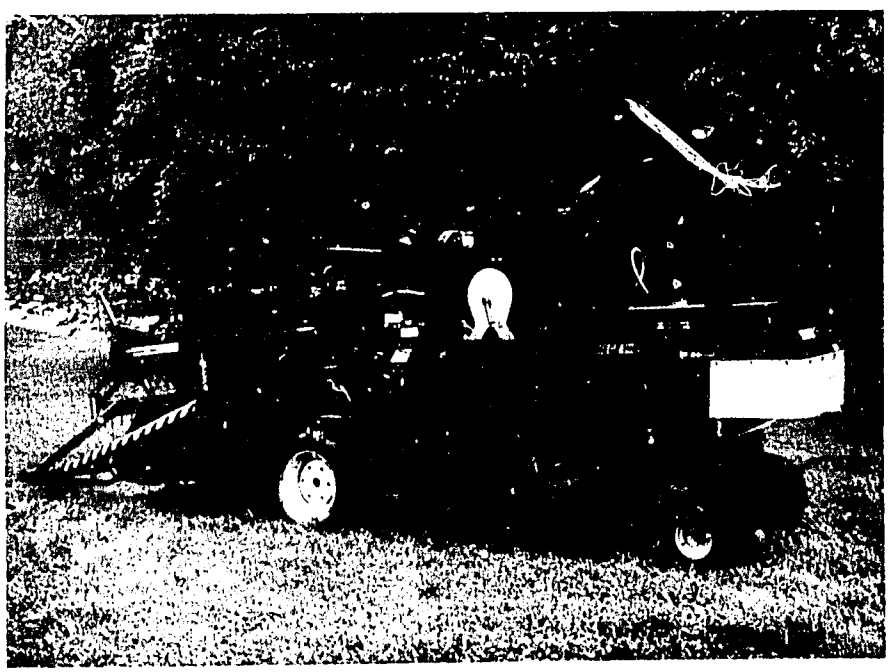

Fig. 2: Hege 140 plot combine.

The machine has a large wheel base. Therefore, a 400-l container can be mounted on the combine. A double-row maize picker can also be fixed. The wide axle distance gives better traction for the front wheels, which is an advantage in difficult soils. Passage over tractor tracks or uneven fields is ameliorated.

The available tires include low pressure floated tires for extreme soil conditions. Hydrostatic or mechanical drive is available as well as a reel drive in the hydrostatic version and a bagging system to supply up to three stations. Some optional equipment for the 125C model are standard equipment on the 140 model.

In threshing multiplication plots, 0.4 - 0.6 ha/h can be harvested. A large side platform with a double bagging station allows continuous harvesting. In the harvesting of loose material, the container is emptied by hydraulic lift or by the side auger.

The Hege 140 plot combine is a thresher that can be adapted to the needs of research stations. Operation, maintenance, and repair are simplified. The machine, however, is not overdeveloped. It remains a proven Hege thresher. Most of the spare parts are interchangeable with other Hege combines.

The Hege 122C Stationary Plot Thresher

The threshing body of the Hege 122C stationary thresher includes components of the Hege 125C plot combine (see Fig. 3). It is a very useful stationary thresher for a very wide range of crops. The advantage of complete self-cleaning is an ideal precondition for seed threshing. This machine is also capable of bundle threshing as well as continuous threshing of crops. It attains a capacity between 800-1500 kg/h.

The thresher is available with different cleaning sieves, a drawer to take out the seed, or an impeller type bagging system to fill large bags. The machine

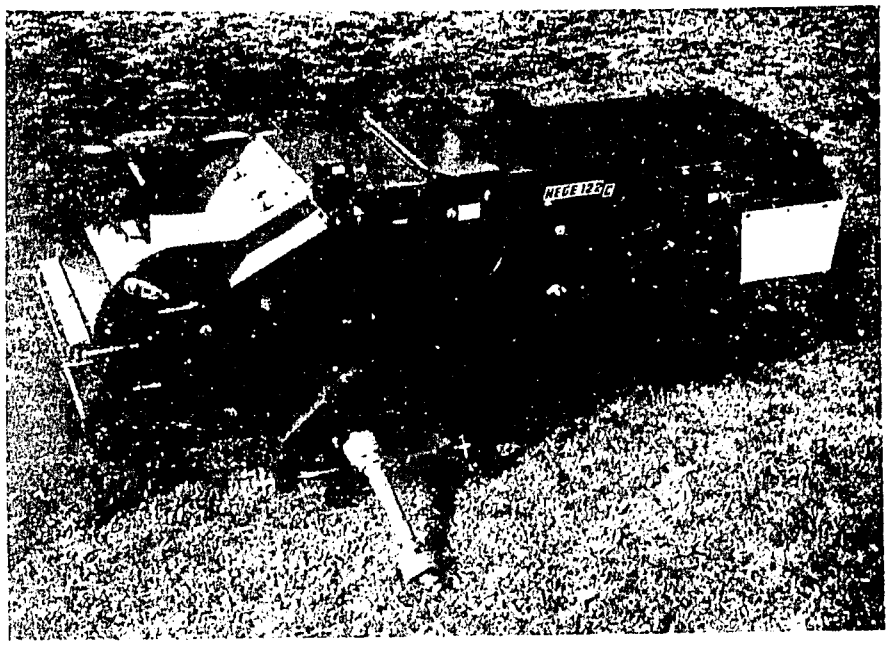

Fig. 3: Hege 122 C stationary plot thresher.

can be driven by pto shaft from tractors or by gasoline and diesel engines.

Transportation can be done by the three-point hitch of a tractor, or tires can be mounted to drive it to the fields. It is hand-fed either by a conveyor belt in front or by a simple feeding mouth of sheet metal. A longer feeding table with conveyor belt similar to the front conveyor of plot combines can be assembled; it allows a good preparation of the feed material.

The Hege 212 Forage Plot Research Harvester

This newly designed machine offers a high plot-harvesting capacity (see Fig. 4). It is useful for all forage crops and plot sizes, as well as for field harvesting, e.g. medicinal plants. A double-knife system cutter or an optional finger-mower with 1.25 m, 1.50 m or 1.80 m widths is designed as a precision mower from 3 - 60 cm cutting height. The Hege 212 forage plot harvester offers the following

walker of the combine and falls directly into the collecting bag due to its own gravity and the main airstream.

The position of the louvres permit changes in the direction and magnitude of the air. The optimum gap between the louvres allows part of the airstream to flow through them, without creating obstacles to the sliding bulk straw.

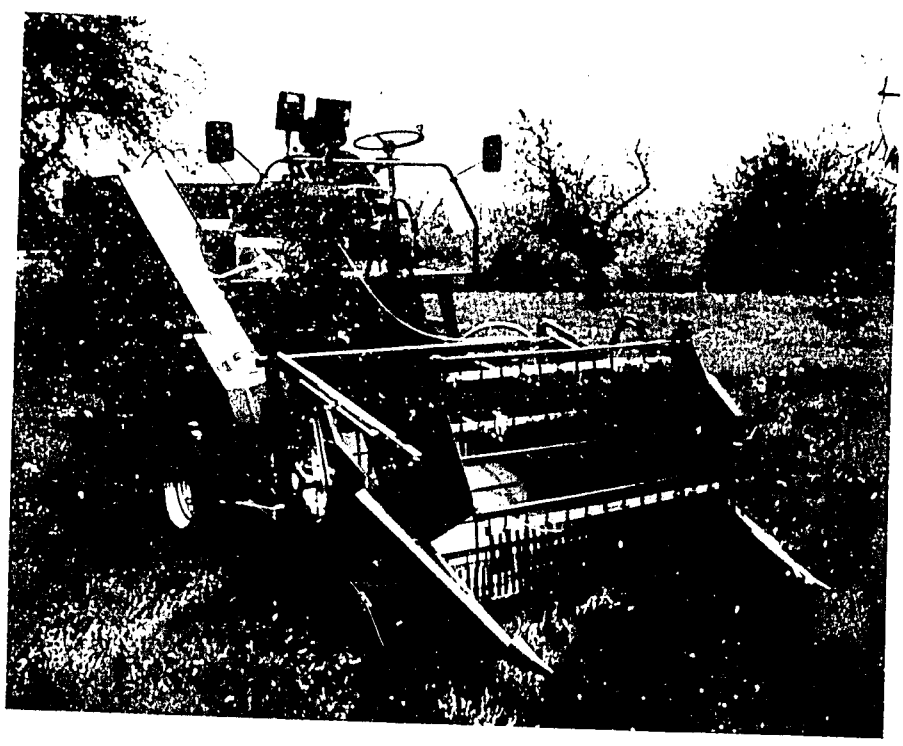

Fig. 4: Hege 212 forage plot research harvester.

features: clean design, optimized handling for the operator, high harvesting capacity, precise mowing and weighing, low noise, and strong construction.

The working principle is a belt conveyor system behind the precision cutter to load the material into a container. An electronic weighing system gives the yield results in a few seconds. After weighing, the harvested material is unloaded by hydraulic to the side or rear of the machine. The harvested material is unbroken; handling is therefore easier after harvest. A special chopping device for the automatic unloading of samples during harvesting is available.

The harvester is equipped with hydrostatic drive and lift systems. Different track widths, tire sizes, and engines are available.

Other options are a larger container and a transfer system for special purposes.

Massey-Ferguson Models

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Abstract

The large Massey-Ferguson 16 plot combine is marketed by Rosenlew Ltd. for small farms. The Massey-Ferguson 8 small plot combine is available for research stations. The model offers a high capacity, many optional equipment, and good economy. After-sales service is good.

Introduction

W. Rosenlew Ltd. has been producing combines since 1957. The total production of combines in 1986 was 2000 units.

Work began in 1967 on modifications of the small and medium combines (less than 3.5 m cutting width) for research requirements. A marketing contract with Massey-Ferguson Company opened new export possibilities.

The Massey-Ferguson 16 Plot Combine

The large Massey-Ferguson 16 plot combine incorporates modifications to the standard combine. Cleaning is performed by directing compressed air into various locations. The feature guarantees fast work and minimum contamination. The combine is very maneuverable. Its turning radius is 3.5 m.

The Massey-Ferguson 8 Plot Combine

The new Massey-Ferguson 8 small-plot combine has been successfully marketed for three years. The aim of Rosenlew Ltd. was to built a combine with the following features:

Strong and durable construction,
Infrequent need for service and spare parts,
High harvesting capacity,
Flexibility to combine small plots as well as multiplications.

Series production of the MF 8 combine provides an opportunity to use modern manufacturing technology which, in turn, results in high quality. The supply of spare parts for these combines can be guaranteed.

The Massey-Ferguson 8 plot combine is a very robust combine. Details such as the Perkins 55 hp diesel engine indicate that there is no crop too heavy for it. A fully hydrostatic transmission is standard, and the one-pedal control provides very convenient driving.

Four different conveyor table alternatives are offered:

1.2 m table as special option,
1.5 m table as standard feature.
The table reels are very large in diameter, and six bars guarantee a good feeding.

The new 2.0 m table has basicly the same strong construction as the standard combine. The cleaning is carried out with a continuous air stream from the fan. Such features as electrical adjustment of reel speed and position give extra convenience for the driver.

The MF 8 combine can obtain a capacity up to 4 t/h with the 2.0 m table and is thus excellent for harvesting multiplications.

The combine can also be fitted with a two-row corn header. Because of the strong basic construction of the MF 8 combine, it can carry the header with ease.

The machine can harvest corn, soybean, grass seed, and sorghum with the alternate table.

The threshing mechanism is the heart of the combine. The MF 8 combine has a high threshing capacity due to its high inertia cylinder. The large 55 cm diameter drum and the completely closed construction guarantee carefree driving and prevent contamination.

The grain is transported to the weighing unit by a paddle elevator. This transportation system, which runs continuously, consists of a round tube and precisely fitted plastic paddles. The advantages of this system are high capacity, fast interior cleaning, and minimum contamination. The mechanical transportation guarantees good cleaning even with very heavy kernels (such as corn).

A good example of versatility of the MF 8 and new ideas is the grain handling system: the grain coming from the elevator drops to the weighing hopper where it is weighed. Then, the grain can be either bagged or directed to an auger which takes it into a 800-l grain tank.

Combining directly to the grain tank is also possible; this feature is especially beneficial when harvesting plot surroundings for multiplications. The unloading height is 2.65 m which enables the use of normal trailers.

The convenience of the driver is as good as with standard combines. The most important adjustments can be made from the driver's seat. On the left-hand side are

Cylinder speed adjustment 600-1300 rpm,
Concave clearance adjustment,
Table and reel adjustment,
Electrical adjustments for reel.

These details enable the driver to make a cylinder speed change or other essential adjustment without stopping the combine.

The Massey-Ferguson 8 can provide:
High capacity in plot harvesting,
Good flexibility with many alternatives,
Good economy thanks to strong construction and good durability.

Good after sales-service and supply of spare parts support is provided by the manufacturer.

Post-harvest Seed Processing

The control of pests and seedborne diseases is an important task in seed production. A review is given of procedures and equipment for treatment of experimental seed with powder, slurry, and liquid formulations. The design and operation of a fumigation facility are also described.

Treatment of Experimental Seed

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Abstract

The control of seedborne pests and pathogens is very important to minimize deterioration of the limited supply of experimental seed and to reduce yield losses. Treatment of experimental seed to control fungi, insects and to some extent, nematodes and bacteria, also reduces the risk of transferring these pests and pathogens to new areas with the seed. The procedure and equipment of the ICARDA Seed Health Laboratory are described for seed treatment with powder, slurry, and liquid formulations. The design and operation of the fumigation facility are also described.

Introduction

All plants can be attacked by various pests and pathogens that are transmitted by seed. These agents could be viruses, bacteria, fungi, nematodes, insects, and parasitic weeds. Some of them can be controlled by seed treatment, namely fungi and insects; to some extent also bacteria and nematodes. Controlling these organisms by seed treatment improves plant stands and reduces yield losses. In addition, seed treatment can also control soilborne organisms, such as Rhizoctonia spp. and Pythium spp., which cause seedling decay, and several insects, e.g. mangold beetle in sugar beets. Even airborne fungi, such as powdery mildew, that attack the plants at later stages, can be controlled at least for a certain period of time.

Control of seedborne pests and pathogens is important for commercial seed; control is even more

necessary for experimental seed. Losses in a limited amount of seed, e.g. in early generation breeding material, must be minimized. Institutions like ICARDA are actively involved in the exchange of germplasm with many countries worldwide, and treatment of the seeds is one way among others to reduce the risk of transferring pests and pathogens along with the seeds.

The seeds received at the ICARDA Seed Health Laboratory from more than 40 countries indicate that there might be some problems with the treatment of the experimental seed. In 1986, 68% of the consignments arrived without any fungicide treatment. Many of the treated samples had received considerable overdosages of powder. Another problem area seems to be the cleaning of experimental seed. Only 58% were found clean, the others had admixtures of weed seeds, straw, or soil. The control of grain weevils and bruchids has improved as compared to the consignments received in previous years; only 4% of the consignments had live insects.

The seeds can be treated by application of powder, slurry, liquid, or gas. Two prerequisites for seed treatment are chemicals and equipment. This meeting is concerned with the equipment component, so I will briefly present the facilities for seed treatment at ICARDA.

Seed Treatment with Powder, Slurry or Liquid Formulations

One of the basic requirements for seed treatment is an even distribution of the required amount of chemicals on the seed. This requirement can be satisfied by slurry or liquid; with powder formulations, measurement of the exact dosage is more difficult. Once the dosage is measured, adhesion of the powder to the seed is a problem, particularly to seeds with a smooth seed coat, such as faba bean. Moreover, powders may create health hazards to the operators.

If only powder formulations are available, the above mentioned disadvantages can be overcome by adding

"incrusters", such as the commercially available Sacrust[1] or simply a dextrine (corn starch) solution.

The appropriate equipment depends on the seed quantity per sample and the number of samples to be treated. When few samples are to be treated with different chemicals, e.g. in fungicide screening, the best method is by shaking the seeds and the measured chemical in a flask. Usually a large number of samples are treated with the same chemical. The amount of seed may vary between a few grams (F_1 material) and several kg (advanced breeding lines) up to several tons (pre-basic seed). In addition to the requirements of exact dosage, even distribution, and minimal health hazards, it is essential that the treaters can be thoroughly cleaned in a short time to avoid mixing different lines.

At ICARDA we have tried:
- Gustafson lab treater,
- drum treaters made at the ICARDA workshop,
- Hege 11,
- Gustafson Mist-O-Matic LA-SS.

The Gustafson lab treater does not give good results as far as the even distribution of the chemicals on the seed is concerned. Some seeds receive too much, others too little. Dosage is also a problem. Measurement of the chemicals is the major difficulty with the drum treaters.

For seed amounts varying between 50 g and 10 kg, the Hege 11 with its three interchangeable stainless steel bowls seems most suitable. For quantities greater than 3.5 kg, the seeds have to be divided into two or three lots. Liquid formulations of chemicals are preferable. If only powder formulations are available, a slurry might cause clogging of the pipetting device. In these cases, the powder can be mixed with Sacrust M and the mixture should be applied

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[1] Supplier: Sarea GmbH, Frankstr. 2, A - 4020 Linz, Austria.

at a rate of 15-20 ml per kg for small-seeded crops (lentil and cereals) and 10 ml per kg for large-seeded crops (faba bean).

The Gustafson Mist-O-Matic treaters give good results if they are properly calibrated; i.e. adjustment of the counterweight to weigh the seed quantity corresponding to the amount of liquid measured by the cups. The correct dosage is then added automatically. Mixing of chemicals with seeds is adequate. However, cleaning takes about 10 to 15 minutes, so this machine is useful only if the quantity of seed per sample is relatively large (about 100 kg).

For quantities between 10 and 100 kg, we still use drum treaters or a concrete mixer. With powder formulations, the best results are achieved when between 3 and 5 ml of a 0.2% dextrine solution is added per kg seed and mixed with the seed before adding the chemical. The dextrine is added by knapsack sprayer.

Fumigation

Different chemicals can be used for fumigation. Methyl bromide and phosphine are frequently good choices.

Airtight structures are essential for fumigation because chemical fumigants are gases that can escape easily. These gases are highly toxic to humans and can pose a serious health hazard. Moreover, the effectiveness of the chemicals is drastically reduced if the concentration is not maintained for the required period of time.

The best results can be achieved with vacuum fumigation chambers. These facilities are, however, very expensive.

Frequently, the seeds to be fumigated are covered with gasproof plastic sheets (PVC or neoprene). The sheets must overlap and be fixed to the ground, e.g. by sand bags. The area should be clearly marked with warning signs to prevent people from inadvertently removing the sheets.

Whole stores can be fumigated if doors and windows can be sealed hermetically, and no other openings allow gas to escape. This is usually not the case. To avoid risks with fumigation under plastic sheets, ICARDA has built a special fumigation room with the following features:[2]

- floor made of concrete, walls of concrete hollow block stones, cement plastered on both sides (walls, floors, and doors are painted with three layers of an epoxy paint with special resistant qualities to fumigants[3]),
- windows tightly sealed with silicone rubber,
- doors with rubber gaskets, to be closed with six large wing nuts,
- fan for either air circulation in the chamber (exhaust pipe closed with tight-fitting flap) or for aeration (flap in exhaust pipe opened from outside).

The volume of each room is 21 m^3. Seeds are placed on wooden pallets or on metal shelves.

If the seed quantity is too small to fill the chamber, a small container of 1 m^3 is used. This container is made of aluminum sheets; the lid is equipped with rubber gaskets and is closed with six large wing nuts similar to the door to the fumigation room.

Both constructions have been tested by a tube detector and no leakage of PH_3 was detected after exposure for five days.

Other methods of treating seeds, such as pelleting, i.e. treating the seeds with adhesives and clay or

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2 Brian Tierney and Antoine Naccash have constructed and maintained ICARDA's fumigation facilities.

3 Supplier: Tretol Paint Systems Ltd., Edgeware Road, London NW 9 OHT, England.

other inert matter, and the respective fungicides and fertilizers until a uniform pellet is built up, are not yet practical for the amount of experimental seed at ICARDA.

Another special case should be mentioned, e.g. treating seeds in the magazines of a Seedmatic or Oyjord plot drill. The equipment is available from manufacturers of the plot drills. ICARDA does not have experience with this treatment.

Data Collection and Processing

The applications of microcomputers for agricultural research include the design of experiments, collection of data, statistical analysis, and the creation of simulation models. Computer-aided techniques of data acquisition and processing are reviewed.

Data Acquisition and Processing Techniques for Agricultural Research

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Abstract

The use of computers facilitates agricultural research in developing countries because automated data capture and computer processing can simplify the work of researchers. Microcomputers now perform several functions in agricultural experimentation, ranging from the design of experiments to the statistical analysis of these experiments. Data acquisition and processing techniques are reviewed at varying levels of sophistication from simple data storage and retrieval to complex statistical analysis and modelling.

Introduction

Today, the management of large volumes of data by computers has become necessary and commonplace. Microcomputers are complementary to research projects in agronomy, soils, horticulture, and other disciplines in developing countries (National Research Council 1986). It is now possible to perform functions ranging from the collection and processing of agricultural survey data to the statistical analysis of experimental field data and the building of simulation models of agricultural systems (Michigan State University 1985). This paper reviews different levels of data acquisition and processing techniques using the computer.

Agricultural Research

Two major types of experiments for the planning of

technology are generation experiments and verification experiments. A suitable experimental design and layout of the experiment are necessary prerequisites for obtaining reliable results.

Generation experiments can be initiated in a research station or on a farmer's field. Special care should be taken in the selection of a test site and the experimental design and layout.

The main objective of verification experiments is to compare the performance of a farmer's practice and a newly developed technology in the farmer's field. The most important bases for comparison are biological yield and profitability.

For the purpose of technology verification, test farms should be representative of the farms in the target area. This makes it necessary to choose the appropriate sampling technique for farm selection. Certain criteria, such as farm size and cropping pattern, should be taken into consideration (Gomez and Gomez 1984).

A number of software programs generate experimental designs for field and laboratory experiments. Specialized statistical software packages offer a range of options for file management.

Data Acquisition

Conventional data collection begins with manual data collection and ends with computer processing. Data in field books are primarily arranged for ease of measurements in the field. Sometimes, this may not be the most convenient form for computer processing and statistical analysis. Thus transcribing the data from field books to the form required for data analysis may be necessary, but the number of times data are transcribed should be minimized to reduce the risk of errors when copying data.

The development of loggers and sensors permits data collection from field experiments in digital form.

Data stored in data loggers can be transmitted directly to a computer or printer. Certain sensors allow the researcher to collect and record many observations of several variables. For example, in 20-30 sec, a photosynthesis - measuring device automatically records up to 10 observations each of CO_2 concentration, relative humidity, chamber air temperature, leaf temperature, and PAR. The data storage capacity of certain data loggers and sensors can be more than 100 pages.

