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AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.31, NO.4, AUTUMN 2000

Special Issue:

The XIV MEMORIAL CIGR WORLD CONGRESS 2000 in Tsukuba

and

10th anniversary meeting of Asian Association of Agricultural Engineering in Bangkok

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

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Edited by

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EDITORIAL

Godspeed to the CIGR Congress and AAAE Meeting !

Towards the end of the year, two big international conferences will be held in the Asian region : the International Commission of Agricultural Engineering (CIGR) Memorial World Congress in Tokyo and the 10th Anniversary Meeting of the Asian Association of Agricultural Engineers (AAAE). The former will be held for a week beginning the 28th of November 2000 in Tsukuba Science City where the country's leading research institutions are located. On the other hand, the latter's week-long meeting will be held in Bangkok commencing on the 4th December.

The CIGR which started in Europe provides the largest network that links all agricultural engineers around the world. In comparison, the AAAE was established in 1990 with the objective of strengthening the ties that bind the agricultural engineers in Asia and the Pacific in a common effort to enhance agricultural productivity in he region through agricultural mechanization, among other considerations.

Their separate congregations, both the CIGR Congress and 10th AAAE Meeting are expected to assess their achievements in the recent past and address important issues they face in the coming years on a world-wide and regional bases, respectively.

It does seem to me, in my capacity as Vice President of the AAAE since its founding in 1990, that the past 10 years went by so fast amidst the various scientific advances that have come about, the internet, for instance.

More than ever before, the CIGR and AAAE are being called upon to speed up the communication among their members and end-users of research results. This is because even when the world seems to be shrinking due to the advent of modern and high-speed comunications systems, the world's population, in contrast, is increasing in great numbers: some 6 billion people at present. All this tells us is that the biggest population problem facing us is short food supply in the coming years. Therefore, the CIGR and AAAE congregations are opportune - coming at the appropriate time.

In this regard, what little contribution the AMA publications have been doing for some 30 years now - first in Asia only, but now includes Latin America and African countries, will continue to fulfill my dream that some day soon, many children and adults as well will no longer sleep on empty stomachs. I envision that this dream will come into fruition sooner or later as agricultural engineers, economists and other academicians continue to support the AMA.

By the way, we are putting up this special issue of AMA for distribution to all attendees of CIGR Congress and AAAE Meeting.

THe AMA staff wishes the CIGR and AAAE a huge success in the conduct of their Congress and Meeting, respectively.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
November 2000

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INTERNATIONAL COMMISSION OF AGRICULTURAL ENGINEERING

B. A. Stout
President, 1999 / 2000
CIGR

Our profession is addressing great challenges facing humanity, such as ensuring an adequate and safe food supply for an expanding world population and managing and protecting the worldís vital water, soil, air, and energy resources. I firmly believe that the work of agricultural engineers is vital and that we are one of the key professions in world development. My perception, however, is that we have failed to articulate the vital nature of our work. In the 21st century the public is not interested in the nuts and bolts of our work. The public, especially the urban public including many politicians and policy makers, wants to know how the work of agricultural engineers helps people, how we contribute to the social, economic, and environmental betterment of humans around the world. There is no question in my mind that we do, in fact, help people through our contribution to food production; food quality and safety; food storage, processing, transport, packaging, and marketing; to a cleaner environment; improved water and air quality; and our many other diverse activities.

I challenge all agricultural engineers to emphasize our helping people when we describe our work. Think not nuts and bolts or the technical details of our work, not mathematical equations or computer models, but focus on how we help peoplemore and higher quality food, reduction of world poverty, help poor farmers raise their incomes, pollution control, resource conservation, a safer workplace, and reduced drudgery.

CIGR is a global network serving agricultural engineers in 65 countries. Check our website (http://www.ucd.ie/cigr/)at for all the details. Best regards to all agricultural engineers in the world.