Data Processing

After the data have been filed, the first stage in a statistical analysis is a descriptive presentation of the data (often in the form of tables). It is highly recommended that a summary of basic statistics (means, variances, standard deviations, or minimum and maximum values) is produced and printed at this stage. It is now possible to create new variables from existing ones. The new variables can be produced by calculations performed on basic data and these, in turn, can be subjected to further statistical analysis (Sokal and Rohlf 1981).

Single-factor experiments

Experiments in which only a single factor varies while others remain constant are called single - factor experiments. In such a situation, the treatments consist only of the different levels of the single variable factor. All other factors are applied uniformly to all experimental units (or plots) at a single level.

Two-factor experiments

In agricultural and biological experiments, organisms are simultaneously exposed to many growth factors during their lifetimes. Because an organism's response to any single factor may vary with the level of the other factors, single-factor experiments are not

applicable. Thus, when response to the factor of interest is expected to differ under different levels of the other factors, researchers use factorial experiments which are designed to handle two or more factors simultaneously.

Regression and Correlation

Regression and correlation analysis allows a researcher to examine any association between:

1. response variables (the biological and physical features of the experimental units that are expected to be affected by the treatments being tested),
2. response and treatments (e.g. fertilizer rates, varieties, and weed control methods, which are generated from one or more management practices and are the primary focus of the experiment),
3. response and environment (e.g. factors such as rainfall, solar radiation, and temperature which represent the part of the environment that is not within the researcher's control).

With the accepted perception of the interdependence between factors of production in agricultural systems and the availability of experimental procedures that can simultaneously evaluate several factors, the use of factorial experiments is increasing and there is a corresponding increase in the need for use of regression procedures that can simultaneously handle several independent variables.

Data Analysis

Data analysis is a recent development in the area of biometry and experimental design. It involves the systematic search through a set of data to reveal information and relationships of interest. The procedures of data analysis, although essentially numerical, are also experimental.

Data analysis consists of such techniques as transformations, robust estimation, and graphics techniques. Transformation techniques are used to determine the effect on the distribution of a sample or the relationships between two variables in a sample.

Other Statistical Techniques

Statistical analysis of data generated by experiments that are conducted at several sites and over a number of years or crop seasons can be handled by one or more of the statistical procedures outlined above. However, in certain situations, a combined analysis of variance, regression analysis, and/or covariance analysis can be used.

In some experimental situations, results of the classical analysis of variance procedures could be misleading. Examples are: competition effects of border plots, different fertilizer rates of adjacent plots, and varietal competition. Special statistical techniques can detect the degree of competition, and the results of classical analysis analysis can be corrected (Mead and Curnow 1983; Sokal and Rohlf 1981).

Modelling and Simulation

Equations in mathematical models describe biological or physical systems. One broad class of models simulates the systems, i.e. predicts the output based on characteristics of the system. After a model has been developed, it can be used for simulation by inserting hypothetical or real data and calculating system output.

Models can be classified into two broad groups: stochastic or statistical models and process or physical models. Stochastic models can only be used within the limits of the universe in which they have been developed. Within these limits, they commonly give reasonably realistic results. On the other hand, a process model can be used anywhere the processes used in the model describe the system that is being modelled.

Recent advances in information technology enable researchers to organize large quantities of data to simulate complex processes in agricultural systems. Crop growth and production models, for example, allow researchers to predict and/or estimate:

phasic development or duration of growth stages as influenced by genotype and environmental factors,
biomass production and partitioning of photosynthates,
dynamics of root systems,
effect of a deficit in soil water and nitrogen deficiency on photosynthesis and partitioning of photosynthates in the plant system.

Another group of models, which are soil oriented, allow researchers to predict and/or estimate:

soil moisture regimes,
effects of alternative management practices on chemicals and runoff in the soil profile,
effect of erosion on potential soil productivity,
economic costs of erosion for designated soils and the costs and benefits of various conservation alternatives.

With the development of complex agricultural models, researchers were able to identify some major voids in their research data. During the construction of some models, many parameters and coefficients needed by the models were often not found in the research database. Researchers learned two facts: first, it is possible to construct models without all the desired research data. By using alternative structural equations in the models, many problems facing researchers can be solved. Secondly, the construction of these models indicated deficiencies in research programs, thus enabling a better allocation of future resources (National Research Council 1986).

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Supply of Spare Parts

Many of the problems in the supply of spare parts in the Sudan are common to other developing countries. Proposed solutions to improve the supply may be applicable elsewhere.

The discussion of procurement by ICARDA as an international center indicates a systematic approach.

One manufacturer stresses the necessary planning of maintenance and spare-parts supply by research centers as well as the responsibility of the manufacturer to provide an efficient after-sales service.

The Supply of Spare Parts for Agricultural Machines in the Sudan

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Abstract

Difficulties in the procurement of spare parts for agricultural machines adversely affect agricultural mechanization in the Sudan. Among the conditions that impact the supply of spare parts are shortage of foreign exchange, unreliable suppliers, and lengthy procurement procedures. Suggested measures to improve the supply of spare parts include improved training programs and maintenance facilities, changes in purchase contracts ensuring the supply of sufficient spare parts for the normal lifetime of a machine, better after-sales service by suppliers, exemption of spare parts from import duties, and the encouragement of local manufacture of spare parts.

Introduction

Agriculture is the principal economic activity in the Sudan. It accounts for 40% of the gross national product (GNP) and 95% of the export.

The total land area of the Sudan is about 263 million ha of which 84 million ha is arable land. The cultivated area is 7 million ha. Rainfed farming is practiced on 5.5 million ha and irrigated farming on 1.5 million ha. Mechanized farming occurs on about 2.8 million ha.

The mechanized agricultural area includes large irrigated schemes, such as the Gezira, New Halfa, Rahad, and Suki schemes, and rainfed areas. The areas of the irrigated schemes range from 120,000 ha to 0.8 million ha. Mechanized rainfed agriculture is practiced in the central clay plains of the Sudan with sorghum and sesame as main crops.

Imports of Farm Machinery

Agricultural mechanization in the Sudan is completely dependent upon the importation of farm machinery because they are not manufactured in the Sudan. Therefore, the discussion of spare parts begins with an examination of import data.

Tractors and Combine Harvesters

Table 1 shows the volume of imported tractors and combine harvesters from 1970 to 1985. The total of 18,510 tractors includes 10 different models. The total of 1,688 combine harvesters includes 7 different models. The proliferation of models[1] is a result of the nature and origin of foreign loans.

The importation of these machines fluctuated during the 16 years. The volume of tractors ranged from 130 in 1972 to 2,074 in 1974 with a mean of 1,157 tractors per year. The volume of combine harvesters ranged from 50 in 1973, 1978, and 1979 to 190 in 1976 with a mean of 106 combine harvesters per year.

B. Farm Machinery

The total number of imported agricultural machinery (excluding tractors and combines) from 1970 to 1978 was 10,230. Disc ploughs, disc harrows, and ridgers are

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[1] All combine harvesters were purchased from a single supplier from 1978 to 1985.

Table 1. Imports of tractors and combine harvesters into the Sudan from 1970 to 1985[a]

Year	Tractors	Combine Harvesters
1970	1271	113
1971	800	135
1972	130	100
1973	2040	50
1974	2074	180
1975	652	170
1976	1722	190
1977	792	120
1978	852	50
1979	950	50
1980	1500	100
1981	1900	80
1982	900	100
1983	950	90
1984	1387	80
1985	600	80
Total	18510	1688

[a] Source: Agricultural Bank of Sudan.

the most widely used machines in irrigated areas. On the other hand, the wide level disc with seeder box is the most widely used machine in rainfed agriculture. (See Table 2.) Although the use of planters had been promising, the experience was disappointing, therefore, the importation declined.

Problems of Mechanization

The agricultural machinery has performed poorly. Factors contributing to the poor performance include:

Table 2. Imports of selected Agricultural Machinery from 1970-1978.

Implement	No. of Units Imported
Disc plow	3454
Ridger	1929
Planter	430
Multipurpose blade	84
Offset disc harrow	622
Wide level disc + seeder box	3166
Groundnut digger-shaker	442
Fertilizer distributer	33
Hay baler	70
Total	10230

[a] Source: Agricultural Bank of Sudan.

1. Lack of spare parts,
2. Inadequate training programs for operators, mechanics, and engineers,
3. Insufficient workshop equipment,
4. Absence of support services for machinery,
5. Poor management and maintenance of machinery,
6. Selection of unsuitable machinery,
7. Poor infrastructure.

The supply of Spare Parts

The unavailability of spare parts is a serious problem; it jeopardises agricultural mechanization in the Sudan. Today about 40% of the machinery in the Gezira scheme, the largest scheme in the world under one management, are idle because of the shortage of spare parts. Thousands of other machines elsewhere in the Sudan are also useless because of this shortage.

Problems

Let us briefly look at some of the problems in connection with the supply of spare parts.

1. The chronic shortage of foreign exchange during the past 16 years prevents the purchase of desired machinery in a straightforward commercial manner. The proliferation of makes and models is the result of importation dictated by the source of the available foreign currency. The large number of models causes additional difficulties for the supply of replacement parts, the performance of maintenance and repair, and the training of operators and mechanics.
2. After changes on the national or international political scene, spare parts may not be available from the original supplier and a new supplier must be located.
3. The purchase of agricultural machinery is usually accompanied by an order for spare parts that are valued at 10 to 15% of the machine cost. Experience indicates that this percentage is not sufficient to satisfy the requirements for parts (neither quantity nor type). The supply of spare parts will not be available for more than one-third of the machinery's lifetime. After the initial supply of spare parts is exhausted, funds are not available to replenish the stock. Therefore, most machines are idle for lack of spare parts although two-thirds of their normal lifetime for possible use remains.
4. Financial institutions determine the type and quantity of machine imports. The decisions are based solely on financial considerations without evaluation of machine efficiency and effectiveness. This policy has greatly affected the supply of replacement parts.
5. The recordkeeping system in the Sudan is inadequate and contains incomplete data. Therefore, the manufacturers' lists of recommended parts are the bases for choosing the parts to be ordered. These standard lists are not always appropriate for conditions in the Sudan.

6. Some suppliers do not provide after-sales service. Other suppliers treat the purchase of spare parts as special orders and place a large surcharge on these orders.
7. Improper operation of machines is the result of inadequate maintenance and repair facilities, untrained operators and mechanics, and the poor infrastructure. These deficiencies contribute to the frequent need for spare parts. Consequently, the requirements and costs of spare parts are very large.
8. In large public-sector projects, the supply of spare parts is aggravated by lengthy procurement procedures. The Rashid Project is a good example of this problem as shown by its procurement procedure in Table 3. The management is located 300 km away in Khartoum; the requested items must be approved by different ministries. Therefore, it is necessary to forecast the needs for spare parts 13 to 19 months into the future.

Table 3. Sequence of events for procurements of spare parts in Rahad Agricultural Corporation.

Procedure	Time required (weeks)
Prepare specification and print tender	4
Approval and dispatch	3
Quotation period and submission time	7
Negotiation of contract	4
Application for foreign exchange, import license, custom formalities, negotiation with carriers and other Governmental approvals	4 - 12

9. Custom duties are applicable to spare parts, although tractors and farm machinery are exempt from these charges. This policy encourages the purchase of machinery and discourages preventive maintenance.

Solutions

The problem areas affecting the supply of spare parts are interrelated. An improvement in any of these areas would not only be beneficial for the supply of spare parts but also for other problem areas.

Let us briefly consider some solutions to the problems.

1. The supply of adequate spare parts for the entire lifetime of a machine should be explicitly stated in the import contract. The local dealers of the manufacturers should be responsible for the supply of these spare parts.
2. New legislation should require the supply of spare parts valued at least 30% of the purchase price for each imported agricultural machine.
3. The recording of performance data for different machines should be improved. Accurate records could provide guidelines for determination of the type and quantity of spare parts needed during the machine's lifetime.
4. Training institutions and maintenance facilities should be enhanced and expanded.
5. The importation of spare parts should be exempt from custom duties.
6. The Government should encourage local manufacture of spare parts by providing facilities, tax exemptions, and other incentives.

Spare Parts Procurement by ICARDA

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Abstract

The procurement of spare parts is the responsibility of the Purchasing and Supplies Department. Competitive prices are obtained for all purchases including farm machinery. Spare parts are stocked on the basis of manufacturers' recommendations and the guidance of workshop engineers. Although suppliers generally respond promptly, delays can occur before the arrival of items at ICARDA. Spare parts procurement and supply are being improved by the standardization of equipment based on research needs, economy of operation, and after-sales service.

Discussion

It is ICARDA's policy that the Purchasing and Supplies Department is responsible for providing the necessary material support to the activities of the Center which include:

Purchase of goods and services, maintenance of stock of materials and supplies, management of movable assets, customs and shipping services, and disposals.

Generally we buy our requirements directly from the manufacturers. Competitive prices are obtained before placement of an order. This procedure is followed in all purchases including scientific equipment, office equipment, vehicles, farm implements and machinery, household furniture and appliances, and computer items.

ICARDA has various machines and implements for farm operation such as tractors, combines, drills, toolcarriers, plows, fertilizer-spreaders, harrows, irrigation equipment, sprayers, harvesters, balers, threshers, and seeding equipment.

The Farm Manager determines the need for new farm equipment and machinery and prepares the specification. Technical information obtained from manufacturers are available to study the product, its adaptability for local conditions, and application in the field.

Spare parts procurement and supply posed a major problem, because ICARDA inherited multiple makes and models of implements, equipment, and vehicles when it was established in 1977. This situation is being changed with standardization of equipment based on research needs, economy of operation, after-sales service, availability of spare parts, and local skill to repair and maintain them.

The needed spare parts are normally imported as they are not available locally. To ensure that idle time of machinery is kept to the minimum, we keep spare parts in stock that are purchased based on recommendations by manufacturers and from our experience.

After the earlier, difficult situation for spare parts, we are now in a better position to order proper items with the guidance of workshop engineers. Orders for parts are therefore reviewed critically by the user department and the stores to avoid excessive holdings. Purchase requests are checked for specifications, availability in stores, and past consumption before the requested item is ordered. While an order is being filled by a supplier and an additional requirement appears, we encourage suppliers to consolidate shipments to save shipping and clearing charges. As in the case of new equipment, parts are generally purchased directly from the manufacturers. To ensure that genuine parts are received, we order the parts by using the parts catalogue or microfiche which we update periodically. The relevant information for identification of the required part, such as make,

model, and serial number, are sent to the supplier. Some items, e.g. tires, batteries, belts, bearings, and other commonly used parts, are purchased from the dealers or manufacturers of these specific items.

We closely monitor the inventory level to avoid unnecessary blocking of the limited funds, the need for a large storage area, and, in certain cases, deterioration due to long storage. Disposal of redundant items is difficult because according to the agreement with the Syrian Government, we cannot sell or otherwise dispose of any imported items except by re-exporting them. We must therefore be very cautious in our procurement of spare parts.

Suppliers generally respond promptly to our inquiries for parts. A few suppliers dispatch the emergency requirements immediately based on telex request. Often problems occur; incomplete orders and incorrect items are sometimes received. Delay in procurement is caused by the necessity for payment to the suppliers before shipment, the Syrian Government requirement for the legalization of invoices by the Syrian Embassy or Arab Chamber of Commerce, and establishment of the Letter of Credit including possible amendment.

ICARDA enjoys duty-free import privileges and can import its requirements without import license or prior approval. Our normal practice is to order parts by airfreight or seafreight depending upon the need. Airfreight shipments arrive at Damascus and seafreight at Latakia. Surface transportation by truck is routed to Aleppo. The customs clearance procedure, inspection, and inland transportation require a little more time than expected with our duty-free import privileges. Even with all our efforts, airfreight shipments reach ICARDA about a week after their arrival in Damascus. Electronic items must be cleared by the relevant authorities before release which sometimes takes additional time.

As soon as a shipment arrives, we must submit the temporary declaration to customs officials. After preliminary inspection, the goods are released. We

then apply for approval to the Government. After the approval is received, we make final declaration. This completes the customs formality.

Sometimes we receive shipments which could have been handled more carefully by the carriers to avoid damage. Minor losses or pilferage cannot be prevented while goods are in transit. However, when serious damages or losses occur, we arrange insurance survey and press our claim for compensation on the insurance company. Replacement parts are ordered at the same time.

We recognize the importance of our service in supplying the parts. To achieve this goal, we urge suppliers to send the items promptly and the local authorities to release them immediately upon arrival.

Spare parts and other items received are checked by the receiving stores and by the spare parts storeman. Parts intended for direct consumption are delivered to the workshop. Stock items are placed in the stores. The parts are stacked on a two-tier storage system and are easily accessible for quick issuance.

Parts related to one piece of equipment are grouped in one location, so that no mix-up occurs or a wrong item is issued. The workshops can withdraw spare parts against approved requests. The cost of the part is debited to the user department at that time. Generally the old parts are returned to the stores for disposal as scrap material when new items are issued.

The spare parts store is located in the same premises as the maintenance and repair workshops so that the workshops receive the item promptly and with least inconvenience. The stores is headed by an officer with a mechanical engineering background who is experienced in spare-part management.

Entry into the stores is restricted to authorized persons only. Adequate safety measures are introduced to safeguard the stored property.

Outside workshops recondition parts when needed.

These jobs are inspected by the ICARDA workshop foreman to ensure quality control.

Stock and inventory control are computerized. This enables easy display of stock movement, costing, verification, reordering, and other information. Periodical reports on stock availability are furnished to the user departments to enable reordering. Stock movement is reviewed closely and steps taken to remove unwanted goods from the stores.

The continuous need of the spare parts service is recognized. Good understanding prevails between the workshops and the Purchasing and Supplies Department. We work with a team spirit for the success of the operations.

Parts, Maintenance and Service

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Abstract

Procurement of equipment in developing countries is inseparably linked to the three areas of after-sales service; e.g. the availability of parts, the opportunity for maintenance, and the existence of a service organization.

Manufacturers and users must take steps to solve these problems. Users must plan the adequate supply of spare parts, maintenance, and service. Manufacturers must provide good after-sales service. Preventive measures are summarized, and a checklist for prospective buyers is provided.

Introduction

Scheduled maintenance and service are basic activities to preserve the functional operation of equipment for its expected lifetime. Breakdown of equipment can cause serious problems regardless of the cause. When a planter is involved, the situation is particularly serious, because a delay in planting might distort an entire experiment and endanger the results. The breakdown of a harvester delays the harvest; when bad weather is expected, the incident becomes a breeder's nightmare.

A responsible manufacturer knows that it is in his best interests to help keep the equipment which he has sold in good working order. This paper is based on the experiences of the Wintersteiger Company with a functional, worldwide after-sales service and its recognition of the interaction between wear and tear,

long service life and consumption of spare parts, and its willingess to accept responsibility in this connection.

The following action must be taken to obtain a spare part:

1. Identify the part by reference to available sources of information depending on:
   - competence of operators in general technology
   - availability of the parts lists and manuals which were supplied with the equipment.
2. Attempt to find local sources of parts:
   - the user's own facilities
   - local supplier
   - other users of the same equipment.
3. Inform the manufacturer, when the parts are not locally available:
   - Telecommunication is the quickest way[1].
   - Dispatch a written order by first-class airmail.

After the parts have been ordered and transport arrangements have been made, they must be received (customs-cleared) either by the user or a forwarder, and given to the workshop.

At this point, the user should take organized follow-up measures to refil. his parts stock immediately; note, list, and cross-reference parts which are locally available; and return parts borrowed from colleagues.

Definition of Terms

Parts are produced either by the manufacturer or are purchased from subcontractors as finished or semi-finished parts. However, the responsibility for all parts will always rest with the manufacturer.

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[1] Telefax is best and telex the second best means. Telephone is only feasible when the same language is spoken, the communication is good, and the message is carefully written before placing the call.

The availability of parts is better when the manufacturer places emphasis on the design of the complete machine as well as on the smallest part. A comprehensive design is the basis for delivery of equipment by the promised deadline and a guarantee for the availability of parts in the future.

After-sales service is a combination of parts supply, training, and communication. It must orginate at the manufacturer but can only be successfully implemented by the user. A two-way flow of information between the user and the manufacturer is necessary.

A case of damage may arise for any of three reasons:

1. Damage within the warranty period. However, not every case of damage arising within the warranty period is automatically a warranty case. Warranty can only be claimed for parts with manufacturing defects. It does not cover parts that become defective as a result of wear and tear, incorrect treatment, or operation.
2. Normal wear of the equipment under conditions of regular maintenance and service.
3. Breakdown of parts caused by incorrect operation, accidents, or force majeure.

The parts under item 1 should not be repaired or reconditioned, because these actions would affect a warranty claim against the manufacturer. Claims of this nature can generally be settled very quickly by contacting the supplier as fast as possible and identifying the machine and the parts involved. The manufacturer will supply the parts whether the claim is justified or not. In case of doubt, he will send an invoice for them until clarification is obtained, i.e. the necessary proof for the reason of the defect. However, depending on the completeness of the information about the warranty claim, the manufacturer may agree that the parts be repaired locally (if possible) without restricting the buyer´s rights under warranty.

The parts needed to cover possible damage under item 2 are predictable in their nature, frequency, and

costs. The manufacturer can provide a list of such parts and suggest the quantities of parts to be kept in stock. The spare-part supply should be planned at the same time new equipment is purchased.

The most difficult cases to handle are those defined by item 3. It is neither possible to foresee them nor to be prepared for them. The following preventive measures could help to avoid these cases:

Operation of equipment only by trained personnel,
Scheduled maintenance and service of the equipment,
Housing equipment in dry, sheltered areas when not in use,

Storage of the equipment with proper protection and conservation until the next season.

As with item 2, the factor of unexpected, accidental breakdowns may be reduced by a well-organized after-sales service system.

Preventive Measures

Several departments of the manufacturing company play roles in an effective after-sales service. The administrative department must provide accurate lists of spare parts for easy identification. The design department should standardize as many parts as possible in different machinery. The manufacturer's sales department should consider plans for parts supply as soon as inquiries are received. The existing or planned service and maintenance should be discussed with the potential buyer. The sales department should provide two lists of suggested parts with the sales offer; one for the initial purchase of the first unit and another for follow-up purchases.

A consignment stock might be arranged under the terms of a special contract. However, such a contract can only be negotiated when a minimum number of each type of machine is to be serviced and the facilities permit the installation of such stock. Local staff should receive technical and administrative training to

maintain the stock properly. Furthermore, full proprietary rights must be guaranteed, and the time periods for accounts and payments must be arranged. The sales department should also arrange suitable transportation of the equipment.