CIGR CONTRIBUTION TO WORLD AGRICULTURE AND INTERNATIONAL COOPERATION

El Houssine BARTALI
Incoming CIGR President 2001 -2002

The XIV th world congress of the International Commission of Agricultural Engineering (CIGR) will take place in Tsukuba, Japan end of November 2000. This first CIGR congress in Asia takes place two years after the first CIGR congress in Africa which was held in February 1998 in Morocco and will be followed by the XVth CIGR congress in Chicago, USA in July 2002. CIGR is celebrating its 70th anniversary this year. It has developed into an international network in which 65 countries are represented through national or regional associations of agricultural engineering. Its activities have been providing a significant support to the development of world agriculture. CIGR congresses and its technical section meetings are international fora to debate various issues related to rural development, increase agricultural production and protect the environment.

Within 25 years from now, the world population is expected to reach 8.5 billion. More than 80% of it will be living in developing countries. There are still 800 million undernourished people. The available resources and technologies to satisfy the demand for food and fiber production are still unclear. 30 to 70% of the population works in agriculture in developing countries while only 5% are employed in this sector in industrialized countries.

Major obstacles are still facing integrated rural development and agricultural development particularly in developing countries: (i)insufficient food production and increasing population; (ii)decreasing water resources in quantity and quality and increasing water needs for irrigation and drinking water. More than 40% of the world population will be affected by water scarcity by the year 2050, (iii) threatening soil degradation (iv) insufficient agricultural mechanization and rural electrification and inappropriate energy use in agriculture, (v) poor roads system in rural areas, (vi) insufficient funding for adequate training and research development.

The success in overcoming these obstacles will depend on international technical and scientific cooperation in which the support of various partners among which CIGR as an NGO is needed. . Sustainable development is becoming a key goal for every one from decision makers to local farmers. Sustainable agricultural production besides respecting the environment and ensuring food supply has also a social and economic dimension.

The added value brought by the profession of agricultural engineering in this regard is in continuous progress. CIGR keeps expanding its system of connecting agricultural engineers over the world and of valuing their contribution to secure food production.

The electronic journal, the system of internet group discussion between specialists in all the fields of activities covered by CIGR, this system is developed in collaboration with FAO, the creation of a new technical section on information technologies, the CIGR Handbook of agricultural engineering, the CIGR newsletter are all efficient tools which CIGR is developing in order to achieve its objectives at the entrance of the 21st century..

CIGR FOR THE WORLD'S AGRICULTURE

Osamu Kitani
Past President of CIGR and
Chairman, Organizing Committee
XIV Memorial CIGR World Congress

International Commission of Agricultural Engineering, CIGR, originally abbreviated from French words 'Commission International du Genie Rural' was founded in 1930 in Belgium as the first international academic organization of agricultural engineering. In the past, twelve World Congresses of CIGR were held in different countries of Europe and North America. Following the 13th World Congress in 1998 held in Rabat, Morocco, the first CIGR world congress held in an African country, the 14th CIGR World Congress to be held on November 28-December 1, 2000 in Tsukuba Science City, Japan is the first time CIGR World Congress in an Asian country.

The 14th CIGR World Congress in Japan also bears special importance in memory of the 70th Anniversary of CIGR and for the turn of the new millennium. On behalf of the Organizing Committee, I heartily welcome you to the XIV Memorial World Congress in Japan.

We are now standing at the entrance of a new era of the 21st Century. Numbers of issues for the future world are ahead of us. Food to support the increasing world population is a pressing and steady problem. About 800 millions people are still on the verge of famine at present. The world agriculture must find a solution. Agricultural engineering is the key technology to solve the problem of feeding additional 3 billions people in the coming fifty years.

The XIV Memorial World Congress will focus many special themes such as life support systems, informatics and paddy field agriculture. Presentation of original papers and scientific discussions will be carried out also on topics within the framework of the current six technical sections of CIGR, namely, Section-I: Land and Water Use, S-II: Farm Buildings, Equipment, Structures and Environment, S-III: Equipment Engineering for Plant Production, S-IV: Rural Electricity and Other Energy Sources, S-V: Management, Ergonomics and System Engineering, and S-VI: Processing. New section of information technology will be initiated during the congress in Tsukuba and special presentations will be made on the relevant topics.

Agricultural engineering has been applying scientific principles for the optimal conversion of natural resources into agricultural land, machinery, structure, processes and systems for the benefit of mankind. We, agricultural engineers are expected to provide young people in the world with more powerful and enjoyable agricultural production system by means of new technologies.

At present, more than half of the world population is engaged in agriculture to meet the world's food demand. The role of agricultural engineers is increasing with the dawning of a new century. In future, agriculture will have to supply not only food, but also other materials such as bio-fuels and organic feedstocks. With a global view, agriculture is the largest industry and will remain so in the coming century. To support the huge industry is a big challenge to us, especially to the agricultural engineers.

This international congress will provide a forum for scientists worldwide to meet and discuss their research findings and the latest advancement and experienced opinions in different fields of agricultural engineering. I believe that all of us in the congress could be able to find some advantage to promote our activities to serve for this purpose. On behalf of the Organizing Committee, I do hope that you could acquire some fruitful results from the congress in Tsukuba and enjoy a pleasant trip in Japan.

As a member of the CIGR Presidium, I would also like to invite you to the worldwide activities of CIGR. Let us think together, what CIGR can do for you if you are working in agricultural engineering and related fields? If you register yourself as a member of CIGR through a regional or national society you can get all the rights to receive the most recent international information from CIGR, pursuit your professional interest in the CIGR networking system, and participate in the worldwide activities of CIGR. You can communicate worldwide through the CIGR-FAO Electronic Network. You can participate in CIGR congresses, conferences and symposia with a member discount fee and purchase CIGR publications such as CIGR Handbook at a lower member price. You can publish your papers in CIGR Electronic Journal.

CIGR welcomes you to participate in any and all activities planned by CIGR. Your contribution to CIGR is of great value to other agricultural engineers in the world and will be highly appreciated.

MASSAGE FOR CIGR AND AAAE

Giuseppe Pellizzi
Honorary President of CIGR

It is a great pleasure for me to mark the 70th anniversary of CIGR, an event that will be celebrated at the XIV World Congress to be held in Tsukuba under the aegis of the Japan Science Council, as well as the 10th meeting of the Asian Association of Agricultural Engineers (AAAE).

The agricultural engineering sector has developed considerably, especially in the past 50 years, driven by the escalating demands of the global population and its primary needs (food and non-food). The management of water, the land and the environment; the use of modern and rational constructions for improving the storage of products, the health and development of animals, intensive productions, and the life of rural populations; the use of modern machines appropriate to the pedoclimatic, social, environmental and economic conditions in the different countries; the consequent energy-related issues, as well as those pertaining to operator safety and comfort - these are all problems of increasing importance and complexity, which underpin the agricultural development of industrialized and emerging nations alike. Hence the need to conduct advanced research and foster frequent and productive contacts between scientists, engineers, agronomists and specialists in various fields, with a view to: comparing the results of their research activities; identifying the specific needs of the various crops; drawing new ideas for further research; better understanding each other; and finally, promoting closer links with the world of industry.

These were the basic reasons for which CIGR was established, with great far-sightedness at the time, as a global organisation for assisting researchers and technicians by promoting periodic meetings between them, thereby enabling them to operate more productively for the benefit of humanity as a whole. And this is all the more important in a world of increasingly globalised commercial exchange, in which the barriers of distance are gradually diminishing, compelling nations to develop together through reciprocal assistance.

I believe that, for the objectives described above, CIGR plays a fundamental and irreplaceable role, precisely thanks to its world-wide organisation which incorporates analogous regional associations (ASAE, EURAGENG, ALIA, SEASAE and obviously AAAE).

This role is then further expanded through the organisations such as the Club of Bologna, which studies strategies for mechanisation development, devoted to promoting the transfer and development of know-how.

I therefore wish CIGR a long and productive life, for a prosperous future. And this will also mean a prosperous future for the entire agricultural and rural worlds, which are the foundations of every nation's economy.