The manufacturer's service organization should engage in the initial training of local technicians and help with the organization and administration of the parts stock, during specially contracted service tours. It should also provide regular training of the local technicans on site or in the factory upon request. On a routine basis, the service organization should send technicians to as many users as possible in one region on a cost-sharing basis to monitor the condition of the equipment and the completeness of the stock and to suggest necessary parts and procedures for the preparation of the equipment for the next season.

The user should consider an initial purchase of spare parts at the time the equipment is purchased. (Costs estimates could be based upon his experience and those of the manufacturer.) He should obtain funding for the training of technicians at the manufacturer's plant, onsite, or at another training location. The costs of a spare-part inventory and staff training should be included in the total investment package.

A review of existing workshops and staff is necessary to plan the needed facilities and staff. The minimum physical requirement for storage of spare parts is shelving in a covered area that can be secured and locked. The technicians responsible for service, maintenance, and the installation of a parts stock should possess the following qualifications:

Appropriate training in technology,
Experience with agricultural equipment,
Strong sense of responsibility and organization,
Basic knowledge of English,

Fundamental knowledge of agronomy and breeding at the facility.

Summary and Recommendations for Users

To select an investment in the best way, first check whether the manufacturer

* is a genuine manufacturer or just a workshop from which good after-sales service cannot be expected,
* offers parts lists with complete information,
* recommends spare parts and complete after-sales service with the sale of the equipment,
* maintains an adequate spare-part department and stock,
* is a communicative manufacturer i.e. one who reacts quickly, answers quickly, and keeps in touch in a fast, constructive, and comfortable way, because only then may he be considered as a reliable long-term partner.

Then check with other colleagues

* the reliability of the manufacturer with regard to promised delivery dates for equipment,
* the thoroughness of the manufacturer's technicians,
* the overall experiences with the after-sales service.

Then decide

* the initial parts stock,
* the persons who should be trained for parts, maintenance, and service,
* the most suitable location and period for their training.

When a list of requirements is prepared

* clearly state the need for parts, maintenance and service,
* include sufficient funds for parts in the application (about 20% of the total price of the first type of machine purchased and about 10% of the total price of the same type of machine purchased thereafter are reasonable estimates),
* reserve funds for the purchase of parts at a later date,
* consider financial sources for the payment of training costs,

* include the after-sales service package in the specifications.

Procurement institutions should insist that a section "parts, maintenance and service" is included in the specifications. Unfortunately, manufacturers often hesitate to offer an after-sales service package, because it would increase the total price in a tender, thereby putting them out of the running. When the cheapest offer is favored at the expense of the most complete offer, the problems are simply "papered over" until a failure occurs.

Neither the manufacturer, the user, nor the procurement institution can alone handle the supply of spare parts, maintenance, and service. Each must assume his share of responsibility for continuous and satisfactory performance.

Training Requirements for Station Management

Improved management and operation of agricultural research stations would be reflected in better experimental results and higher yields. A proposal to provide training courses for operators and managers in the ICARDA region includes subregional training sites, course outlines, and suggested phases of a five-year project.

Proposal: Regional Training Project for Improvement of Management and Mechanization of Agricultural Research Station Operations

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Abstract

Deficiencies in the management of agricultural research stations have been identified previously. A regional training project is proposed to correct these deficiencies. A series of courses for all levels of staff from operators to managers is outlined. The selection of potential training sites in the region is based on the different agricultural conditions in the region.

Introduction

The countries of West Asia and North Africa are committed to national agricultural programs for the advancement of food productivity through manpower development, farming practices improvement and the establishment of supportive infrastructure. Agricultural research stations have a critical role in scientifically defining local crop problems, designing appropriate experimental approaches, and ultimately proposing reasonable solutions.

More than 350 agricultural research stations dealing with cereals, food legumes, or forages are located in West Asia and North Africa. (See Table 1.) The limited qualitative evidence available on the operations of these experimental stations suggests severe constraints in both trained personnel and adequate equipment and material resources. For example, ICARDA scientists in frequent field visits

Table 1. Agricultural research stations located in the ICARDA mandate region with primary research activities in cereals, legume, or forages.

North Africa		**Nile Valley**	
Morocco	40[a]	Egypt	23
Algeria	20[a]	Sudan	16
Tunisia	25	Ethiopia	5[a]
Libya	34	Somalia	5
Subtotal	119	Subtotal	49
West Asia		**Arabian Peninsula**	
Cyprus	3	Kuwait	1
Lebanon	4	Bahrein	1
Syria	18	Saudi Arabia	13
Jordan	5	North Yemen	4
Iraq	13	South Yemen	3
		Oman	3
		United Arab Emirates	1
		Qatar	1
Subtotal	43	Subtotal	27
High-altitude Area			
Iran	79		
Afghanistan	6		
Pakistan	14		
Turkey	20[a]		
Subtotal	119		
TOTAL	357		

Source: Directory of agricultural research institutions in the Near East. Food and Agriculture Organization Near East Regional Office, 1979.

[a] Country not included in above quoted source, figure estimated.

throughout the region often report serious limitations in the effective operations of these stations. Observations include: the lack of homogeneity in growing conditions; inconsistent experimental treatments; inaccurate data reporting and analysis; improper selection, operation, and maintenance of mechanical equipment; and, deficiencies in design and development of field sites for agricultural experimentation and trial procedures.

The economic significance of food crops in the region has been adequately documented by the Food and Agriculture Organization, World Bank, and other international agencies. Effective and efficient agricultural research is a critical element in any strategy aimed at the improvement of agricultural practices and increased food productivity.

The magnitude of the deficiencies encountered in agricultural research suggests that an economy of scale can be achieved through a coordinated, well-designed, and comprehensive manpower development project in the region focused on management and mechanization technology levels of station operations.

Objectives of Proposed Training Project

The Regional Project for Improvement of Management and Mechanization of Agricultural Research Station Operations would be designed to:

1. Prepare appropriate job profiles for managers and technicians of agricultural research stations of West Asia and North Africa based on rigorous task and skill analysis.
2. Provide theoretical and practical training on experimental station management for approximately 80 management-level persons from the region.
3. Provide technical training on mechanized farm operations to approximately 300 technicians from the experimental stations of the region.
4. Establish a follow up training scheme to maintain and upgrade the proficiencies of management and technical-level personnel in agricultural research station operations.

Outline of Proposed Training Program

The training project is designed to proceed through the following four stages over a period of five years.

Phase I: Preparation

The preparatory phase of the training project will be addressed to an extensive study of manpower requirements for experimental station management and operation. In this effort, ICARDA will request the collaboration of the International Service for National Agricultural Research (ISNAR). The end-products of the study will be clearly established job profiles for station managers and technicians based on the needs of agricultural research in the region.

Phase II: Development

The development of a program of training activities will be ultimately defined by the results of the manpower development study achieved during the preparatory phase of the project. ICARDA station operation experts will draw on their previous training experience in these development activities. They will be guided and supported by internationally recognized training specialists who will be contracted to provide specialized assistance to the project.

In addition to the training materials that are selected from the commercial sector and through other international centers of the Consultative Group on International Agricultural Research, ICARDA will produce all other required course manuals and audiovisual materials through its Training Support Services and Communications sections.

Phase III: Implementation

Based on preliminary analysis of the current skill levels of management and technical personnel at agricultural research stations in the region, a tentative schedule and outline of training program activities can be proposed for consideration. The

suggested schedule includes specific individualized and group training activities at the ICARDA Tel Hadya station and at subregional sites. The geographical subregions are based on rainfed conditions, irrigated conditions, and high-altitude conditions with spring planting.

Countries with similar agricultural conditions are grouped in the following subregions: North Africa, West Asia, Nile Valley, Arabian Peninsula, and High-Altitude.

The North Africa and West Asia subregions include countries with semi-arid conditions but they are separated in the training scheme for logistical reasons. In the Nile Valley subregion, agriculture is based on surface irrigation and land levelling. Low-cost equipment is used throughout this subregion.

In the Arabian Peninsula subregion, agriculture is based on sprinkler irrigation of the light soil. Operations are highly mechanized.

In the High-Altitude subregion, seedbed preparation and planting takes place in the spring after the winter rains.

A. Management - Level Training: The program will include individual and group training activities.

1. Individual Training: Each year during the five-year period of the project, a management training candidate would be selected from each subregion for a 10-month program at the ICARDA Tel Hadya station. The candidate would be selected by a rigorous competitive process from nominations submitted by host governments of that subregion.

   Training topics would include:
   - Experimental station management principles and organization,
   - Farm machinery selection, operation, and maintenance,

- Machinery workshop design, organization, and support,
- Techniques in group organization and training presentation.

2. Group Training: Station managers will be selected from particular subregions each year to participate in an intensive three-week course at the ICARDA Tel Hadya station. The course would include the following topics:

   - Planning and selection of experimental station sites,
   - Planning and implementation of crop rotation procedures,
   - Selection of farm machinery according to functional criteria,
   - Management of fallow lands,
   - Management of personnel, stores, and experimental schedules,
   - Budget planning and management,
   - Application of cost-effective procedures in machinery utilization.

B. Technical-Level Training: The program will include group courses offered on an annual basis at the ICARDA Tel Hadya station and at selected sites in each subregion. The extensive ICARDA machine park will be available for courses in Crop Protection and Weed Control (Operators II): and Plot Harvest Methods (Operators III). The training course in Seedbed Preparation and Planting (Operators I) will be offered in each subregion. Suggested course outlines are:

1. Operators I: Seedbed Preparation and Planting of Small Plots
   - Methods and techniques to improve the uniformity of fields,
   - Soil tillage and seedbed preparation for plot work,
   - Fertilizer application,
   - Plot planting methods,
   - Weed control (pre-emergent),
   - Maintenance of equipment.

2. Operators II: Crop Protection and Weed Control
   - Pesticide application including boom sprayers, knapsack sprayers, weed wipers, seed dressing, and other applicators,
   - Physical and mechanical methods including interrow cultivation, soil sterilization, and flame thrower control,

3. Operators III: Plot Harvesting Methods
   - Operation of plot harvesters, including cutter bars and forage harvesters,
   - Operation of plot combines,
   - Operation of stationary threshers,
   - Seed cleaning and storage techniques,
   - Maintenance of equipment.

The distribution of trainees between the ICARDA Tel Hadya Station and the subregional training sites during the five years is shown in Table 2.

Table 2. Trainees at subregional sites and at Tel Hadya station.

Year	Subregional Site	Tel Hadya
First	30	46
Second	15	46
Third	30	46
Fourth	30	46
Fifth	45	46
Total	150	230

Phase IV: Continuation

Training initiatives established during the funded period of major program activity must be sustained after project completion, albeit at a more modest level. ICARDA's long-term commitment for steady and

continuous improvement of agricultural research in the region demands a realistic determination of follow-up activities, which can be anticipated to include:

Periodic visits to experimental stations by senior scientists and staff of ICARDA during their regularly scheduled travel in the region to provide consultative support.

Preparation and distribution by ICARDA of an Experimental Research Station Newsletter, containing current developments in station management and farm mechanization.

Development and implementation of annual training courses on specialized topics in management and mechanized operations of agricultural research stations.

Consultative support of ICARDA training specialists for collaborative projects with national agricultural research institutions of the region, including preparation of funding proposals to international aid agencies.

National and Regional Experiences

Progress in mechanization of field experiments is reported from Australia, Cyprus, Turkey, and West Germany. The status of mechanization of the ICARDA food legume experiments is described.

Mechanization of Field Experiments in Cyprus

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Abstract

Field experiments at the Agricultural Research Institute are primarily concerned with cereals, legumes, and forage crops. From the early days to the present, there has been continuous development in the mechanization of the experiments to improve timeliness, increase the number of trials, reduce costs, and attain greater accuracy and uniformity. A satisfactory level of mechanization has been attained by modifying machinery and adapting plot layout. Attention is now being given to several problems with large seeds and seed drills. Work continues on mechanization of fertilizer application, control of vegetation between plots, and all aspects of the manual faba bean experiments.

Introduction

Agricultural research in Cyprus is undertaken almost entirely by the Agricultural Research Institute (ARI) which was established in the early 1960's. Field experiments, mainly with cereals, legumes, and forage crops are carried out by the Field Crops Section. Most work was formerly done by hand. Continuous development in the mechanization of experiments has occurred at ARI since its inception.

Early Developments in Mechanization

Seeding and harvesting were the first operations to be mechanized. For the seeding operation, one Oyjord cone (tractor mounted) and later one self-propelled and one

tractor-mounted drill were imported. The first drill had a small cone and could not accommodate seed exceeding a certain weight. The problem was greater with barley and oats than with wheat, especially with forage trials where much higher seed rates are used. Consequently, the length of the plots had to be restricted. The self-propelled seeder was therefore ordered with a larger cone feeder.

Another weakness of the new seed drills was the difficulty in penetrating the hard, cloddy soil to a uniform depth. Moreover, clogging occurred often in wet soil conditions. To overcome these problems, extra weights were ordered for the coulters of the tractor-mounted seed drills. These coulters were replaced by spring-loaded disc coulters obtained from an old commercial seed drill. At the same time, special effort was made to ensure a fine seedbed. For the self-propelled seeder, which uses the original coulters, the problem of clogging was nearly solved by enlarging the seed outlet. Clogging due to a build-up of trash and mud during operation now occurs less frequently. Seed covering and soil compaction by tractor-mounted drills fitted with the disc coulters was overcome, more or less satisfactorily, by attaching rubber wheels behind the coulters. (These wheels were also obtained from the old commercial seeder.)

The experimental plot drills are employed for sowing trials of grain and forage cereals, some food legumes, and new crops, e.g. safflower and rapeseed. However, some crops cannot be handled by these drills, e.g. faba bean because of large seed size, and sunflower, chickpea, and groundnut, which are sown on a fixed interrow spacing. These crops are sown by hand; an implement has been constructed for opening the furrows for sowing.

The application of fertilizers before sowing was done by hand, even for a time after the acquisition of the plot drills. Fertilizers were weighed in the laboratory, usually for whole replications, and broadcast after preparation of the seedbed and marking of the trials.

Locally manufactured fertilizer hoppers were fitted onto the tractor-mounted drills. (Cereal growers used these drills, which were also manufactured locally.) The feeding mechanism of the hopper could be adjusted for different application rates. Weight limitations of the self-propelled plot drill prevented the installation of a hopper on it.

The first imported combine harvester was a Massey-Ferguson MF30 model that was converted for harvesting experimental plots. It was used only for the larger, cultural practices trial plots. A Hege 125B combine harvester was acquired in 1976 and a Walter and Wintersteiger machine in 1983. The Massey-Ferguson combine is not currently used because it is unsuitable for small plots.

Threshing was done mechanically from the beginning of research, except single ears or small bundles from early generations of the breeding program which were threshed and cleaned by hand. Two plot threshers were used: an Almaco Vogel and a Saat cyclonic type. These threshers were fitted with gasoline engines and often were used for threshing hand-harvested sheaves in the field. After acquisition of the combine harvesters, the plot threshers are used only if sheaf weight is required or to thresh some new crops. Single ears and small bundles from the cereal breeding program are threshed by small threshers. ARI imported two Almaco laboratory threshers, (one with an electric motor and one with a gasoline engine, which was later replaced by an electric motor), a third small thresher, and a single-ear thresher.

Seed cleaning was originally done by hand, using hand sieves and fans similar to those used in offices or homes for cooling during the summer. Manual cleaning was improved by the introduction of cleaners with handles. A motor-driven NIAE machine was subsequently imported for seed cleaning. A small rotating drum-sieve cleaner with a fan and cyclone was acquired recently. This machine handles small quantities of seed and is excellent in performance especially in the separation of broken and whole seeds. It is very successful with chickpea. The volume of

seed cleaning was drastically reduced with the use of plot harvesters, but seed cleaning remains a considerable operation.

At the beginning of research at ARI, the laboratory tests on seed samples were restricted to moisture content, 1000-grain weight, volume weight, and simple measurements and observations. The subsequent availability of laboratory equipment enables the performance of numerous other tests including protein and carotene content, and breadmaking quality of cereals.

Chemical treatment against seedborne diseases was done initially by hand in plastic containers, then in a locally constructed, hand-operated machine, and more recently in an efficient, motor-driven, imported machine.

Trials with forage crops, mainly barley and legumes cut for hay, were sown and fertilized in the same way as those with cereal grain crops. Harvesting was initially done by hand (sickle). Green forage was placed in canvas sheets, tied at the four corners with ropes, and weighed. Samples of 500 g were also weighed in the field, placed in paper bags and brought to the laboratory for drying, milling, and chemical analyses. Cutting of the crops was later done by pedestrian-operated, knife mowers. Recently, a binder was acquired to cut erect forages like barley, oats, and triticale. The binder cuts the forage and binds it into bundles, which are weighed.

Cultural practices have always been carried out on plots large enough to accommodate standard farm machinery and implements. These trials include rotations, test of cultivation implements and methods, seed and fertilizer rates, and test of seeders. Harvesting was first done by the Massey-Ferguson combine and later by the other two experimental plot combine harvesters.

Plant protection and top dressing of fertilizers were, and still are, applied in a similar manner in all trials. Chemicals are sprayed by a commercial,

tractor-mounted, 400 l sprayer with 10-m spray booms or by a 100-l, wheelbarrow sprayer with a spray gun. Top dressing of fertilizers is still done by hand. Pre-weighed amounts of fertilizer are broadcast by hand over specified areas of the trials.

The special design, small number, and absence of local agents for imported machinery caused serious difficulties for the procurement of spare parts. At first, efforts were made to find the required parts in the local market. If the item was not found, repair or fabrication was attempted by local workshops. The local market and workshops could supply many of the spare parts required and almost all the parts necessary for the modifications. Other spare parts were ordered from the manufacturers abroad.

A recurrent problem is the transport of machinery and implements to the experimental locations. All machinery and implements are kept under sheds at Athalassa, near Nicosia, and must be transported as far as 160 km to field locations. Almost all field machines and implements (including the tractor and the combine harvesters) have to be transported. Trailers and special loading platforms have been constructed but they are not strong enough to transport the heavier machinery. Trucks are usually hired for the transport of these heavy machines, but timeliness is sometimes a problem.

Plot Layout and Work Organization

Various changes have been introduced in plot layout and the organization of field and laboratory work. The changes were necessary to accommodate the new machinery and to improve the efficiency and accuracy of the work. The description that follows refers to current practices:

As far as possible, the same methodology is applied for covering trials of advanced cereal breeding material and yield trials of cereals and other field and forage crops. The trials are designed in advance and plans of the trials are drawn similar to the sample shown in Fig. 1.

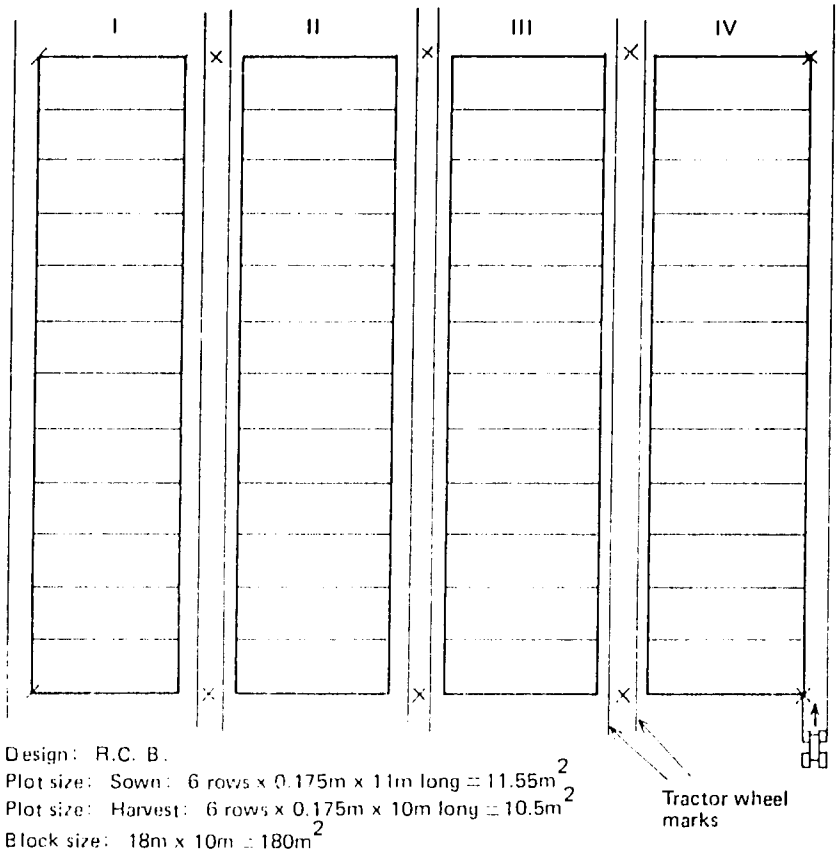

Fig. 1: Plot layout for barley yield trial.

The seeds are weighed and put in envelopes. The route of the tractor during sowing is predetermined and the envelopes are placed in proper sequence in boxes at the laboratory. Preparations in the field include preparing the seedbed, marking the four corners of the trial and the middle of the ends of the passages (marked by x on Fig. 1), and producing tractor-wheel marks at the two ends of the trials (as many as possible trials are placed adjacent to each other) and within each passage, as shown on the trial plan. After these preparations, only two persons (a tractor driver and a seed drill operator) sow the trials.

The seed drill operator drops the seed of the first plot at the beginning of that plot and in the passages as soon as the seed of the previous plot is finished, using the tractor marks for checking. The amount of seed is enough for the plot length plus 1 m. When sowing the next row of plots, the tractor operator uses the tractor wheel marks of the previous run to position the tractor. In this way, a space of about 60 cm is maintained between adjacent plots. Each plot has 6 rows which are 17.5 cm apart. In the past, each plot had 8 rows, but the plot combine harvesters could not pick and cut all 8 rows. The number was therefore reduced. After emergence, the plots are measured to the `harvest´ size and cut to that size by a rotavator. At this stage, the plots and replications are formed to the design shown on the trial plan.

Spraying of chemicals, top dressing of fertilizer, and the harvesting of forage and grain have already been mentioned. Harvested grain is placed in labelled cloth or paper bags and transported to the laboratory for weighing, testing, and analyses. Other plot layouts and methods are applied to early stages of genetic material of the cereal breeding program, large-seeded food legumes, cultural practices and grazing forage trials, where the nature of the work, seed amount or size, make it impossible to apply mechanization to the extent described above.

Present Situation and Future Needs

The mechanization of field trials has reached a satisfactory level but there is still room for improvement and further mechanization. The faba bean experiments present the largest opportunity for mechanization because most of the operations (sowing, weeding, harvesting, and threshing) are now done by hand.

The cone seed drills have problems with large cereal seeds like oats because it is difficult to `shake´ them down the cylinder over the cone. The clogging of seed at the outlet of the coulters of the

self-propelled drill due to the collection of trash and soil is also a problem. The press wheels to compact the soil over the seeds are not satisfactory. The two end rows of the tractor-mounted drills are sown deeper than the other rows. Efforts continue to solve these problems. Special seeders for sowing small amounts of seed and large seeds (like faba bean) will be investigated. An urgent need exists for precision-spaced seed drills (e.g. pneumatic) for crops like sunflower and groundnut.

Several opportunities exist for mechanization of the application of fertilizer in both top dressing operations and applications in fertilizer experiments. In the latter case, unsuccessful attempts have been made with a ground-wheel drive metering system. An improved fertilizer applicator should be flexible for use with all types of fertilizers at variable rates.

One serious problem in the field is the control of vegetation in the passages and spaces between plots. Present use of the rotavator produces a loose, soft soil which causes difficulties for movement of the small-wheeled plot combines. One solution to this problem could be a machine for chemical weed control within strictly defined boundaries.

During the mechanical threshing of durum wheat, some seed embryos are broken by the force of impact with a resulting reduction in germination. The mechanical threshing of faba bean is problematic as many seeds are broken. Furthermore, the milling of faba bean for chemical analyses has also been found to be problematic when using the existing cereal mills.

Improvement is desirable in the mechanization of forage crops that cannot be harvested with a mower-binder. The collection of cut legume and short cereal forages might be accomplished by a box collector drawn behind the mower.

Finally a strong, low truck with loading and unloading facilities to transport the tractor and the combines would be a very desirable improvement.

Mechanization of Field Experiments in Central Anatolia

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Abstract

Two university faculties and six agricultural research centers are located in Central Anatolia. Field research is carried out on 368 hectares of land by these organizations. The equipment and machinery are pooled for use by all the organizations. The level of mechanization of field trials is sufficient for Turkish conditions.

Introduction

The 10 provinces in the Central Anatolia region occupy 17.5 million ha, of which 9.2 million ha (52.6% of the total land area) is farm land. The most important factor in Central Anatolia Region controlling and restricting crop growth is insufficient and irregular precipitation during the year.

The regional yields for wheat, barley, rye and chickpea are above the national average and yields for oats and lentil are below the national average. The regional production accounts for the following percentages of the total national production: wheat - 36.2%, barley - 46%, lentil - 13.7%, and chickpea - 26%.

Agricultural Mechanization

Two university faculties and six agricultural research centers occupy 1500 ha in Central Anatolia. Most of them are located in Ankara Province.

The total area devoted to field research by these organizations is 368 ha. Table 1 shows the area for field research of each organization.

Table 1. Agricultural Research Organization in Central Anatolia.

Organization	Research area (ha)	Province
University of Ankara Agriculture Faculty	60	Ankara
University of Selcuk Agriculture Faculty	0	Konya
Turkish Sugar Industries Sugar Institute	128	Ankara
Central Anatolian Agricultural Research Institute	120	Ankara
Plant Protection and Quarantine Research Institute	0	Ankara
Ankara Rural Research Institute	10	Ankara
Eskisehir Regional Agricultural Research Institute	40	Eskisehir
Konya Rural Research Institute	10	Konya

Different requirements for experiments permit each organization to obtain agricultural machinery from a common pool of equipment that includes 20 tractors. The available equipment listed in Table 2 are now discussed.

Soil tillage equipment. Most of the primary tillage equipment is three-point hitch. It includes mouldboard and disc ploughs, Anatolian ploughs, ducksfoot cultivators, chisels and other equipment to till the soil close to the surface without turning it over. There are 21 machines that till the soil to a depth of 15 to 45 cm for the first treatment, and 55 machines that till the soil to a depth of 8 to 12 cm. Among the equipment for seedbed preparation are discs, rollers, and harrows.

Table 2. Agricultural equipment and machinery in the common pool.

Machine and equipment	Number
Tractor	20
Soil tillage equipment	21
Seedbed preparation equipment	55
Plot drill	23
Fertilizer distributor	10
Sprayer - blower equipment	14
Plot combine harvester	8
Spike thresher	10
Plot thresher	17
Seed cleaner	6
Laboratory equipment	sufficient

Sowing machines. There are 23 plot drills for different purposes and seed species. The row number, distance, and sowing width can be varied. These machines are three-point mounted, towed, and self-propelled types.

Fertilizer distributors. Ten distributors are available for application of nitrous fertilizer in the tillage period. Machinery is also available for distributing fertilizer with the seed during sowing. For fertilizer application after emergence and in the seedling period, several separators and fertilizer distributors are used. In small plots and in cases where sowing is done by hand, fertilizer is also distributed manually.

Harvesting machinery. There are eight combine harvesters for plots with variable working widths for harvesting small seed cereals. Some of these machines can be adjusted to harvest other field crops. Scythe and sickle are used in small plots and pulses.

Threshing machines. The threshing of crops not harvested by combines is done by spike or plot

threshers according to plot size and the crop volume. The equipment includes 10 spike threshers and 17 plot threshers. The drum speed, concave clearance, and cleaning fan can be adjusted in some models. For high protein crops (especially legumes), threshing is done with rubber-covered beaters.

Seed cleaning machines. Adequate equipment is available for the cleaning and separation of seeds obtained in field experiments according to density, size, shape, and hardness. Six selectors are used for seed obtained in the trial production of other seed stocks.

Laboratory equipment. There is sufficient equipment for analyses of field experiments. Some special analyses can be done in facilities of other organizations.

Although the level of mechanization is adequate for conditions in Central Anatolia, the inventory of machines increases with the purchase of new machines.

Organization and Mechanization of Variety Trials and Field Experiments in Bavaria

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Abstract

Variety trials and field experiments are conducted on a main station and on state and private farms in different parts of Bavaria. Mechanization is used in soil tillage, sowing, and harvesting operations. The organization and equipment used for field experiments in the state experimental system are described.

Introduction

The Government of Bavaria supports a system of trial and field experiments. It also provides an advisory service for farmers. Experiments are also carried out by the fertilizer and plant protection industries.

The state experimental system in plant cultivation is organized and financed by the Bavarian Institute for Agriculture and Plant Cultivation (LBP) which is directly subordinate to the Ministry of Agriculture. The LBP supervises eight offices of agriculture and plant cultivation (AfLuB) in different regions of Bavaria.

Experiments are carried out by LBP at the main experimental station on an area of about 150 ha and on state and private farms in different parts of Bavaria. Experiments are also carried out by the Aflub offices in different parts of Bavaria. These experiments require the cultivation of about 80,000 trial plots every year.

Mechanization of the LBP Field Experiments

Soil tillage and other general work like fertilizing and plant protection are carried out with the usual machines which are also used by farmers. Experiments and trials are performed with special plot machines, which are only used on the experimental station and which are adapted to the respective vegetable and kind of experiment.

Plot drills from Hege (belt distributor) and Wintersteiger (System Oyjord) are used for sowing cereals. For sowing maize and legumes (e.g. beans, peas, and fine seeds), special machines have been purchased and others fabricated by LBP.

Different types of portable and tractor-mounted sprayers and fertilizer distributors are used in the cultivation of trials.

Hege and Wintersteiger plot combines are used for harvesting cereals, oil crops, and legumes. For harvesting forage and intermediate crops, a Hege forage-plot harvester is used. It has an electronic weight recorder and special motor mowers and a tractor-mounted flywheel chopper with maize attachment.

Equipment is transported great distances (up to 200 km) by truck or Unimog to the site of experiments supervised by the LBP in different parts of Bavaria. The special equipment which is too expensive or infrequently used at the AfLuB is also transported to the AfLuB field trials.

In Bavaria, the farmers keep many livestock, primarily cattle and pigs. Therefore, the exact distribution of liquid manure and sludge plays a very important role in determining the best use of nutrients and in avoiding the pollution of drinking water. During the last few years, many trials on liquid manure have been performed. The special plot spreaders developed for these trials consist of a 1000 l steel tank, a distribution boom with a length of 2.5 m and 5 outlets with nozzles, which can be drawn out on one side. Therefore, the tractor must not be driven over

the plot. The distribution of liquid manure is more exact than with watering cans.

To harvest maize trials, an ensilage harvester was developed on the base of a flywheel chopper mounted on a Unimog. The maize is cut row by row, bagged, and weighed on the field with an electronic weight recorder.

A large variety of AFLuB field trials with regional significance is carried out on private farms. The AFLuB machines must be precise and easy to transport over distances as great as 50 km.

Basic Machines

Each office owns a Volkswagen transporter with a trailer, a truck with a special loading platform, and various cars for the transport of machines, seed, crop material, and staff. Each office also has two small special tractors (Schanzlin or Agria) which can be transported by truck. The tractor has an engine with 27 kW and a variable track width from 75 cm to 90, 125 to 140 cm. It can be used for many different kinds of cultures and vegetables with different interrow distances.

Special Machines

For sowing cereals, the AFLuB have a tractor-mounted, Hege plot drill equipped with a belt distributor. It can also sow beans, peas, and fine seeds. A modified, two-row Becker Aeromat is used to sow cereals. This tractor-mounted machine can also used to some extent for sugar beets or sunflowers. Because the seeds of sugar beet are pills and the experiments are generally not very large, a mechanical cell-disc sowing machine is often sufficient. It can be filled for each row by hand; the rest of the seeds must be sucked off by air.

Different applications of fertilizers on the plots are performed with a tractor-mounted Hege fertilizer distributor. A tractor-mounted, 12-m-sprayer is used

for plant protection. The left, right, or middle part of the crop-spraying boom can be closed. Portable knapsack sprayers are also used.

Each AfLuß office owns two plot combines for harvesting cereal trials. Potatoes, sugar beets, and silo maize are harvested throughout the region by the LBP.

All data such as assessments, yields, weights, and weather data are either registered manually on paper or recorded by mobile electronic data collectors or recorders and than evaluated in personal computers at the experimental station or in the data center of the Ministry of Agriculture. All data and results are collected and analysed at the LBP and serve as basic knowledge for further planning and for the advisory service for the Bavarian and German farmers.

Experience with Research Equipment for Dryland Experiments in Australia

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Abstract

The majority of cereals and pulse crops in Australia are grown in areas which receive an average of 300-400 mm of rainfall each year. The agricultural techniques and varieties, which came with the early settlers from Europe, have been progressively modified to the drier and often sandier soils encountered in Australia. The research equipment necessary to develop many of these improved varieties and agronomic techniques has also required adaption to the local environment.

Introduction

The early attempts at agricultural research (before 1935) depended almost entirely on farm equipment for field experiments. Horses provided the power which effectively limited the width of most cultivating, sowing, and harvesting equipment to 2-3 m. This equipment therefore produced field plot widths which were suitable for the degree of sophistication required in research at that time. The majority of farm machinery used in Australia at this stage was produced by local manufacturers. Innovations to improve the performance under both farm and experimental situations include the stump jump cultivator, the stripper harvester, and the combination seed and fertilizer drill.

After the second world war, tractors rapidly replaced horses. The extra available power enabled farmers to increase the size of their equipment until

it was no longer suitable for field plot experimentation. It therefore became necessary to obtain equipment specifically for research purposes. Despite the specialized application, experimental equipment was still constructed as small-scale farm machines until 1970, when radical design changes improved their application to research.

From 1970 until the present, field research equipment has evolved into specialized machinery. Australian agricultural research establishments have generally adopted a policy of purchasing, and often modifying, suitable equipment from two specialized European manufacturers or designing and constructing their own equipment.

Plant variety rights legislation is now being prepared for Australia, which will encourage commercial participation in plant breeding and research. The small scale of most commercial companies will prevent them from manufacturing their own equipment. They will therefore seek manufacturers who can produce research equipment suitable for Australian dryland conditions.

Australian Field Research Equipment

The equipment used for cropping research is now described.

1. Seeding machines

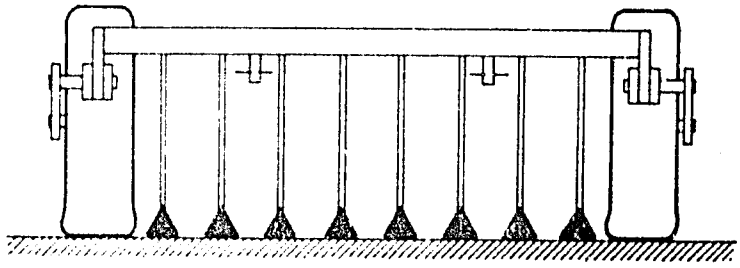
Belt cone seeders are almost universally used for sowing dryland experimental crops in Australia. Sugar beet is not grown in Australia and the very small areas of corn are limited to the wetter areas, so precision seeders are not generally required. The belted cone developed in Australia described by Mock 1977 is similar to that manufactured by The Hege Company.

The machines on which the cones are mounted are however often specially designed for low rainfall situations. Design criteria include the following considerations:

a) Precise sowing depth. Sandy soils rapidly dry out on the surface so that within 24 hours of light rain, the surface 25-50 mm of soil may be too dry for sowing. Spring-loaded tines are selected that will maintain their set depth in the soil until the load on the point of the tine exceeds 50 kg. This enables any sowing depth between 10-100 mm to be selected and maintained regardless of soil conditions. The seeders are usually equipped with wide tires that provide sufficient flotation to prevent soil compaction under the tires affecting sowing depth.

b) Ability to sow into stubble or trash. Wind erosion can be a serious problem when sandy soils are fallowed or cultivated before sowing. It is therefore necessary for seeders to be able to sow into fields that have had little or no cultivation. Wide clearances between sowing tines and wheels enables successful sowing into paddocks containing up to 3t/ha of dry matter in the form of crop or pasture residue. Crops grown in semi-arid areas seldom produce stubble in excess of 3t/ha, which would then require use of disc sowing units. Fig. 1 illustrates how attention to tine spacing will assist trash clearance and prevent blockage of the seeder.

c) Versatility. Most agricultural research in Australia is conducted by government organizations which require seeders suitable for a wide range of experimentation including plant breeding, agronomy, and pathology. All seeders are therefore equipped with at least one fertilizer box and often a seed box as well. The variable treatment can be applied through the belt cone and the fixed treatment through a bulk box. For example, when sowing a rate of application of nitrogen fertilizer experiment, the seeder would be used in the following way. The various rates of nitrogen fertilizer would be sown through the cone to facilitate rapid changes in application rate. The seed for the crop would be sown from the bulk seed box and the phosphate fertilizer (always sown with Australian crops) would be sown from the bulk fertilizer box. The versatility of these seeders, therefore, enables quite complex experiments to be



BASE FOR TRASH CLEARANCE SEEDER

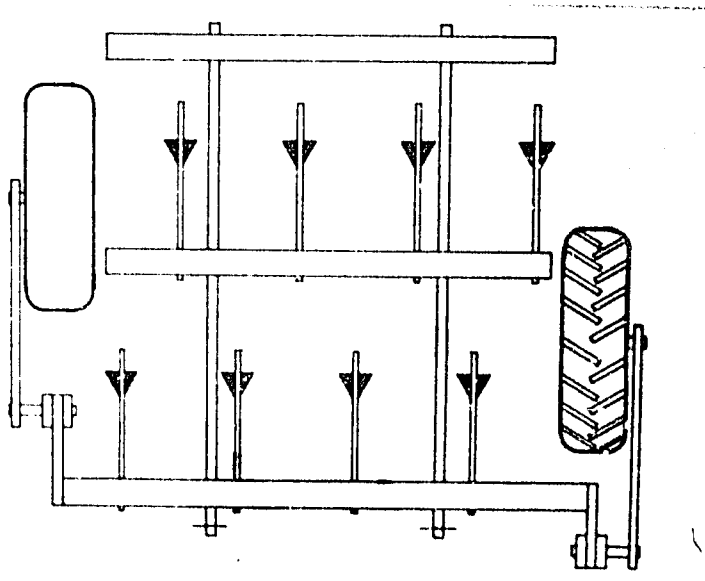


Fig. 1. Schematic diagram of wide clearance between sowing tines and wheels.

sown with one pass of the machine. This capability is a considerable advantage on very sandy soils where repeated machinery movements can result in the removal of the protective trash cover and the occurrence of erosion in the wheel marks.

d) Dependability. Seeders are constructed with sufficient strength to withstand stumps and rocks

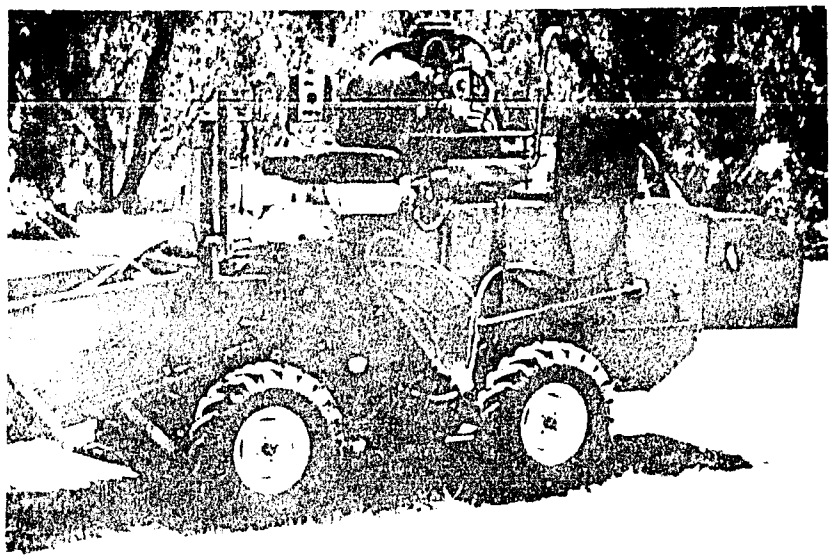
hidden in the uncultivated sandy soils. The steel needed to build a machine with the necessary strength will result in the average 8 run seeder weighing approximately 600 kg. This weight is easily handled by the three-point linkage on a 30 kW tractor. Four-wheel drive or front-wheel-assist tractors in the 25-40 kW range are usually used for seeding to minimize wheel slippage, which is particularly undesirable on the weakly structured sandy soils.

2. Harvesting equipment

The complexity of self-propelled plot harvesters has generally discouraged the design and manufacture of these machines in Australia. Several local attempts have however been made to overcome the problems encountered when using the European plot harvesters on Australia's sandy soils. These problems invariably relate to the self-propelled mechanism which is either too weak or causes excessive wheel slippage. Therefore, the use of Wintersteiger or Hege harvesters on the sandier soils was not possible. The small Claas harvester had superior traction although it was not suitable for pure seed and is no longer manufactured.

To obtain sufficient traction for harvesting pure seed on sandy soils, the following solutions have been used:

a) The Mallee Research Station at Walpeup developed a four-wheel drive modification for a Hege 125B harvester to enable research on the sand dune systems in that locality. The existing Hege drive system was replaced by a new chassis containing a hydraulic motor in each wheel hub, two hydraulic pumps, oil reservoir, filters, valves, etc. (see Fig. 2). This system provided constant four-wheel drive and total control over speed, direction, and braking by two control levels. Traction is adequate for all soil types and operational speed is improved due to higher transport speeds (20 km/h) and simplified controls (Mock 1984).
b) A 125C harvester with hydraulic four-wheel drive was made by The Hege Company. This harvester is



MODIFICATIONS TO THIS HEGE PLOT

HAVE IMPROVED ITS:

(A) TRACTION IN SANDY SOILS

(B) OPERATING SPEED

Fig. 2. Modified Hege 125 B harvester.

similar in appearance to the standard two-wheel drive harvester although it has hydraulic motors fitted in the wheel hubs of the steerable rear wheels. (See Fig. 3.) The sophisticated hydraulics enable the operator to select either two-wheel drive or four-wheel drive on a locked four-wheel drive (where all wheels must turn at the same speed). Small turning circles are possible in the standard four-wheel drive mode without soil disturbance or loss of traction. The hydraulic drive described in solution (a) caused substantial soil disturbance as steering relied on skidding the wheels.

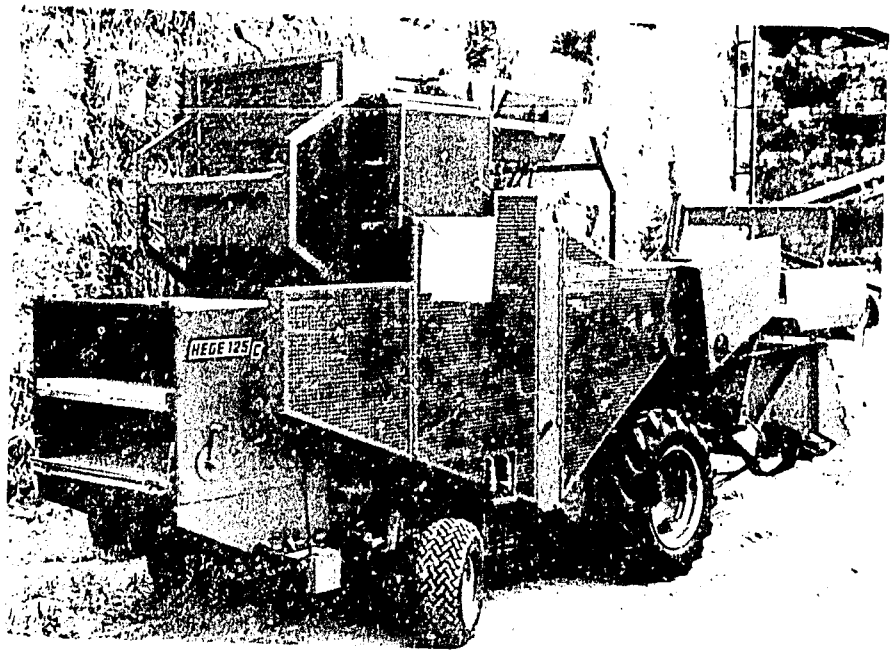


Fig. 3. Modified Hege 125 E harvester.

The continuously variable speed obtained with the hydraulic drive described in both solutions has proved very satisfactory for harvesting crops grown on semi-arid sands. Harvest speeds up to approximately 6 km/h can be used for the low yielding crops as gear shifting is not necessary. The sealed hydraulic circuits also eliminate the wear caused by abrasive sand and dust in the drive system thereby substantially reducing maintenance costs.

3. Mechanical soil sampling

Soil moisture is often a limiting factor to crop growth in low rainfall areas. Experiments requiring soil moisture measurements in the root zone can often necessitate extracting soil samples from as deep as 2.0 m in the profile. Numerous core sampling machines have

been built in Australia that can extract cores from this depth in approximately 2-4 minutes. Inserting and extracting a 50 mm diameter soil cube to this depth will usually require forces of approximately 4.0 t, although up to 7 t is required on occasions. Hydraulic rams can easily and economically produce these forces without the danger of a violent spring action should a tube or other component fail. The force needed to insert a sample tube will often exceed the weight of the sampling machine, unless mounted on a large tractor. A hydraulic hammer is often built into the machine to assist in the insertion of tubes as the downward force exerted by the hydraulic rams must be limited to the weight of the machine.