MESSAGE FROM UNACOMA

Carlo Ambrogi
UNACOMA Director

The XIV CIGR World Congress is being held in Japan to coincide with the beginning of the third millennium, that is, a time which brings to mind the great progress made by mankind, especially in the past two centuries. This progress was, however, incredibly speeded up in the closing years of the century just past thanks to developments in mechanical engineering, genetics, electronics and the application of information technologies to open horizons without frontiers for the near future.

The congress will be held in a country which has been capable of admirably joining its great cultural traditions with what is new to conquer an oligopolistic position on the market of goods with a high technological content while maintaining the country in a harmonious and respectful relationship with nature. And this is the crucial point for our era: the challenge we must face and win so that our children and grandchildren have not only sufficient food but also vital space for moving in an environment made up of forests, croplands, flowers and animals.

The rural genius and the various sectors of skill it is divided into -from mechanics to water management, from construction to ergonomics- embrace a number of disciplines which hold preÅEinent positions in the world scenario because they are aimed at finding the best of all possible solutions for the primary well-being of mankind. The solutions can be -and certainly must be- different according to the way they can be applied to geopolitical and socio-economic realities, but I believe that the principles behind them must remain shared. These are principles which recall the commitment of means and instruments which are environmentally eco-compatible, capable of ensuring profitability for farm enterprises and safe for users from all points of view.

In this framework, the CIGR Congress will provide an opportunity not to be missed for a comparison of different conditions and for profitable debate on the issues chosen from time to time, those which have the great merit of bringing forward the emerging scientific trends to be subsequently transferred to the level of practical agriculture, thereby working as a flywheel in the process of agricultural modernization. This is a process which never rests and -as is shown by the issues on the agenda for the 14th CIGR Congress- is now facing a new frontier of robotics and an agro-environmental approach with the aid of expert artificial intelligence systems.

The manufacturers of agricultural machinery are awaiting the CIGR Congress appointment with keen attention. They are fully aware that only through an ongoing and institutionalized relationship with universities and research centers and institutes will it be possible to introduce the process and product innovations needed for putting the latest generation of mechanical technologies at the disposition of farmers and agro-mechanical enterprises in support of an activity which is essential but pressured by conditions deriving from the globalization of the markets.

The Italian manufacturers UNACOMA has the honor of representing are especially sensitive to this issue, so much so that ten years ago they sponsored the formation of the Club of Bologna. The 11th work session of the Club of Bologna, whose members are the most highly qualified experts in the field at the world level, will coincide with the CIGR Congress 2000 to show their conviction that the annual meeting on current issues of agricultural mechanization will serve to ensure suitable and modern mechanization in various countries around the world in relation to their specific requirements.

Four years ago, moreover, UNACOMA established a prize for each of the CIGR Congresses, like this one in Tsukuba 2000, to be awarded to a figure of outstanding merit because of his or her activities in the field of world agricultural mechanization.

OUTLOOK FOR AGRICULTURAL ENGINEERS

Harmon Towne
ASAE President

Will the need for agricultural engineers continue? I'm sure this question is on many individual minds with the move in the U.S. to call our engineering programs something other than agricultural engineering. But if we carefully look at facts and statistics I believe that the answer will be very clear.

The population of the world is continuing to grow at a rapid pace. We have seen a slowdown in birth rates so some of the predictions of a few years ago now appear to have estimated too high of numbers in the coming years. However, even though the growth rate has slowed, there continues to be more mouths to feed on this planet every day.

Another fact that we must look at closely is the economic growth in many developing countries. Even today many countries struggle to feed there people, but as more and more countries start to improve the income of there people, diets are the first thing to change. This means that the demand for more and higher protein food increases dramatically.

The need for more high protein food, which is free of food borne pathogens, is an area that agricultural engineers have excelled in for years. Along with producing more food on less land, greater emphasis will need to be placed on water conservation, soil conservation, and more friendly treatment of the environment. Who better to do this work than agricultural engineers with their training and understanding ?

Agricultural engineers have always worked in the areas of soil and water conservation. The need will be even greater as water resources start to be of concern. Already there are many areas of the world where abundant safe water is scarce. As populations continue to grow this will become an even greater issue. Agricultural engineers will work with plant scientists to develop varieties of plants that require less water. They will also develop ways to reduce the ways to get the water to the plant system without the large amounts of evaporation we see today.