Light duty soil sampling machines have been mounted on vehicle tow bars although larger capacity machines are either tractor mounted or have a substantial trailer or chassis of their own. The chassis described in section 2(a) has been the basis for a very successful soil sampling machine. It is easily detached from the harvesting components to provide a self-propelled chassis with ample hydraulic output to power the sampling rams and hammer.

4. Spray applicators

Field experiments often require various sprays of herbicide, fertilizer, insecticide, or fungicide to be applied as a uniform treatment over the experiment. The volume required is too large for the backpack sprayers used in many countries. A tractor-mounted boom spray will often result in permanent wheel damage to crops sown on soft sandy soils.

Small boom-spray units, specifically designed for the recently developed four-wheel drive motor bikes, are well suited to spray applications on field experiments. The light weight of these bikes (approximately 300 kg) and low pressure balloon tires cause minimal crop damage. Their excellent traction also ensures that precise application rates at a constant speed can be maintained.

Many other innovations incorporated into research equipment used in Australia are not unique to this country or to dryland experimentation. They have previously been discussed (Mock 1985).

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Mechanization of Field Experimentation in Faba Bean, Kabuli Chickpea, and Lentil at ICARDA

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Abstract

Plot mechanization is an asset to the ICARDA research program on the improvement of food legumes. Seed drills are used for sowing lentil and chickpea, and a faba bean planter has been tested. Chemical and mechanical weed control is carried out. Seed increases of chickpea and lentil are harvested by a plot combine; seed increases of faba bean are mowed with a double-knife cutter bar. Plot threshers are used on all three legumes. A variety of machines are used to thresh single plants. Work continues on the problem of large-seeded faba bean in sowing, harvesting, and threshing operations.

Introduction

The production of food legumes by farmers and on research stations is labor intensive. Rising labor costs have encouraged experimentation on the mechanization of food legumes in the developed world and now increasingly in the developing countries. ICARDA has a worldwide responsibility for research on faba bean (*Vicia faba* L.) and lentil (*Lens culinaris* L.), and, with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), for kabuli chickpea (*Cicer arietinum* L.). The vigorous research program on food legume improvement at ICARDA has necessitated extensive field experimentation in Syria and, in cooperation with national programs, throughout North Africa and West Asia. As part of this

undertaking we have mechanized much of the field plot activity from seeding, through weed control to harvesting and threshing. This paper describes our experience in plot mechanization.

Problem

Considerable labor was initially required for seed preparation, sowing, weeding, harvesting, threshing, and recordkeeping of field experimentation on the food legumes. But the adoption of existing systems for cereal field plot mechanization was not immediately possible because of specific features of the food legumes:

Seed size and shape	- chickpea and faba bean
Proximity of pods to the soil because of lodging or short short stature	- faba bean and lentil,
Pod dehiscence	- lentil,
Absence of selective herbicide	- chickpea, faba bean, and lentil

Consequently, we have searched for new solutions to the specific problems of plot mechanization of the food legumes.

Systems of Mechanization

1. Seed preparation for sowing

Seed counting of small (100 seeds or less) food legumes samples is done manually. Attempts to mechanize the process for lentil using a suction pad punctured with holes and attached to a vacuum cleaner were discontinued because two seeds/hole often collected on the pad. Indented trays have also been tried. Larger samples of chickpea and lentil are counted with an Audiotronics electronic seed counter. Volume measurements made with a cylinder are used for seed packeting in chickpea; a manual adjustable-cylinder dispenser is utilized for preparing lentil seed

packets. Faba bean seed preparation is done by manual counting. The system for seed treatment of experimental samples of food legumes has been described earlier by Diekmann[1].

2. Sowing

The use of different seed drills for sowing the food legumes into individual rows, plots, and seed increases is summarized in Table 1. Lentil seed is similar in size to cereal grain and consequently all types of cereal drills may be used for lentil. At ICARDA, the seedmatic system is used for individual rows, the Oyjord plot drill for lentil plots, and a three-cone drill for seed increases[2]. In chickpea, the pneumatic precision planter is utilized for single rows and plots, and for seed increases of greater than 1 ha, a Maxicorn drill is employed. At present faba bean experiments are sown by hand, but the faba bean planter is being tested[3].

3. Weed control

The control of weeds in food legumes requires an integrated approach to minimize hand weeding. The control of volunteer cereals was previously by a summer irrigation (50 mm) to germinate seeds before preparatory tillage using sweep, but deep mouldboard ploughing (to 28 cm) is now preferred.

Effective pre-emergent herbicides are currently available for the control of winter and early spring weeds in the food legumes. Pronamide (0.5 kg a.i./ha) is effective against grasses in all three crops. It

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[1]See the paper, "Treatment of Experimental Seed" by M. Diekmann on pages 98-103 of these Proceedings.

[2]See the paper, "Mid-Mounted Three-Cone Planter" by P. Jegatheeswaran on pages 40-42 of these Proceedings.

[3]See the paper, "Faba Bean Planter" by J. Diekmann on pages 43-45 of these Proceedings.

Table 1. Seed drill used in the planting of single row, plot and seed increase trials of the three food legumes.

Crop	Single row	Plot	Seed increase
Chickpea	a	a	b
Faba bean	(hand sown)	(hand sown)	c
Lentil	d	e	f

a. Pneumatic precision plot planter.
b. Maxicorn seeder (commercial mechanical precision planter)
c. Pneumatic precision plot planter for faba bean.
d. Magazine cone planter (seedmatic).
e. Cone plot drill.
f. Three-cone plot drill.

may be usefully combined with the broadleaf herbicides cyanazine (0.5 kg a.i./ha) for lentil and chickpea, methabenzthiazuron (2.0 kg a.i./ha) for chickpea and faba bean, or terbutryne (2.0 kg a.i./ha) for faba bean. Fluazifop-butyl (1 kg a.i./ha) is also a good post-emergent herbicide for the control of grasses in both faba bean and lentil.

Interrow cultivation is practiced using sweeps mid-mounted on a Fendt toolcarrier or a system of revolving brushes (Baertschi) on the same toolcarrier, which has a wider weeding action between rows than sweeps but is only useful on young weeds (see Figs. 1 and 2). The row-to-row distances are 45 cm for chickpea and faba bean and 37.5 cm for lentil.

4. Pest and disease control

The control of pests and diseases by the spray application of pesticides is made with a tractor-mounted 12-m-boom sprayer working in the alleys between plots. The most commonly used prophylactic treatments for field experiments and seed increases of the three food legumes are summarized in Table 2.

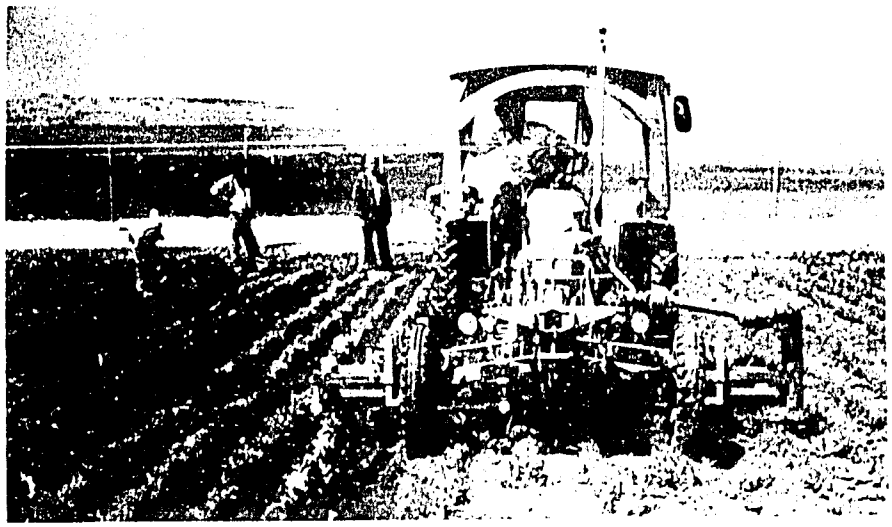

Fig. 1. Interrow cultivation using sweeps mid-mounted on a Fendt toolcarrier.

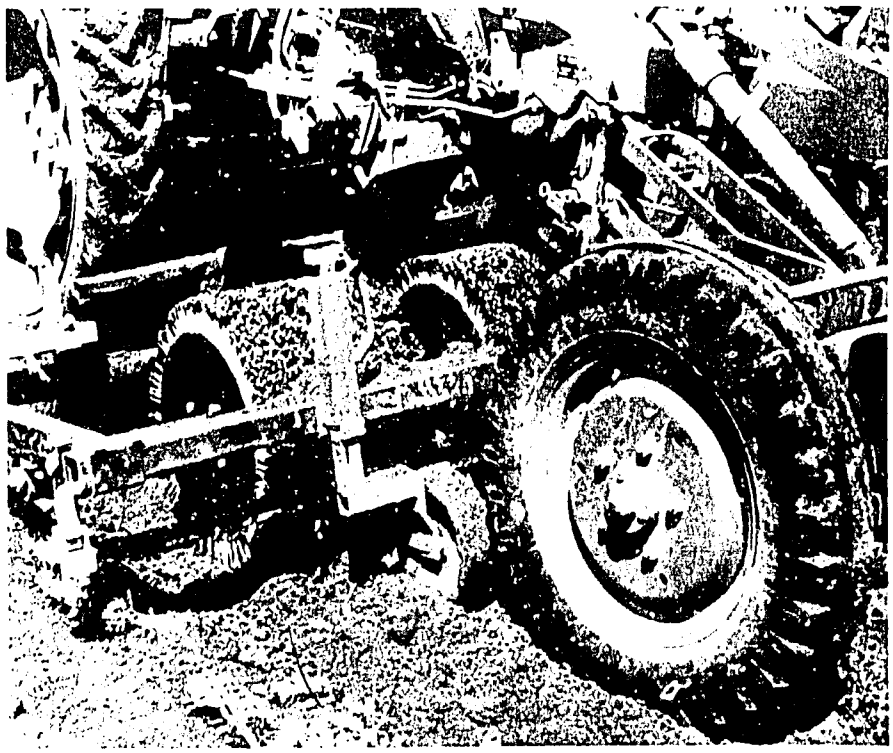

Fig. 2. Interrow cultivation using a system of revolving brushes (Baertschi) on a Fendt toolcarrier.

Table 2. Summary of major prophylactic pest and disease control for field plots and seed increase plots.

Pest/disease	Chemical	Rate (a.i./ha)	Stage of application and frequency
		Lentil	
Sitona spp.	Methidiathion	0.4-0.6 kg a.i./ha	Seedling (fortnightly)
Bruchus spp.	Methidiathion	0.4-0.6 kg a.i./ha	Flowering (fortnightly)
Ascochyta lentis	Chlorothalonil	0.5 l/ha	Podding (fortnightly)
		Faba bean	
Ascochyta fabae	Chlorothalonil	0.5 l/ha	Spray when disease first observed and then fortnightly.
Botrytis fabae	Vinclozolin	0.5 kg/ha	Spray when disease first observed and then fortnightly.
Bruchus dentipes	Endosulfan	0.7 kg/ha	Pre-flowering, then twice fortnightly.
Orobanche crenata	Glyphosate	0.08 kg/ha	Start of flowering, then twice fortnightly.
Aphis spp.	Pirimicarb	0.15 kg/ha	Pre-flowering, then twice fortnightly or with infestation.
		Chickpea	
Ascochyta rabiei	Chlorothalonil	1.0 l/ha	Spray starts end of January and continues until beginning of May.
Liriomyza cicerina	Nuvacron 50	0.8 l/ha	Spray twice, first during end of April and second at mid-May.

5. Irrigation

Irrigation of plots is predominantly applied by a sprinkler system. However, we are testing a mobile reel-hose irrigation machine with a sprinkler boom to mechanize irrigation application in faba bean plots.

6. Harvest

Individual rows and plots of the food legumes are hand harvested into cotton bags. In lentil, the straw has a high economic value and no attempt has been made to cut

or mow plots because of the need to measure straw yield. Seed increases of both chickpea and lentil are harvested by plot combine. The cylinder speed is adjusted to below 500 rpm and the distance between concave and drum put to near its maximum for both crops. Upper sieves of 10-15 mm (lamellae) and lower sieves of 8-12 mm (lamellae or round holes) are used for chickpea, depending upon their kernel size. Standard cereal sieves are acceptable for lentil. Faba bean plots for seed increase are mowed with a double-knife cutter bar into a swathe. The use of a plot combine for large-seeded faba bean (seed size > 0.8 g/seed) utilizing a modified threshing drum is now under investigation.

7. Threshing

The process of threshing in food legumes is a compromise between opening pods and breaking seeds. The Bills Welding stationary plot thresher with rubber rollers is acceptable on all three food legumes. In addition, the Vogel cereal plot thresher has been modified with flail fingers attached to the threshing drum to give a rapid clean thresh of faba bean. For single plant threshing, a variety of machines are used: chickpea is threshed in a standard cereal head thresher; faba bean single plants are threshed in a cereal head-thresher modified with flail fingers (Diekmann et al. 1983); lentil single plants are threshed with a small rubber-roller thresher.

8. Record keeping

Field books and plot labels for seed packets, harvest labels, and bags are now produced by the VAX computer.

9. Conclusion

The mechanization of many activities in food legume experimentation is being routinely achieved with its attendant advantages over hand labor in efficiency and cost saving. However, the major remaining problem is the sowing, harvesting, and threshing of large-seeded faba bean (> 0.8 g/seed).

Reference

Diekmann, J., Papazian, J., and Mutran, H. 1983. Cracking free thresh'ng principle for dry faba bean. FABIS 7:39.

Machinery Exhibition and Demonstration

Specialized machinery for field experiments was featured in an exhibition and demonstration.

The following machinery was presented by the Hege Company:

- Hege 80 plot drill, mounted on Fendt 200 V tractor
- Hege 90 single-row drill mounted on Fendt 200 V tractor
- Hege 95 pneumatic plot drill mounted on Hege 75 toolcarrier
- Hege 125 plot combines with standard cutter bar and double-knife cutter bar
- Hege 140 plot combine with double-knife cutter bar and electric scale
- Hege 60 trailer for plot equipment

The following machinery was presented by the Wintersteiger Company:

- TRM 6-row pneumatic plot drill mounted on Fendt 305 LSA
- Plotman with Oyjord cone planter
- Nurserymaster Elite plot combine
- Seedmaster Advance plot combine

The Massey-Ferguson plot combine MF16 was described in a videotape presentation.

A three-cone planter designed at ICARDA was also shown, mounted on a Fendt toolcarrier 231 GT.

Seminar on the Mechanization of Lentil and Chickpea Harvest

At the end of the conference, a seminar was organized to share the experiences derived in several countries concerning the mechanization of lentil and chickpea harvest. Papers were presented from Jordan, Syria, Turkey, and ICARDA. After the discussion, the participants witnessed a demonstration of the following equipment being developed or tested at the ICARDA main farm: lentil puller, double-knife cutter bar, lentil blades, and combine harvester.

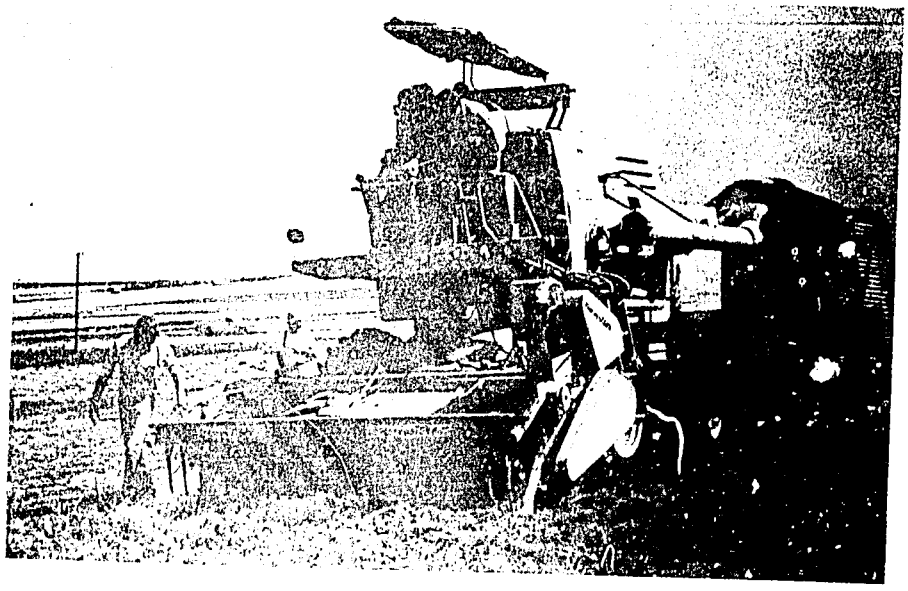

Fig. 1. Combine with header modified for Lentil harvest (straw collector at the near of combine)

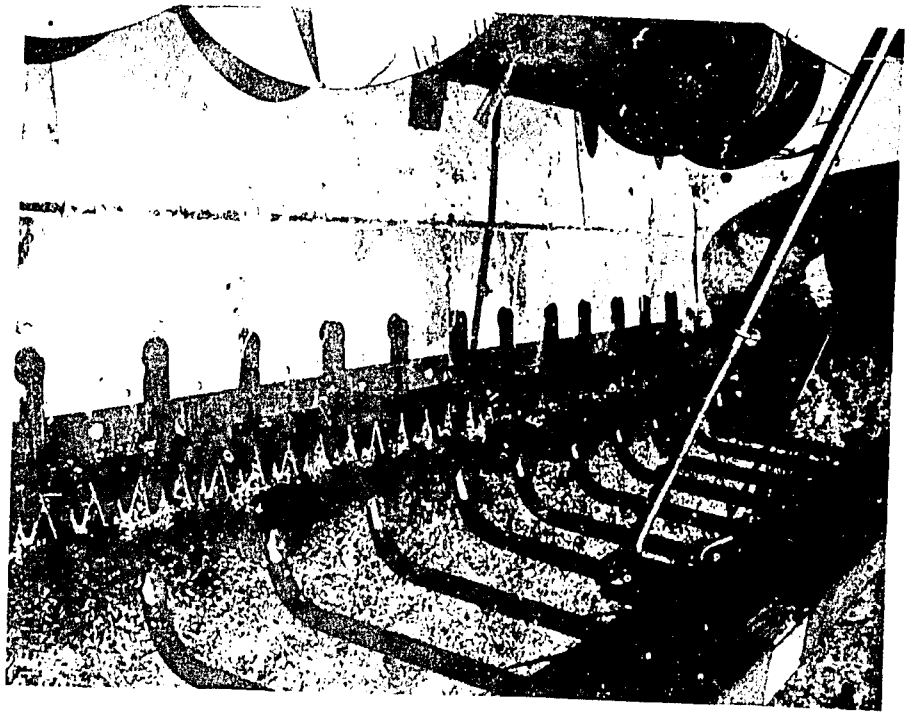

Fig. 2. Details of header modification : steel fingers single blade replaced by double--knife cutter bar, and reel replaced by blower.

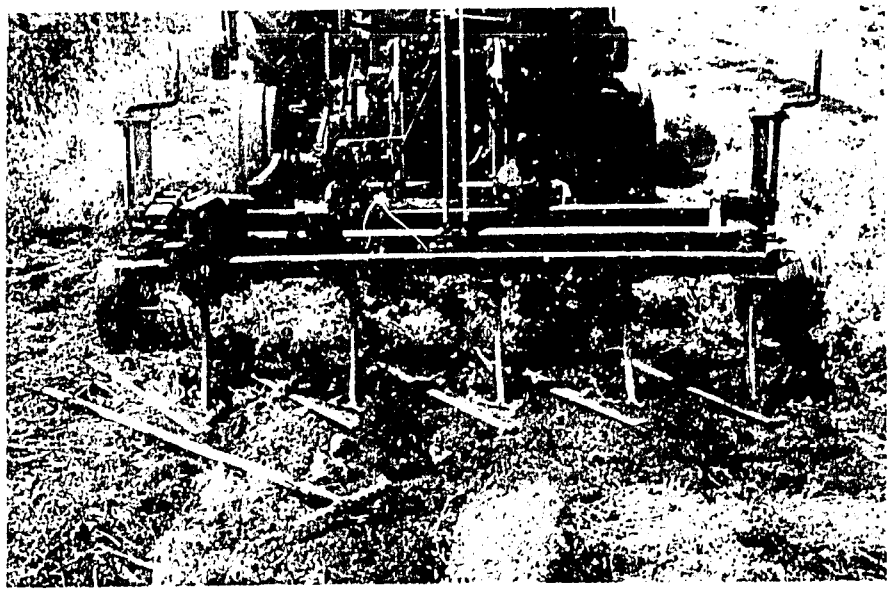

Fig. 3: Lentil cutting blades

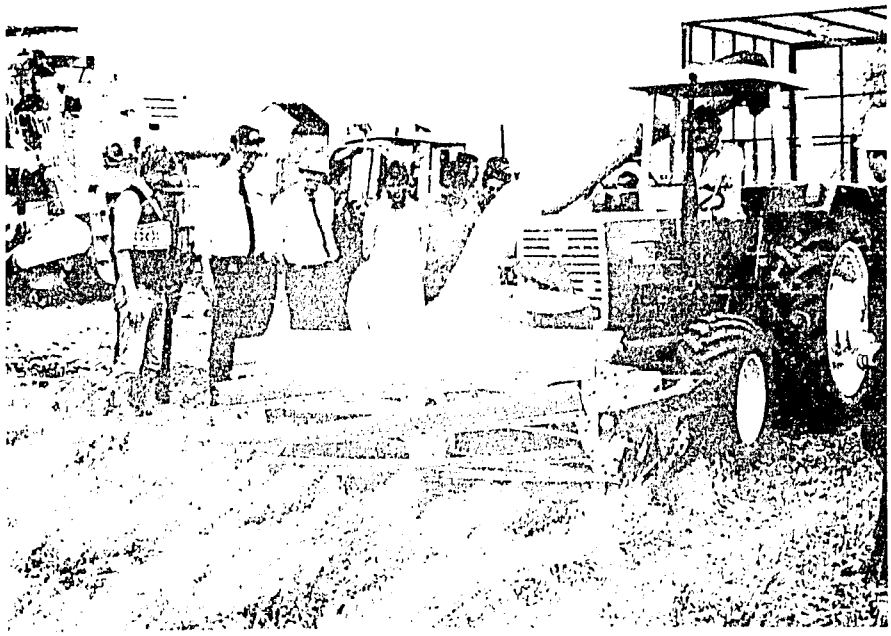

Fig. 4: Lentil puller

The Mechanization of Lentil Harvesting in Turkey*

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Abstract

Conventional and mechanized harvesting and threshing methods were studied in terms of field efficiency, energy consumption, and costs. A suitable cutting system was developed. The following harvesting and threshing methods were studied:

Method I: Hand pulling, loading with a hayfork, transporting and threshing with a domestic thresher,

Method II: Cutting with a scythe, gathering with a hayrake, loading with a hayfork, transporting, and threshing with a domestic thresher,

Method III: Cutting with a double-knife cutter bar, gathering with a hayrake, loading with a hayfork, transporting, and threshing with a domestic thresher,

Method IV: Harvesting with an aspirated lentil harvester, transporting and threshing with a domestic thresher,

Method V: Harvesting and threshing with a combine harvester.

Conventional harvesting and threshing methods were found to have low field efficiency and high cost. Although the combine harvester had the highest field efficiency and lowest costs of all the tested methods,

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* This invited paper was not presented to the Seminar.

it would only be applicable for large areas. The aspirated lentil harvester could be used on small and medium-sized farms.

Introduction

Lentil is a very important crop in Turkey with about 55% of the production exported. The lentil production was 550-600 thousand tons in 1982. Most of the lentil were Lens culinaris Medic. L., microsperma subspecies of red cotyledon, which was used in this research. (The other lentil were macrosperma subspecies with green cotyledon.)

Mechanization of the lentil production presents serious harvesting problems. Labor-intensive harvesting with scythes causes product losses. A reduction of these losses and an increase in the lentil production may be attained by introducing new mechanized methods.

In this study, harvesting methods are compared in terms of energy consumption, field efficiency, and quality of the harvest. The design of a prototype lentil harvesting machine is also introduced.

Materials and Methods

Field research was carried out in the Urfa-Harran and Ceylanpinar plains in southwestern Anatolia. New harvesting methods and conventional methods were tested.

Some properties of the machinery and the lentil plant were determined. The technical and economic efficiency of manpower and machinery was also tested under field conditions.

The following properties of lentil were measured: 1000-seed weight was 32.67 g at 5% moisture (W.B.), the volumetric weight was 829 g/l, the average seed diameter was 4.38 mm, and the average seed thickness was 2.72 mm.

A unique method was used to determine the optimum cutting height for the harvesting machine. The lentil plant was divided into five levels, and the distribution of seed on each level was determined. (See Table 1 and Fig. 1.)

Table 1. Distribution of lentil seed on a plant.

Height of level (cm)	Seed Quantity (%)
0 - 5	2.7
5 - 7.5	12.1
7.5 - 10	23.8
10 - 15	47.5
> 15	13.9
Total	100

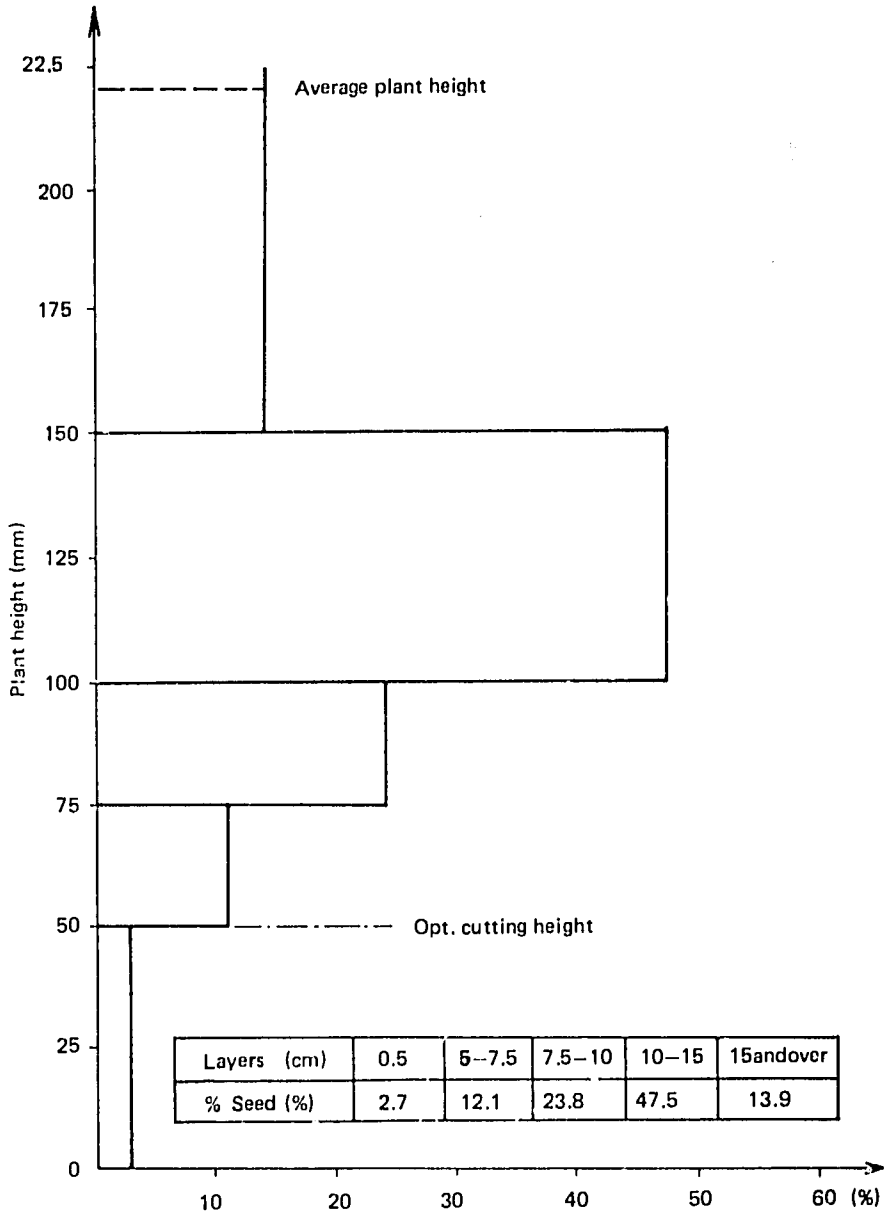
The average plant height depends on the annual precipitation. In years with rainfall below the average, plant height was about 22 cm; in years with rainfall above the average, it was about 27 cm.

The following harvesting and threshing methods were studied:

Method I: Hand pulling, loading with a hayfork, transporting, and threshing with a domestic thresher,

Method II: Cutting with a scythe, gathering with a hayrake, loading with a hayfork, transporting, and threshing with a domestic thresher,

Method III: Cutting with a double-knife cutter bar, gathering with a hayrake, loading with a hayfork, transporting and threshing with a domestic thresher,



Layers (cm)	0.5	5–7.5	7.5–10	10–15	15andover
% Seed (%)	2.7	12.1	23.8	47.5	13.9

Fig. 1. Vertical distribution of the lentil seed on the plant.

Method IV: Harvesting with an aspirated lentil harvester, transporting, and threshing with a domestic thresher,

Method V: Harvesting and threshing with a combine harvester.

Results and Discussion

1. Results of field research

The criteria for comparing different methods were stubble height, seed loss, field efficiency, energy consumption, and cost. These factors were determined as follows:

A worker pulled 0.0048 ha/h. For hand pulling, the average suitable moisture content was 35% (W.B.) and seed loss 8%.

A worker scythed an area of 0.056 ha/h. The average suitable moisture level for this operation was 35% (W.B.) and the seed loss 8.8%. The scythed plants were collected by a hayrake which caused 0.7% seed loss. These plants were left on the field to dry. Then they were loaded onto trailers by hayfork for transport to the threshing floor.

A worker collected 0.108 ha/h of the cut plants with a hayfork. This operation caused 1.3% seed loss. The plants were transported to the threshing floor and threshed. The average seed capacity of the domestic thresher was 800 kg/h and its average seed loss was 5%.

Mowers can be used for lentil harvesting instead of scythes. The performance of mowers with a standard cutter bar and a fingerless cutter bar (Active II type) was tested on stubble with 25% (W.B.) moisture content. The seed loss was 8.5 - 1[illegible].0%.

The parameters given above were also tested with a double-knife cutter bar (busatis type). The performance of this machine was as follows: field efficiency was 0.88 ha/h on 6 cm stubble height with 10% (W.B.) moisture content, and seed loss 5.5%. The double-knife cutter bar was more productive in lentil harvesting. The plants mown by machine were collected by hayrake; this operation caused 2.5 - 3.3% seed loss.

The combine harvester had the largest field efficiency with 1.182 ha/h lentil harvest. The total seed loss was 15% at 20% moisture content. The stubble

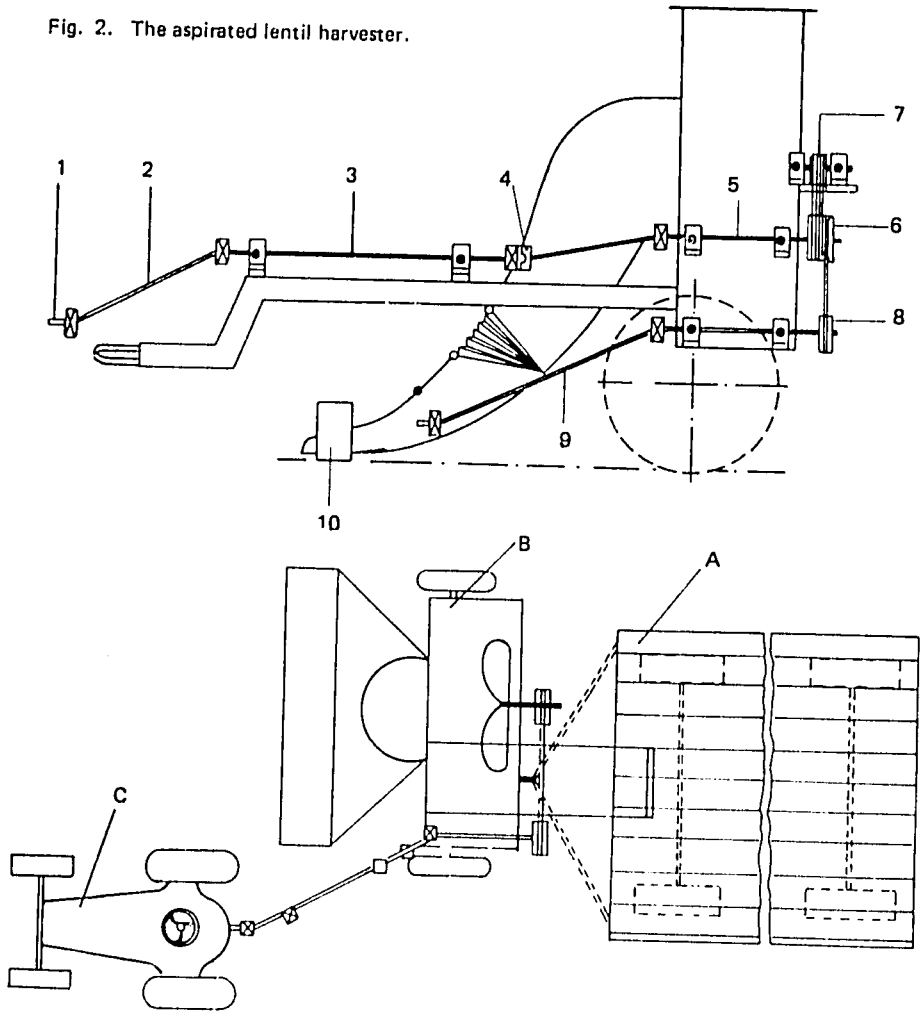
height was 9 cm for the combine harvester. However, the combine harvester has two disadvantages; namely the combine header is wider and therefore it cannot operate properly on a given field surface. Due to the uniform surface level, the machine catches some soil which subsequently mixes with seed. It also leaves stubble on the field. The second disadvantage comes from the threshing and cleaning units. The combine is not able to process the entire plant for straw. The leaves are ground to very small pieces and blown onto the field; this is a very serious loss because lentil leaves have a high protein content.

A prototype aspirated lentil harvester was designed and improved during this research. The improved machine was tested under field conditions and proved to be very succesful.

The harvesting machine is shown in Fig. 2. Its main components are a double-knife cutter bar, floating header, an aspirator, and a frame on two wheels. The connection of the cutting system to the floating header is flexible. The floating header contains the aspirator sucking channel and cutting system. A venturi tube is formed with an adjustable concave plate at the front end of the floating header where the cutting takes place so that the cut material is sucked out with a high airflow. The two-way flexibility permits the machine to work more efficiently under field conditions. Considerable time is saved by the flexible cutting system and floating header. Uniform, short stubble height is obtained. A centrifugal aspirator is used in the machine; it has a four-blade fan with a diameter of 80 cm. The fan rotates 750 rpm and supplies 10,000 m^3/h airflow. As a result, the airflow at the sucking channel entrance is 15 m/sec while it is 10 m/sec at the exhaust. The aspirator sucks the cut lentil from the cutting system and transfers them to a trailer mounted behind the machine.

The aspirating harvester gave a 1.72 m effective cutting width and 0.546 ha/h field efficiency. It harvested the crop at 5% moisture content and left a stubble height of 4 cm. The seed loss for this moisture content was 3.7%.

Fig. 2. The aspirated lentil harvester.



1) PTO Shaft, 2) Shaft, 3) Connecting shaft, 4) Tork limited shafting, 5) Main shaft, 6) Pulley, 7) Aspirator pulley, 8) Cutting system pulley, 9) Cutting system shaft, 10) Cutting system.

A– Trailer B– Aspirated lentil harvester C– Tractor

2. Energy and cost analysis

The energy requirement and the total production cost for a 1-ha lentil field with the methods which were used or could be used in 1982 are given below: (The cost included ploughing, seed drilling, seed, fertilizers, chemicals, oil, manpower, and other production costs.)

Method I required 2156 MJ/ha energy for harvesting and threshing lentil. Since most of this energy was supplied by manpower, the cost was 337 US $/ha. This was the most costly method.

The smallest energy of 1562 MJ/ha was required by method II. The total lentil production cost of this method was still high because it is labor intensive; it was 246 US $/ha.

In method III, even though mowers were used, the large energy requirement of 2158 MJ/ha was caused by the lack of correlation between harvesting and threshing. The cost was 230 US $/ha.

In method IV, the prototype harvesting machine was used, and the harvesting cost was estimated to be 50 US $/ha. In fact, the cost was 212 US $/ha. The energy requirement for this method was 2439 MJ/ha.

Two different values were calculated for the cost of method V. The first value corresponded to the cost when the plant body was not processed into straw; for this work, the energy requirement was 1574 MJ/ha and the cost 160 US $/ha. In the second calculation, the cost of collection, transportation, and making straw was added to the first cost. The energy requirement was 2447 MJ/ha energy and the cost 191 US $/ha.

Hand pulling and scything were used less in southeastern Anatolia than in central Anatolia. Machine harvesting was very much limited by small, stony and uneven fields. Hand pulling and scything seemed to be the only alternatives to mechanical harvesting in these fields as long as they are used for lentil production.

In method III, the mower had a very high cutting rate and efficiency. However, it was an expensive and time-consuming method due to the collecting and piling of the cut plants. It was suitable for small-scale production.

The method that used a combine harvester is the cheapest and fastest. It seemed to be the only method

applicable for larger areas. Farmers who have small and medium-size farms cannot afford to buy a combine and can only use a rented combine. Since the combine cannot produce straw and rental is another cost, the small and medium farmers prefer production methods that produce valuable straw.

In method IV, the harvesting and collection of the lentil were carried out in one step by using an aspirated harvester. This method also improved straw and seed quality. According to this research, an aspirated lentil harvester will solve the mechanization problems encountered in lentil harvesting on small and medium-size fields.

The experiment was carried out on farmer fields and in optimum moisture conditions. The seed loss for lentil becomes appreciable in moisture levels below the optimum and it may be as high as 100% or more of the loss obtained in optimum moisture levels. The other factors that effect seed loss are levelling and stoniness of the field.

Conclusion

For successful lentil harvesting, the surface of the field should be as level as possible. The harvesting machine should have a high efficiency and should perform at a low cutting height and work in low moisture levels without appreciable seed loss.

Problems in the Mechanical Harvesting of Lentil in Syria

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Abstract

The mechanization of lentil harvesting in Syria is hampered by several problems. Some of the most serious difficulties are caused by the dispersed, small fields on uneven, rocky terrain and insufficient research. The research, equipment, and manpower requirements for the development of mechanized lentil harvesting are suggested.

Introduction

Lentil is the foremost food legume in Syria and neighboring countries. The area sown in lentil increased from 92,080 ha in 1973 to 178,350 ha in 1977. However, this area declined to 71,710 ha in 1981 and 59,480 ha in 1984 (Ministry of Agriculture and Agrarian Reform 1984). This reduction can be partially attributed to insufficient use of farm machinery in the cultivation of this crop, especially in harvesting which is still done manually.

The lentil-growing areas are located in the northern parts of Syria (Aleppo and Hasaka) and in the southern plains (Hurán). More than 95% of these areas are rainfed. The land is rough terrain with stones of different sizes which hinder the mechanical harvesting of lentil. Farmers do not generally consider lentil as

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a main crop. Therefore, areas planted with lentil are scattered as small fields among other major crops. (The area of most fields is less than 1 ha.)

Traditionally, lentil is planted manually or the seed is mechanically broadcast on unprepared soil after the harvest of cereals. Seeds are then covered by a one-way disc harrow or by a mouldboard plough to a depth of 10-12 cm (The Arab Center for the Studies of Arid Zones and Dry Lands 1985). Some farmers use local chisel ploughs to prepare rows 25-59 cm apart and 16-18 cm deep. The seed rate is about 150 kg/ha. Seeds are covered by a long heavy metal or wooden bar (2-3 m long) drawn by a tractor.

The few farmers, who use planters, plough their fields and harrow them before sowing. The plants receive no other treatment until harvesting.

Lentil is harvested manually by pulling the plants in the yellowish stage, when the seed moisture is about 25%. Harvesting should take place 4-8 days before full maturity, which depends on the temperature, humidity, wind conditions, soil type, depth, and inclination, and the lentil variety and size. High loss may result if a farmer cannot harvest the crop on time. The farmer's family harvests the crop on small fields, but paid laborers harvest the crop on large fields. After the crop is harvested, the plants lay in the fields for 4-8 days while drying. Then the dried plants are transported from the field and placed in a large stack. Simple threshing is carried out with animal power. The lentil are cleaned manually.

The labor required to harvest one hectare of lentil is about 140 h. Another 60 hours are required for transport, threshing, and cleaning. This labor requirement could be reduced to one-fourth by the use of the proper combine. Harvest costs are one-third of the total production cost. The costs of harvesting, threshing, and cleaning are more than one-half of the total production cost.

Some farmers use local threshers which reduce the cost, but result in a high percentage of broken seeds

(40%). This crop is marketed at a lower price, especially when it is to be used for seeding.

The price of lentil has increased rapidly in the last decade. The kilo price rose from less than 1 Syrian pound (SL) in 1977 to 4 SL in 1985 and to more than 12 SL in 1987. This price increase emphasizes the importance of solving the problems of lentil production in Syria.

Problems in the Attempted Mechanical Harvesting of Lentil

Many attempts were conducted in the late 1970's to harvest lentil by machines. Engineers of the Ministry of Agriculture and Agrarian Reform (MAAR) witnessed mechanical harvesting of lentil in the United States and other developed countries. They reported that lentil is harvested directly by adjusted combines or mowed in the yellowish stage, dried, and then threshed by combine. Relatively tall (40-70 cm) cultivars facilitate the mechanical harvesting of this crop (El-Biestar 1977).

In 1977, the mechanized harvesting of lentil was attempted in Al-Hasaka and Daraa Provinces. The results were not encouraging, but the research continued. Early in 1980, a few adjusted combines were bought by MAAR to harvest lentil, but they caused large losses during the harvesting process. Tests were conducted on the ICARDA Tel Hadya farm in 1983 and 1984 on the following equipment:

(1) Front two-wheel tractor mower, cutting width 90 cm, 6 hp,
(2) Self-propelled mower, cutting width 130 cm, 14 hp,
(3) Side mower, driven by a tractor pto, cutting width 150 cm,
(4) Lentil harvesting blades (bean blades), cutting width 190 cm,
(5) Front puller for row and broadcasted crops, cutting width 200 cm, mounted on a 70 hp tractor,
(6) Plot combine, cutting width 120 cm wide.

The efficiency of the mowers (1) - (3) and the puller (5) is greatly affected by soil levelling, stones, and plant height. The lentil harvesting blades are affected by soil levelling and hardness.

Lentil is harvested by mowers in the yellowish stage, dried, and threshed by combine or local thresher. The performance of the combine is affected by plant height, lodging, stones in the soil, uneven land surface, and moisture content of the crop. Direct harvesting may cause up to 25% loss in yield and a high percentage of broken seeds (Hassan 1983 and 1984a).

The evaluation of equipment indicated that solutions to the following problems of mechanized lentil harvesting are necessary:

1. The lentil cultivars are very short (20 cm), especially the Hurani type, which begins to lodge at heights greater than 20 cm. The cultivars are not pure and vary in maturity. Their pods are easily opened when dried by the sun; they also drop off easily.
2. Fields in which lentil are grown generally have rough surfaces, ridges, and large stones.
3. Lentil fields are dispersed among other crops. The size of those fields, in many cases, is less than 1 ha.
4. The harvesting period is very short (4-8 days).
5. Farmers cannot afford to buy expensive equipment for use in only one crop.
6. Mechanical harvesting of lentil has not been a high priority in the research program of MAAR; this has been reflected both in the design of equipment and the assignment of research personnel.

Some problems can be solved easily; other problems can be solved gradually if the technical and financial resources are provided.

Harvesting Methods

1. Manual harvesting

Little loss of seed occurs with this method if the crop

is harvested on time. The lentil straw is fed to farm animals. This method results in few broken seeds but requires a good deal of labor for harvesting and cleaning. It is very costly. Therefore, if lentil production is confined to manual harvesting, production of this important crop will continue to decline.

2. Combining

In temperate areas with minimal pod shattering and drop during harvesting, modified combines with a special knife and adjusted concave and fan speeds are used. The special knife is 15 cm lower than usual and has a reel with long elastic fingers. The concave is adjusted to 9 mm for inlet and 3 mm for outlet. The speed is 400-500 rpm (Papazian 1983). The large capacity of the combine enables harvesting of the crop in a short time, but the yield loss is high (15%), and the number of broken seeds is also high. Since these combines require special conditions, their use is limited.

3. Indirect harvesting

Lentil plants are pulled or mowed in the yellowish stage, dried, and threshed by an adjusted combine or local thresher. Pulling machines are used for row crops. One puller uses two clamping belts similar to the model from the University of Reading, England, which was manufactured by Sperry Gyroscope Company, and to the Russian and European flax pullers. A puller for row and broadcast crops similar to the Tauscher puller was manufactured with the support of the GTZ (German Agency for Technical Cooperation). This machine was tested at Tel Hadya in 1983 and 1984. It is very costly and requires spreading the harvested plants on large areas until they are dried. Therefore, the loss may be high. Some mowing machines are mounted on the front or side of the tractor, and others are self-propelled. These machines may not be suitable for the local, short types of lentil. Bean blades may be suitable for mowing the short types if the blades could be adjusted to harvest individual rows. One problem is the exposure of lentil plants to direct sunlight. Farmers probably prefer the indirect pulling method.