Agricultural engineers trained in the food processing area will continue to find new and better ways to process food while reducing the waste, or finding ways to use the waste rather than just discard it. They will also find ways to reduce the amount of water used in the processing as well as ways to clean and reuse that water.

And yes, there will still be a need for those traditional agricultural engineers to develop machinery for all aspects of food production. While they will still have training in mechanical engineering they will also have courses in biological areas so that they more fully understand the relationship between plants and machinery interaction. The same can be said for the structural and environmental area. In order to develop buildings, ventilation systems, manure disposal systems and other facets of animal production, they will also take some of the same core courses as in the past as well as more biological related courses.

The fact remains, regardless of what we call ourselves, biological engineers, bioresource engineers, agricultural engineers or some other related name, the profession will continue to flourish and grow. People will have to continue to eat and they will look to us to provide inexpensive wholesome food. There is no other group in the world that has the necessary education to do what we excel at. As engineers involved in agricultural, food and biological engineering, we need to be proud of what we do and let people know that because of us, they continue to eat better more wholesome food

Is there a future for Agricultural Engineering? There certainly is. While the name may be somewhat different depending on the country you live in, engineers trained in the agricultural and biological arena will continue to improve the diets and lives of the people in the world.

MESSAGE FROM ALIA

Jose Manuel Cabrera Sixto
Presidente de ALIA 1998-2000
Asociacion Latinoamericanay del Caribe de Ingenieria Agricola (ALIA)
Latin American and Caribbean Association of Agricultural Engineering.

According to the 1999 report on human development elaborated by the United Nations Development Program, only 45 countries, out of 174, are classified as having a high human development index (HDI); and from those 45 countries only 5 are from the Latin-American and Caribbean area. One of the 3 criteria used to compute the HDI is the income per capita. Even when the relation between economical prosperity and human development is not clear or automatic, a higher income generally means a greater opportunity for a better quality of life. An important sector of the economy in the less developed countries is the agriculture because of the high percentage of population dedicated to this activity. Unfortunately, most of these people have a low standard of living, because of the low resources and systems not always well designed that they use in agriculture.

In the 21st century the equity among nations and individuals has to improve, and Agricultural Engineering can be an important factor for this to happen. Agricultural Engineering in the less developed countries has to have a big impulse to improve the agricultural production in quantity and quality and to recover and sustain their natural resources. There is still a lot to do to mechanized special crops, to reduce production costs in order to improve competition in a globalized market, to maintain the quality of the food produced through the distribution channels until they reach the final consumer, to preserve the quality of water, soil and air to have sustainable production systems, etc. It is important to make available to the different kind of farmers, depending upon their size, education and income; the most appropriate technologies for them. At the present time there are very sophisticated and expensive technologies but also simple and inexpensive ones. Agricultural engineers has to advice to the farmers which is the best technology for their specific situation or has to develop the technology they need.

This big impulse of Agricultural Engineering has to come from inside each country but also needs to be strongly supported for an international cooperation. The regional associations in Agricultural Engineering as CIGR, AAAE, ALIA, EurAgEng and others have to play an important role in this cooperation to facilitate and speed up the process of adoption and transfer of technology, as well as to promote the formation of large research groups between countries in strategic topics. Cooperation among the associations is needed also to improve and provide certain level of standardization between the educational programs in Agricultural Engineering so that graduates from different countries can interact effectively to solve common problems.

MESSAGE FROM EurAgEng

Bent S. Bennedsen
President of EurAgEng

In the general awareness, the most important contribution of Agricultural Engineering has been the mechanisation of most of the processes, which used to depend on human or animal labour.The trademark of the 19th and 20th centuries Agricultural Engineering has been: Replacing (hard) manual work with machines, and making machines bigger and better. High productivity and increased yields were pursued by high input of mechanization, fertilizer, plant protecting chemicals and energy.

While this approach was, and still is, a prerequisite for providing food for the worlds population, it is also subject to an increasing concern regarding the impact of agriculture on environment, the quality of the raw materials produced, and of safety and ethical aspects of the production.