Conclusion

On the basis of the discussion above, the following solutions are suggested to the local problems of lentil harvesting:

1. Assign priority to the lentil problem among MAAR projects with adequate provisions for field trials, equipment, and personnel,
2. Obtain help from specialists in the universities and centers such as ACSAD and ICARDA for training personnel and for designing experiments,
3. Obtain machines (pulling machines and threshers) through ACSAD and ICARDA and test them locally,
4. Adjust the bean blades to harvest individual rows,
5. Encourage lentil farmers to continue removal of big rocks from their fields.

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Mechanization of Chickpea Production in Turkey

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Abstract

Traditional methods using manual labor prevail in the sowing, cultivation, and harvesting of chickpea in Turkey. Work at the Aegean Research Institute is devoted to mechanization of these operations. A simple chickpea sowing machine offers the advantages of seed drills. A combine harvester can be used in plots of tall, erect plants. The concave of a cereal thresher has been extended for use in lentil threshing.

Introduction

Food legumes are major crops in Turkey. They are grown on more than one million ha of land. The average annual production is 1.05 million t. As seen in Table 1, lentil is the main food legume crop and chickpea the second.

Chickpea Production

Chickpea is grown in almost all regions of Turkey, but the production is concentrated in the Aegean and Mediterranean regions. (See Table 2.)

The average chickpea yield can be increased by the development of new varieties with disease resistance, higher yield, cold resistance, and attributes such as large seed size, high protein content, and suitability for mechanization.

Work at the Aegean Agricultural Research Institute concerning the mechanization of chickpea cultivation also includes the breeding program.

Table 1. The 1984 production of food legumes in Turkey[a]

Crop	Area sown (thousand ha)	Production (thousand t)	Yield (kg/ha)
Lentil	620	570	919
Chickpea	345	335	971
Common bean	112	264	1464
Faba bean	42	76	1800
Pea	1.8	3.7	2050
Cowpea	3.14	3.1	987

[a] Source - Tarimasal Yapi ve Uretim 1984. D.I.E. Yayin No. 1168, Ankara 1986.

Table 2. Regional production of chickpea.

Region	Area sown (ha)	Production (t)	Yield (kg/ha)
Mid-north	66022	61680	930
Aegean	80638	73475	910
Marmara	2282	2877	1260
Mediterranean	70273	66445	945
Northeast	1053	1071	1010
Southeast	37946	32895	866
Black Sea	3018	2430	805
Mid-east	30093	33829	1120
Mid-south	53675	60280	1120

Chickpea Cultivation

Traditional methods are still used in chickpea cultivation. Modern growing techniques are not yet used. Sowing and harvesting are manual work; herbicides or mechanical means are rarely used in weed control.

Mechanization of chickpea sowing

Seed drills are the best method for sowing chickpea. The use of seed drills offers several advantages compared to sowing by hand. The soil between crop rows can be cultivated using a rotavator or other cultivator; a higher percentage and more synchronous seed emergence occurs. The application of insecticides or other chemicals is easier because the crop is in rows.

Unfortunately there is only one simple chickpea sowing machine in Turkey. It consists of a supply hopper, three seed cells, fluted force feeds, three seed tubes, and a mechanical drive wheel. This apparatus can be mounted on a plough or cultivator. Seed rates can be varied from 70-175 kg/ha. Other seed drills, e.g. wheat or cotton drills, can be used for chickpea sowing.

Mechanical interrow cultivation

The chickpea interrows may be cultivated by machine two or three times during the growing season. If the interrow distance is 45 cm, interrows can be cultivated by a four-row rotovator; if the rows are 30 cm apart, another cultivator can be used for cultivating the soil (Acikgoz 1987). Post-emergent herbicides can be applied after the interrow cultivation.

Chickpea Harvesting

Chickpea harvesting is usually done by hand. After pulling the plants from the soil, they are gathered at one site and then threshed.

Combine harvesters have rarely been used for chickpea harvesting because the plants are short and semi-prostrate. The development of tall, erect plants could enable the use of combine harvesters in chickpea harvesting.

A modified John Deere 955 combine can be used to harvest the ILC 195-2 line in the multiplication plots at the Aegean Agricultural Research Institute. The modifications of concave and cylinder revolutions and the size of concave clearance are:

cylinder revolution	500-700 rpm,
concave clearance (front)	19 mm,
concave clearance (rear)	9.5 mm,
ventilator revolution	700 rpm,
size of the upper sieves	16-19 mm,
size of the lower sieves	9.5-12.5 mm,

Threshing

Chickpea threshing is commonly done by hand. Recently a thresher has been developed for chickpea using a modified cereal thresher (see Fig. 1). In this system, the concave has been extended to three-fourths of the circumference of the threshing drum (Zender 1986).

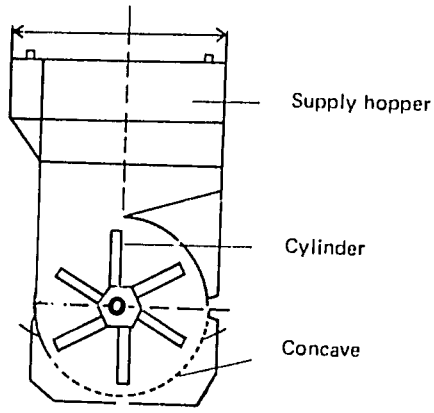

Fig. 1: Concave and cylinder unit of the chickpea thresher

Modifications to cereal threshing machines have been suggested by Demir 1986. His threshing parameters are:

cylinder peripheral speeds - 15-18 m/sec,
ratio of cylinder coverage by concave - 36%.

Although large problems exist for the mechanization of chickpea production, the slow, labor-intensive sowing, cultivation, harvesting, and threshing operations will be changed by future solutions to these problems.

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The Jordanian Experience in the Mechanization of Lentil and Chickpea Harvesting

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Abstract

The following harvesting methods were compared to traditional hand harvesting: direct harvest using a conventional grain combine, cutting by double-blade cutter bar, cutting by bean-cutter blade, and pulling by a mechanical device. The combine harvester was the most economical and least time-consuming. Although straw loss was significantly higher with a combine harvester than with manual harvesting, farmers could either recover some of the straw by raking it or rent the fields to herders for animal grazing. Rolling the land reduces grain and straw losses. Good land preparation, mechanized sowing, and levelled fields without stones are essential conditions for the use of combine harvesters.

Introduction

The area of cultivated lentil and chickpea has declined continuously in Jordan. Among the factors causing the reduction in the production of these crops, the increasing cost of manual harvest is the most important one. The cost of manual harvest is currently as much as 75% of the market price. However, other input costs may well exceed the remaining 25%. If it was not for the income obtained from recovering the crop residue, lentil and chickpea cultivation would cease to exist.

Lentil and chickpea crops are important in the crop rotation of rainfed areas. However, some of the lentil fields have been converted to forage production in the

crop rotation. The farmers realize that wheat planted after lentil yields less than wheat planted after other crops.

One way that may convince farmers to cultivate more areas of lentil and chickpea is to increase the net income generated from their production, since these foods are still very important in the Jordanian diet. An economic method to harvest the crop is one means to reduce production costs. Mechanized harvest will reduce the cost of production as compared to the cost of manual harvest. Hand harvest is not only expensive, but it also causes seed loss due to shattering and delay in harvesting. An appropriate mechanized harvest method should also reduce the grain loss, thus further increasing the net income.

Several mechanized harvest techniques could be tested for lentil and chickpea crops:

1. Direct harvest using the conventional grain combine,
2. Cutting by double-blade cutter bar,
3. Bean-cutter blade,
4. Pulling by mechanical device.

In Jordan, lentil and chickpea producers wished to mechanize harvest, yet allow for the recovery of most, if not all, crop residues including the plant portion below the soil.

The Faculty of Agriculture, University of Jordan, initated a research program in 1974 to develop a lentil and chickpea puller harvester, because the technique of plant pulling was more appealling to growers than cutting techniques. Continuation of this work was possible through the Legume Improvement Project which was partially funded by the International Development Research Centre (IDRC) in 1980.

Research and Development in Jordan

Several research projects were funded to conduct studies on lentil harvest mechanization over three

seasons (1974, 1975, and 1976). The relevant characteristics of lentil plants for 10 cultivars, including 2 local ones, were studied (Snobar 1978). These characteristics included the length of the plant above the soil surface, the height of the lowest seed on the plant, the force needed to pull the plant up by the roots, and the length of plant the portion below the soil. Results of the study suggested that if a cutting device is to be used with a maximum recovery of seeds and straw, good land preparation and soil without stones are required. The small pulling force which was required to pull plants from the soil indicated the feasibility of using a plant puller. This device would allow the recovery of the last 30% of the crop residue otherwise left in the soil after harvest by the cutting technique.

A plant puller was designed to pull up plants grown in rows. The machine was pushed by the operator as shown in Fig. 1. The performance of this puller in the field during the 1978 season indicated that the catching and pulling efficiency was low. Since the results of this test were somewhat promising, several modifications were recommended to improve the performance (Snobar 1979).

A modified puller was tested for two seasons (1979 and 1980). The modified puller was mounted on the three-point hitch of a tractor as shown in Fig. 2. When the plant rows were 30 cm apart in fairly well-prepared soil and a grain drill had been used for uniform seeding, the catching and pulling efficiency of the improved puller per single row was 85 to 90%. The rate of harvest was up to 75 kg/h compared to 10 kg/h) for manual operation (Snobar 1981).

A further modification of this puller was made in 1984. Double-row pulling units were mounted on the frame of a self-propelled Oyjord plot drill (See Fig. 3). The same plot drill was used to plant lentil in rows 30 cm apart. The power needed to rotate the catching-pulling device was transmitted from the driven rear wheels of the seeder through a sprocket and chain. The puller was driven by a 7.35 kW (10 hp) engine. This self-propelled unit was initially tested during

Fig. 1 : Hand driven plant puller

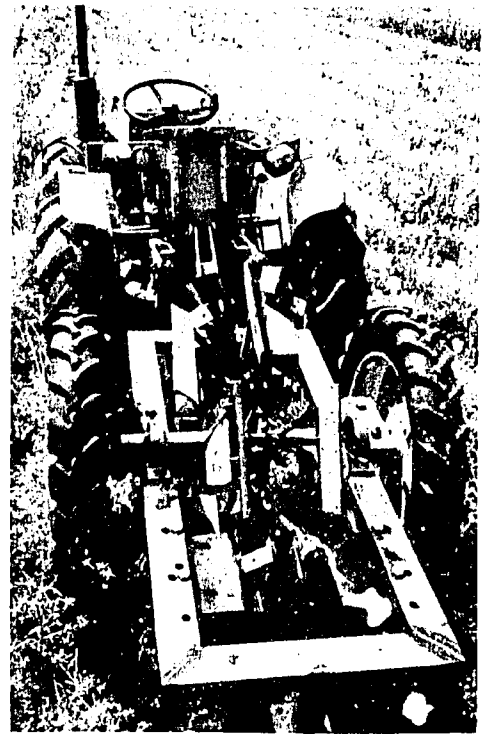

Fig. 2 : Tractor mounted one row plant puller

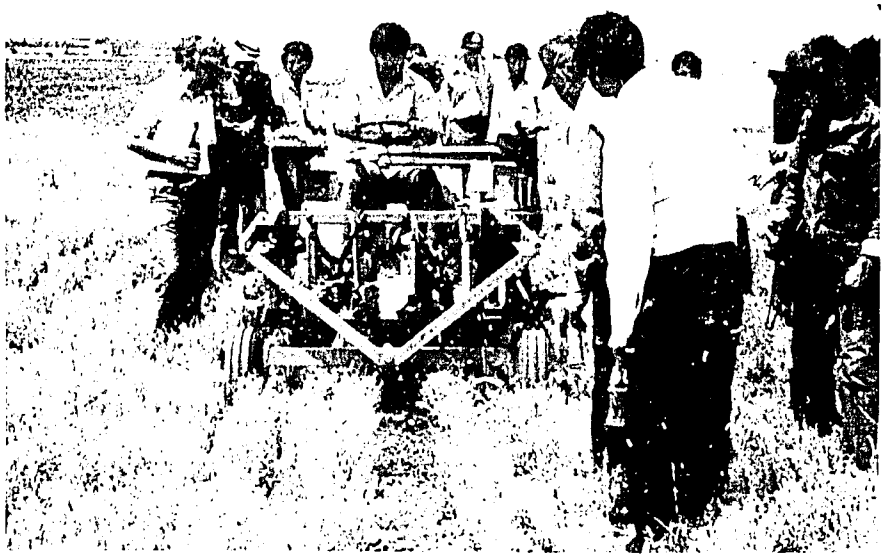

Fig. 3. Self–propelled two-row plant puller

the 1984 lentil season and slightly modified. Further testing of the puller was discontinued in favor of other harvest techniques, because of the lengthy process to design, manufacture, and introduce the puller to farmers, technical problems, and the lack of funding.

The introduction of tall and high-yielding lentil and chickpea cultivars through the Legume Improvement Project prompted study of other harvesting techniques such as grain combine harvesters and other cutting mechanisms, because harvesters are available in Jordan to harvest cereals. Therefore, the performance and cost of several harvest techniques by cutting and hand harvest were compared. The use of a grain combine to harvest lentil was the most economical and least time-consuming method, even though the straw was not recovered and grain loss was highest of all methods (Haddad et al. 1984). An extra advantage to the use of a grain combine harvester was that threshing and seed cleaning are performed in the same operation as cutting. On the other hand, the grain losses during transport and threshing operations may equal the losses from the combine harvester. The study concluded that in general, the use of the cutter-bar mower was economically feasible in spite of the high percentage of grain and straw losses as compared to hand harvesting.

With tall cultivars, an emphasis was made on using the grain combine to harvest lentil and chickpea. However, good land preparation is essential (using a chisel plough followed by a sweep cultivator, then planting by grain drill followed by rolling with a land roller).

The use of grain combine harvesters is possible in Jordan because they are available in sufficient number. However, the use of a narrow cutter bar (2.4 m) on the combine harvester will improve the performance of the machine and reduce grain losses significantly (Arab Organization for Agricultural Development 1983). The use of grain combines means that lentil and chickpea growers should forego straw recovery in favor of other advantages. However, the straw left on the field and

the root system in the soil may improve the soil structure and organic matter, thus, leading to a higher yield. If necessary, a portion of the straw could be collected, either at the discharging end of the combine or by raking and baling. The straw remaining on the fields could be grazed by animals.

The following harvest methods were studied during the 1983/84 season: hand pulling (T1), tractor-mounted mower (T2), self-propelled mower (T3), and combine harvester (T4). Effects of rolling the soil after planting, grain yield, straw yield, plant height, lowest pod height, seed loss, and soil moisture were studied.

The data indicated no significant difference between the grain and straw yields, plant height, and lowest pod height in rolled and non-rolled soil for both lentil and chickpea crops (Table 1). Soil moisture content was not influenced by rolled as

Table 1. Some agronomical measurements of local lentil, winter chickpea (UJC 84) and local spring chickpea grown in rolled and non-rolled soil at the M'shagar research station (latitude: 31°34'N, longitude: 35°48'E, altitude: 785 m) during the 1983/84 season

Crop and treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Plant height (cm)	Lowest pod height (cm)
Lentil				
Rolled	641	1149	29.1	8.2
Non-Rolled	701	1225	29.2	8.2
Winter Chickpea				
Rolled	1018	1330	32.9	12.7
Non-rolled	1059	1478	34.7	13.2
Spring chickpea				
Rolled	841	1166	36.9	14.5
Non-rolled	894	1191	37.3	14.3

compared to non-rolled soil. However, grain and straw losses were significantly less in rolled soil than in non-rolled soil in the three mechanized harvest methods, excluding method T2 for straw loss in lentil and spring chickpea for straw and method T3 for spring chickpea for grain (Table 2). The straw loss from the combining method T4 was only partial because most of the straw at the discharging end of the combine was recoverable; only the uncut part of the plants and the chaff were not recoverable. The grain loss due to the use of the combine harvester is higher in lentil than in chickpea. However, the straw loss was higher for chickpea than for lentil.

Although rolling the land will not negatively affect the desired plant characteristics, yield, or the moisture content of the soil, it will reduce the grain and straw losses. The cost of rolling the land will be minimal as compared to the total cost of production inputs (1% to 5%).

Snobar et al. 1985 studied the losses occurring during several methods of harvesting lentil and chickpea. Results indicated that traditional hand pulling, handling, and threshing caused a total grain loss of 18.6% as compared to 2.4% when hand pulling was performed in the early morning, when shattering is minimum, and threshing was done mechanically. The losses in chickpea harvest were 48% for a one-axle, self-propelled mower (M3), 36% for a rear-mounted tractor mower (M2), and 25% for the hand-harvested crop (M1).

Conclusion

Results of the studies indicate that emphasis should be placed on mechanized harvest of lentil and chickpea by direct combining. This approach requires well-prepared land, mechanized sowing, and the removal of stones from the fields.

If successful, the use of a grain combine harvester will enable custom operators of combines to operate their combines for longer periods of time during the

Table 2. Loss of grain and straw of local lentil, winter chickpea (UJC 84) and spring chickpea (local as influenced by rolling the soil for four methods of harvest at the M´shagar research station during the 1983/84 season.

Product and treatment	Lentil (%)			
	T1	T2	T3	T4
Grain				
Rolled	2.7	20.2	28.6	53.3
Non-rolled	3.5	23.9	39.5	59.0
Straw				
Rolled	0.0	25.3	28.4	33.4
Non-rolled	0.0	25.6	32.4	39.0
	Winter chickpea (%)			
	T1	T2	T3	T4
Grain				
Rolled	4.7	16.8	34.0	35.4
Non-rolled	4.5	21.9	39.2	47.2
Straw				
Rolled	0.0	25.0	30.1	37.1
Non-rolled	0.0	26.3	35.8	46.2
	Spring chickpea (%)			
	T1	T2	T3	T4
Grain				
Rolled	4.0	23.1	44.8	48.3
Non-rolled	6.0	25.7	42.3	52.1
Straw				
Rolled	0.0	28.0	33.1	46.5
Non-rolled	0.0	29.2	46.3	59.1

T1: Hand pulling, T2: Tractor rear-mounted mower, T3: Self-propelled mower and T4: Combine harvester.

season for cereals, lentil, and chickpea, thus, reducing the depreciation cost. On the part of combine owners, a minimal investment is needed in this case, e.g. purchase of a header with 2.4 to 3.0 m wide cutter bar.

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Mechanization of harvest in lentil and chickpea in semi-arid areas*

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Abstract

An integrated research program at ICARDA is devoted to problems in the mechanization of lentil harvesting. The approach is based on the determination of appropriate harvest systems; changes could occur in crop management practices and cultivar and by the introduction of suitable equipment. Several systems of mechanical harvest are suitable for the diverse conditions found in lentil-growing areas of West Asia and North Africa. The most promising equipment for use with broadcast sown land races are the lentil puller-swather and the angled blades. The double-knife mower requires a flattened seedbed and a non-lodging cultivar. Use of a modified combine harvester requires a very flat seedbed (obtainable only by drilling) and a tall, non-lodging cultivar.

Mechanization of chickpea harvest presents fewer problems than lentil harvest. With the taller growing cultivars the traditional grain combines can be adjusted to the seed size and other parameters of the chickpea crop. The introduction of winter sowing in the Mediterranean region will improve the economy of chickpea production.

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1. Introduction to pulse harvest problems in semi-arid areas

Lentil (*Lens culinaris* Medik.) and kabuli chickpea (*Cicer arietinum* L.) are the most important rainfed pulse crops around the Mediterranean Sea and in West Asia. The International Center for Agricultural Research in the Dry Areas (ICARDA) has a world mandate for research toward increased production in both crops. National pulse programs in this region recognize that the current hand harvest and lack of harvest mechanization is the major constraint to lentil production and also an important bottleneck in chickpea cultivation (Algeria: Khayrallah and Hachemi 1979; Egypt: Ibrahim *et al*. 1979; Jordan: Abi Antoun and Quol 1979; Iraq: Mayouf 1979; Lebanon: Lahoud *et al*. 1979; Syria: El-Matt 1979; Turkey: Eser 1979).

The area bordering the Mediterranean Sea and the Middle East have different conditions for pulse harvest than northern Europe and North America, representing strikingly different harvest problems. Firstly, there is the climate. Harvesting takes place under conditions of high temperature and low humidity. On the positive side, these conditions cause forced maturation and relatively even ripening of pods within the crop. On the negative side, they lead to losses in lentil of pods and seeds. Secondly, there is the soil. It is often uneven and poorly levelled. Stony soils are common in the area, as are clayey soils which crack as moisture is lost in the sea on. Thirdly, there is the management factor. The best soil-tillage equipment is not always present. Sowing methods, such as the broadcast of lentil on to ridges, leaves a difficult soil surface for harvest. Lentil plants, particularly, are poor competitors with weeds; and, since weed control is often woefully inadequate, the presence of a heavy weed crop makes harvesting difficult.

These problems and others specific to the two crops do not allow the direct introduction of harvest technologies to the region without modification and testing. Consequently ICARDA has conducted harvest research focused primarily on lentil but also to a lesser degree on kabuli chickpea since its inception in 1977.

2. Lentil harvest

2.1. Harvest problems specific to the lentil

Several botanical features of the lentil must be considered in relation to harvest. Firstly, there is the growth habit of the crop. In Syria farmers' crops are only from 25-35 cm tall. Secondly, the crop is prone to lodging. Thirdly, the high temperatures and low humidity lead to losses from both pod dehiscence and pod drop.

In West Asia the straw of lentil has a high economic value dependent on the availability of alternative sources of sheep feed. For example, in Syria in dry years lentil straw is often worth more to the farmer than the seed (Nordblom and Halimeh, 1982). Clearly, harvest methods must allow for the collection of an economic proportion of the straw and chaff in these areas.

2.2. Harvest research

Since the problems of lentil harvest mechanization are not entirely mechanical, the approach at ICARDA is to seek appropriate systems of harvest. Such systems may involve changes in both crop management practice and cultivar, in addition to the use of novel machinery. Consequently an integrated research program embracing agronomy, plant breeding, farm machinery, and economic analysis is underway at ICARDA with close contact with the Ministries of Agriculture in various national programs, together with a strong component of training.

Evaluation of existing methods

Testing of harvesting equipment started with an evaluation of different methods in our main station in 1978/79 but more intensively in 1980/81.

The main objective of a trial in 1980/81 was to evaluate six methods of lentil harvesting and six types of planting combinations involving two lentil genotypes

(small and large seeded), and three methods of planting (conventional sowing, drilling, and drilling plus rolling). The six harvesting methods were hand pulling, scythe cutting, use of a bean cutter, side mower, forage harvester, and a combine harvester. The effects of these variables on the following characteristics were studied: grain and straw yield, grain and straw loss, grain breakage, germinability and physical purity of seeds, straw quality (protein and fibre content), timeliness, manpower and energy requirements and total harvest cost. The results (Table 1) showed that hand pulling gave the highest yields, but labor requirement and harvesting costs were the highest. The bean cutter was the most promising method. The use of a scythe resulted in large grain and straw losses and required skilled labor. The combine was the cheapest method, but losses were highest. The use of a cutter bar resulted in 40 to 50% straw loss and large loss of grain, but rolling reduced losses. Planting by drill gave higher yields than conventional planting, but rolling reduced the yields. Large seeded lentil yielded higher than small seeded genotype (Papazian 1982).

Table 1. Grain yield (kg/ha) of small (V1) and large (V2) seeded genotypes as affected by method of planting (C = conventional planting; D = drilled; DR = drilled followed by rolling) and method of harvesting.

Method of harvesting	Genotypes and method of planting						Mean	Relative
	V1			V2				
	C	D	DR	C	D	DR		
Hand pulling	719	661	508	785	815	484	662	100%
Bean cutter	555	594	482	585	668	428	552	83%
Scythe	437	630	478	514	710	462	539	81%
Side mower	239	253	328	329	456	192	299	48%
Hege 211	427	340	389	473	559	369	426	64%
Hege 125	228	343	382	422	484	387	374	56%
Mean	434	470	428	518	616	387	476	-
Relative mean	100%	108%	99%	119%	142%	89%	-	-

LSD at 5%:
Main plot (Genotype x method of planting) = not sig. ....C.V. = 51.52
Sub-plot (Method of harvesting) = 59.3 ....C.V. = 21.78
Main plot x sub-plot interaction = not sig.

Evaluation of two-stage harvesting methods

A three-year program was begun in 1984 to find an intermediate, two-stage harvest technology. This system is to be built in a way that only minimal changes from the traditional agronomy are needed.

The traditional method of sowing lentil in Syria is by hand broadcasting followed by a cultivator pass to cover the seed, leaving a ridged field. This was compared with lentil sown with a locally available drill, and also to broadcasting followed by a cultivator with a heavy bar behind. The sowing treatments were: (a) Broadcast by hand (300 seeds/m^2), covering with a tractor pulled cultivator; (b) Broadcast by hand (300 seeds/m^2), covering with tractor pulled cultivator towing a heavy bar; (c) Drill with local cereal drill (200 seeds/m^2); and (d) Drill with local cereal drill (200 seeds/m^2), covered by a heavy bar.

Comparison of a local cultivar with an ICARDA selection was also included as one of the factors in the trial. These main plots were then split and harvested by hand, by a double-knife cutter bar, and by angled blades passing just under the soil surface.

Differences between harvest methods and the interactions between harvest and sowing methods were highly significant for both seed and straw yields (Table 2). With the hand harvest, the use of a heavy bar behind the cultivator covering seed increased lentil seed yield over the traditional cultivar alone. The double knife cutter bar required land flattened by either a bar or a seed drill to optimize straw yields. The angled blades worked best on the traditional broadcast seed bed.

The lentil selection 78 S 26002 yielded 1161 kg/ha seed, which was 21% more than the local cultivar. Since 78 S 26002 lodged less than the local cultivar, its advantage was greatest with a cutter-bar harvest (ICARDA, 1986). Further, a lentil puller, simulating hand pulling, developed with support from the GTZ (German Agency for Technical Cooperation) has been

Table 2. Lentil seed and straw yields (kg/ha) from different sowing and harvesting methods.

Method	Hand harvest		Cutter bar		Angled blades	
	Seed	Straw	Seed	Straw	Seed	Straw
Broadcast	1152	2896	951	1094	732	3531
Broadcast + bar	1479	2976	1075	1617	829	3262
Drilled	1618	3294	1071	1600	616	2142
Drilled + bar	1479	2929	1092	1780	633	2348
Mean	1432	3024	1047	1523	703	2820

LSD (5%) Harvest method: Seed = 91 kg/ha; Straw = 399 kg/ha
LSD (5%) Harvest x sowing methods; Seed = 183 kg/ha;
Straw = 799 kg/ha

tested for the first time during the 1986 harvest and will undergo a two-year completion program during the 1987-89 seasons. The machine is front-mounted to a 50-60 hp tractor, working down a 2 m strip by means of a ribbed conveyor belt placed over two bottom mounted steel rollers, against which the plants are squeezed by rubber lips of a top mounted reel. The machine is powered partly by a front pto and partly by adjustable hydraulic motors. The plant material on the conveyor belt is separated by a suction blower from heavier material like soil clumps and stones. The blower transports the material into a rear-mounted trailer.

Advantages of the machine are: Ability to work on ridged or flat seedbeds; ability to handle broadcast or row planted lentil; front-mounted design, so no damage to standing crop; ability to pull complete plants without loss of straw material; provision for complete collection into a trailer.

Disadvantages are: (a) It is a special machine and is not as universally useful as a cutter bar; (b) investment costs are higher than those of other alternatives; and (c) trailer-collected harvesting material tends to ferment if placed in piles.

The development of a simple version of this machine without a pneumatic transport system and possibly without a rubber conveyor belt is desirable.

Combine harvester development

For the one-stage harvest a commercial combine (Clayson 1530) with a 3.4 m cutter bar was modified and tested for the first time during the 1986 harvest. The modifications required were:

(a) At the front end: Because of stones and the required low stubble length a double knife cutter bar was fitted. The reel was replaced with a blower system in order to reduce any loss of seed which could otherwise occur if the mature crop is touched by the reel tines.

(b) At the rear end: Because of the high value of the lentil straw (up to 50% of the revenue), it is necessary to offer an effective straw and chaff collection system. This was tried with a US-made trailed unit of a self-powered system, consisting of a collection trough and auger, linked to a blower and an automatically tipping box, powered by a 15 hp benzine engine.

The system can be operated to collect either straw and chaff, or only chaff. We have collected all non-grain material, but found the unit quite large for Syrian lentil fields, which very often are not more than 2-3 ha, although they are collective fields.

Agronomic research

Agronomic research for lentil harvest mechanization has focused on three main areas: (1) methods of sowing and seedbed levelling, (2) weed control, and (3) effects of height of cut on seed and straw quality and yield.

Preparation for a machine harvest begins with sowing into a flat seedbed. However, lentil is currently sown in Syria by broadcasting on to ridges 45-47 cm apart made with a country plough (Feddan) or with a ducksfoot sweep; seed is then covered by bisecting the ridges. This results in a ridged field that is difficult to harvest by machine. Studies in 1978/79 at the ICARDA Tel Hadya research station

compared traditional sowing method with that in which the surface is made even by disc harrow and with drilling. Results (Table 3) showed that drilling resulted in increased yield and traditionally sown crop could not be harvested by side mounted cutter bar. However, flattening the surface by disc harrow following the traditional sowing did permit mechanical harvest although the harvest losses in comparison to hand harvest were higher. In another study various systems of seeding, to effect improvement over the traditional system of seeding on ridges, were compared with drilling. Results (Table 4) showed that drilling was best. Replacing hand broadcast by seed distribution using a fertilizer spinner also showed some advantage. The yield levels in the 1978/79 season were generally low because of low seasonal precipitation of only 247 mm.

In the 1980-81 season the traditional method of broadcasting was compared with drilling at 13 locations in northern Syria using hand harvest (Table 5). There was a 9% increase in seed yield of drilled over broadcast lentil, but the difference was non-significant at 5%. The use of a drill flattens the seed bed facilitating harvesting operations, and clearly does not reduce yields. More recently we have compared drilling at 200 seeds/m^2 with broadcasting at 300 seeds/m^2 and found similar yields, thus saving seed for sowing (ICARDA 1986).

Although rolling was found to reduce both seed and straw yield in one season (Papazian 1982), the use of a bar (40 kg) dragged behind the sweep covering broadcast lentil contributes to the levelling of the seedbed (ICARDA 1986). This improves mechanical harvest, and, if a hand harvest is done, then there is no reduction in yield of straw and seed compared to the traditional system.

Weedy lentil fields are a common sight in the area, and weeds hinder mechanical harvest. Extensive screening of herbicides has been undertaken at ICARDA on lentil. The best pre-emergent herbicides for broadleaf weed control are methabenzthiazuron (2 kg a.i./ha), cyanazine (0.5 kg a.i./ha), chlorbromuron

Table 3. Effect of method of sowing and method of harvesting on the seed yield of Syrian Local Large (ILL 4400) lentil at Tel Hadya, 1978/79.

Method of sowing	Seed yield (kg/ha)		% loss due to mechanical harvest
	Hand harvest	Cutter bar	
Drilling (30 cm apart)	604.4 ± 92.2	525.8 ± 41.8	13.1
Feddan[a]	466.3 ± 53.6	b	b
Feddan[a] + disc harrow	464.0 ± 80.5	333.7 ± 120.6	28.1

[a] Feddan is a country plough that leaves the field in ridged surface.

[b] Could not be harvested by side-mounted cutter bar because of ridged surface.

Table 4. Effect of method of seeding and method of harvesting on the seed yield of Syrian Local Large (ILL 4400) lentil at Tel Hadya, northern Syria, 1978/79.

Method of seeding	Seed yield (kg/ha)		% loss with mechanical harvest
	Hand harvest	Cutter bar	
1. Hand broadcast + covering by disc harrow	400.8 ± 38.7	349.0 ± 40.2	13.0
2. Hand broadcast + covering by spike-tooth harrow	348.3 ± 31.8	298.8 ± 50.1	14.2
3. Seeding by fertilizer spinner + covering by disc harrow	431.6 ± 29.1	379.8 ± 45.0	12.0
4. Seeding by fertilizer spinner + covering by spike-tooth harrow	454.9 ± 30.5	384.1 ± 48.5	15.6
5. Seeding with local (Kashashian) seed drill	489.6 ± 22.6	439.4 ± 35.0	10.3
6. Seeding with Amazon seed drill	510.9 ± 28.8	471.5 ± 31.8	7.8

Table 5. Mean seed and straw yield (t/ha) of a comparison between broadcast and drilled lentils over 13 locations in northern Syria in the 1980/81 season.

Sowing method	Seed yield	Straw yield
Broadcast	1.17	3.61
Drilled	1.28	3.62

Table 6. Effect of height of cut on lentil seed and straw yield.

Harvest method	Yiield (kg/ha)	
	Seed	Straw
Hand pulling (control)	879	1729
Cut at ground level	800	1603
Cut 5 cm above ground	756	1184
Cut 10 cm above ground	741	1042
LSD (5%)	92.0	186.6

(1.5 kg a.i./ha) and prometryne (1.5 kg a.i./ha). Pronamide (0.5 kg a.i./ha) provides good control of narrow-leaved weeds through a pre-emergent application, and it mixes well with both cyanazine and chlorbromuron. Graminae are also effectively controlled by the post-emergent herbicide fluazifop-butyl (1 L a.i./ha).

The effect of height of cut by double-knife mower on lentil straw and seed yields and straw quality has been studied. The results given in Table 6 show that, compared with hand pulling, cutting at ground level and 5 and 10 cm above ground resulted in seed yield losses of 9, 16 and 17%, respectively, due to pod drop (ICARDA 1985). Straw yield losses were 7, 32 and 39%,

respectively, because of the stubbles remaining in the field. Both the digestibility and protein content of the straw increased with the height of cut above ground because of the exclusion of the lower quality plant parts (lower parts of stems and roots).

Breeding for a mechanized harvest

Lentil land races in the Middle East and North Africa are shorter in height than the cultivars mechanically harvested in North America. They are also prone to lodging and both seed and pod losses (Erskine 1985a). Tall cultivars, which do not lodge and do not shed pods and seeds, are needed for most harvesting systems. With these aims ICARDA is undertaking a vigorous breeding program to develop new cultivars.

Growth habit

For harvest mechanization two simple measurements of growth habit are useful, namely plant height and the height of the lowest-borne pods above the soil surface (henceforth called lowest pod height). The distance between the soil and the pods must be 12-15 cm for cutting or pulling systems of harvest.

The average plant height of the ICARDA world germplasm collection grown in 1979 at Tel Hadya farm was 26.5 cm. There was a range of 10-45 cm amongst 1746 accessions (Erskine and Witcombe 1984). The average lowest pod height was 13.9 cm with a range of 3-30 cm. Clearly there is ample genetic variation in the cultivated lentil for selection towards increased plant height and lowest pod height.

In the breeding program we are recombining the tallest germplasm with other traits. As an indication of progress in selection, in nine replicated yield trials including a total of 198 selections at the F_7 generation grown at Tel Hadya in the 1984/85 season, 54% of the selections were taller and 58%, had a greater lowest pod height than the check. The mean plant height of the repeated local check, (ILL 4401) was 29.6 +/- 0.4 cm, and its corresponding lowest pod height was 12.3 +/- 0.4 cm.

Lodging resistance

Farmers' lentil crops frequently lodge resulting in high losses from a mechanical harvest. The seed yield advantage of a non-lodged selection over the lodged land race increased from 9% with a hand harvest to 39% with harvest by a double-knife cutter bar in northern Syria in 1984/85, indicating the role of standing ability in mechanization.

We studied the genetic, environmental, and genotype-environmental variation of the lodging of 242 lines grown at three locations contrasting in rainfall in northern Syria and Lebanon (Erskine 1987). Lodging was assessed at harvest on a 1-5 scale with 1 = no plants lodged in a plot and 5 = more than 75% plants lodged. There was no lodging (lodging score = 1) at the dry site, Breda, where only 1.5 t/ha biomass was harvested on an average. In contrast the lodging scores were 2.3 and 2.4 at the two wetter sites, where the mean total biological yields exceeded 3 t/ha. The narrrow sense heritability of lodging across sites was 0.41 $\pm$ 0.046.

In a separate trial of 25 genotypes in one location, detailed morphological measurements were made to relate to lodging scores. Path analysis revealed that genotypes with thick stems lodged least, and there was a low direct effect of both seed and straw yield on lodging.

We have observed a response to selection for decreased lodging in the selection program. The line 78S 26002, which yielded an average of 16% more than the check in 26 on-farm trials in Syria, also has an increased resistance to lodging over Kurdi 1, the local check (Table 7). The line 78S 26002 is now being considered for release in Syria.

Pod indehiscence and pod retention

In the Middle East lentil reach physiological maturity and dry out rapidly with the onset of summer because of the prevailing hot, dry conditions. A timely hand harvest is needed to avoid losses from pod

Table 7. The average seed yield (kg/ha), plant height (cm), lowest pod height (cm), and lodging score of the lentil lines 78S 26002 and the local check (Kurdi 1) in 26 on-farm trials in Syria.

Entry	Grain yield	Plant height	Lowest pod height	Lodging score[a]
78S 26002	1074	32	17	1.9
Kurdi 1	924	33	17	2.4
Standard error +/-	26.9	0.5	0.3	0.1

[a] Lodging score on a 1-5 scale with 1 = no lodging and 5 = >75% plants lodged.

dehiscence and pod drop. The time available for harvest averages a week, but varies from 4 to 10 days depending on the weather. If the time-window for harvesting can be extended by a further week through slowing or postponing the crop's tendency to shed its seed yield, then a farmer's family could harvest twice the previous area reducing the peak demand for harvest labor. Any use of the combine harvester also increases the need to slow the shedding of yield.

We examined the genetic potential in lentil to reduce losses from a delayed harvest, with a six-week delay in the timing of harvest in various segregating populations from four lentil crosses (Erskine 1985b). The bulk segregating populations had previously been subjected to different numbers of selection by means of a delayed harvest. The loss from a delayed harvest in two seasons accounted for 551 and 105 kg/ha seed and 34% and 11% of the yield of a correctly timed harvest. Pod drop accounted for 65% of the losses, whereas pod dehiscence gave 34% of the losses across both seasons.

Substantial genetic differences in pod dehiscence were found with 74TA 550 showing relative indehiscence. Natural selection within segregating populations by delaying the time of harvest decreased pod dehiscence, demonstrating the benefit of this simple expedient.

Amongst the genetic material studied there was little genetic variation for pod drop, the major determinant of the yield loss from a late harvest. This and further unpublished observations on the ICARDA world lentil germplasm collection suggest that pod drop may best be manipulated through other, non-genetic factors. For example, lentil farmers are well aware that early morning hand-harvesting before the dew evaporates is not only more comfortable but also leads to less crop loss. Since pod drop occurs mostly at the moment of impact of harvest, design of the cutter-bar area deserve attention.

In conclusion, we are now recombining the existing variation in plant height, lodging resistance and pod indehiscence to produce suitable cultivars for the Middle East.

Proposed solutions for three different management regimes

From our above studies, we can conclude that there are several systems of mechanical harvest appropriate to the diverse conditions of lentil growing areas in West Asia and North Africa.

1. With broadcast sowing of land races, the most promising lentil harvesting equipment, other than the hand, are a simplified version of the GTZ lentil puller-swather and the angled blades.
2. The minimum change to existing management for the successful use of the double-knife mower is a seedbed flattened with a bar and a non-lodging cultivar.
3. A very flat seedbed, obtainable only by drilling, and seed of a tall, non-lodging cultivar are needed to successfully harvest with a modified combine harvester; which may or may not collect straw and chaff depending on local needs.

3. Chickpea Harvest

3.1. Additional harvest problems specific to chickpea

Seed Size: The seed size varies considerably from 11 g/100 seeds to more than 60 g/100 seeds, although seed size difference in any given country will not be that wide. This necessitates the development of a machine that could harvest chickpea differing in size without too much breakage.

Plant Height: The plant of chickpea sown during winter in the Mediterranean region or subtropical region of the Indian subcontinent and Mexico generally attains a minimum height of 40 cm. This is ideal for mechanical harvest. But the spring-sown crop in the Mediterranean region and more southerly latitudes hardly reaches the height of 25-30 cm. This is certainly too low for effective mechanization. Thus, there is a need to develop taller plants.

3.2. Machinery testing

Unlike lentil, harvest mechanization with a combine is achievable in ICARDA's mandate area with little changes to agronomy, and a taller plant. Table 8 presents the results of a mechanical harvesting study using a plot combine (Hege) and two kabuli chickpea cultivars of differing plant height sown in the end of winter 1985. The mechanical harvest of the cultivar with conventional plant height (ILC 482) resulted in

Table 8. Seed yield of a conventional (ILC 482) and a tall (ILC 3279) kabuli chickpea cultivar as affected by method of harvesting at Al-Bwabeya, northern Syria, 1985.

Cultivar	Plant height (cm)	Seed yield (kg/ha)		% loss in mechanical harvest
		Hand harvest	Harvest with Hege Combine	
ILC 482	30	1370 ± 37	975 ± 42	28.9
ILC 3279	50	877 ± 56	931 ± 35	0.0

about 29% loss in yield, whereas with the tall cultivar (ILC 3279) there was practically no loss, when compared to hand harvest. The tall cultivar has now been released for winter sowing in Syria, Cyprus, and Tunisia.

A Clayson Combine 1530 was tried in the 1985/86 season with the standard cutter bar and pick up reel. Adjustments were as follows:

Drum type	-	as for corn,
Drum speed	-	550-600 rpm,
Concave type	-	as for corn,
Concave opening	-	2 x seed diameter,
Shaker	-	standard,
Sieves	-	according to seed size,
Wind	-	stronger than required for cereals.

The machine has been evaluated as far as capacity, losses, and breakage are concerned. It was observed that the chickpea can clog the concave if the clearance does not match the seed size.

3.3. Agronomy research

Winter sowing

The chickpea crop is generally spring-sown, but ICARDA has developed a production technology to advance the sowing date to early winter, using cold tolerant and ascochyta blight resistant cultivars (Saxena and Singh 1984). Many countries have already introduced winter sowing as it tends to increase yield by about 50% over that from spring sowing (ICARDA 1986). With winter sowing the crop also attains a reasonable height to enable the plants to be harvested by machine.

Drill planting for better levelled seedbed

In many countries chickpea is broadcast by hand. This results in an uneven seedbed which poses problems for machine harvesting. To overcome this, sowing by drill is suggested. Many drills, such as standard cereal drills or precision corn planters, can be set or adapted to suit the requirements of chickpea planting.

3.4. Breeding research

Ascochyta blight and cold resistant chickpea have been developed which could be planted during winter (ICARDA, 1986). Besides giving higher yield, the crop could be machine harvested.

Breeding efforts are continuing to develop tall chickpea cultivars for spring sowing. These cultivars should be available to the growers in the near future.

Under high fertility and favorable moisture supply conditions, the chickpea crop may grow excessively and lodge. Breeding efforts are underway to develop non-lodging cultivars.

3.5. Conclusion

In conclusion, harvesting of chickpea is not as problematic as that of lentil. Introduction of winter sowing in the Mediterranean region and the use of tall cultivars will further facilitate mechanized harvesting using the traditional grain combines suitably adjusted according to the seed size and other parameters of chickpea crop.

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[b] Invited paper received but unable to attend.

APPENDIX

IAMFE CONFERENCES

First International Conference on Mechanization of Field Experiments, As, Norway. 15-27 June 1964. 71 participants from 16 countries.

Second International Conference on Mechanization of Field Experiments, Braunschweig, West Germany. 1-6 July 1968. 189 participants from 26 countries.

Third International Conference on Mechanization of Field Experiments, Brno, Czechoslovakia. 10-15 July 1972. 173 participants from 37 countries.

Fourth International Conference on Mechanization of Field Experiments, Ames, Iowa, United States. 5-10 July 1976. 168 participants from 22 countries.

First Regional IAMFE Conference on Mechanization of Field Experiments (NJF/IAMFE Seminar) Ultuna, Uppsala, Sweden. 7-9 December, 1977. 130 participants from 8 countries.

Fifth International Conference on Mechanization of Field Experiments, Wageningen, The Netherlands. 4-8 August 1980. 180 participants from 36 countries.

Sixth International Conference on Mechanization of Field Experiments, Dublin, Ireland. 8-13 July 1984. 200 participants from 34 countries.

Second Regional IAMFE Conference on Mechanization of Field Experiments, Bhopal, India. 11-12 April 1985. 70 participants from 3 countries.

Third Regional Conference (IAMFE/ICARDA) on Mechanization of Field Experiments in Semi-Arid Regions, Aleppo, Syria. 24-28 May 1987. 66 participants from 20 countries.

FUTURE IAMFE CONFERENCES

Seventh International Conference on Mechanization of Field Experiments, University of Agricultural Sciences, Debrecen, Hungary. 11-15 July 1988.

Fourth Regional IAMFE Conference, IAMFE/CHINA Conference on Mechanization of Field Experiments, Beijing, China. 1990.

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