Sustainability, quality, animal welfare, ecological etc., these are words, which will achieve increased importance in the agriculture of the 21st century.

The challenge of Agricultural Engineers is, to provide the technology for agricultural production, with focus on these items, because such productions will depend, not only on technology, but on technology which is very different from what is currently used.While it is theoretically possible to achieve some of the objectives by turning the clock backwards, and reinstalling human labour, it is not an option in practise. The sheer amount of food, needed throughout the world excludes this. Fortunately, there is another way: The classical agricultural machinery is "all muscle and no brain". It is capable of doing a uniform job, fast and efficient. However, it is not able to take into consideration, all the variations within the fields, adjust itself to changing conditions, and to make decisions on the best approach and solution to problems. In order to accomplish this, the future, agricultural machinery must be provided with a "brain". The trademark of the 21st century agricultural technology will be to replace heavy machinery, high input and energy consumption, and manual labour with intelligent machines, in order to optimise production, improve quality, and reduce harmful, environmental impacts.

The future agricultural machinery will depend on sensors to monitor the situation, on complicated models, build into decision making software, and on highly refined actuators, to perform tasks adapted and optimised with relation to time, and position.

The future Agricultural Engineer will face the job of providing such machinery. In doing so, he/she will need knowledge and skills, not traditionally connected to Agricultural Engineering. This includes physiology related to the development of sensors for crop status and animal health. It includes knowledge on plant nutrition and development, in order to produce decision systems, and competence within advanced mechanical engineering to produce the actuators. The future Agricultural Engineer is challenged with encompassing all this. At the same time, Agricultural Engineering faces the risk of being fragmented and absorbed in the many, related disciplines.

The most important task of Agricultural Engineering in all its manifestations, but mainly in the societies, regional as well as international, is to find and define the identity of Agricultural Engineering, and of the Agricultural Engineers, in the intersection of all the related disciplines. This must be matched by an adaption of the education of Agricultural Engineers.

Hence, we can envisage a future, where agricultural machinery looks, and mainly acts, very different from what we know today. We can look back at well over a century of development to get to where we are now. We will not be granted another century to bring Agricultural Engineering into the next phase. The requirements to accomplish this is more than one nation can manage. It will take the combined potentials of all the Agricultural Engineering institutions and companies in the world, and yet, this will not be enough, if the effort is not coordinated through collaboration on all levels: Between research and industry, on national levels, on regional levels, and internationally. With this in mind, we cannot overestimate the importance of exchanging and disseminating information and visions. To that end, we are relying heavily on the societies for providing journals and bringing Agricultural Engineers, and other professionals together for conferences. I would like to take this opportunity to thank the organisers of The XIV MEMORIAL CIGR WORLD CONGRESS 2000, and the10th anniversary meeting of Asian Association of Agricultural Engineering for providing these events, and extend my best wishes for two successful events.

MESSAGE FROM AAAE

Makoto Hoki
President of AAAE

First, I would like to extend my warmest greetings to AMA and all the readers. Let me commend the AMA for the continued publication and timely information dissemination of agricultural engineering favorable to the modernization of developing countries in the world. I hope that AMA keeps up the good work for the years to come.

On behalf of the Asian Association for Agricultural Engineering I congratulate all the participants of and organizers of The XIV Memorial CIGR World Congress 2000 in Tsukuba, Japan. Also I would like to extend greetings to all the participants of the International Agricultural Engineering Conference 2000 and AAAE 10th Anniversary Celebration to be held in Bangkok, Thailand. Also I would like to take this opportunity to thank all of you who are helping in making AAAE into the sound and active organization.

Geographically Asia incorporates one-third of the earth's surface or an area of about 50 million square kilometers. It also includes more than two-third of the world population, around 3 billion people. Asia has a number of rapidly developing countries. Their economic and agricultural advancement over recent years has been at an incredibly high rate. In spite of the current temporary slump in some countries, I believe that Asian countries will continue to have a great potential to form one of the main economic centers in the world in the 21st century.

Agriculture is the main economic sector of the developing countries in Asia. However agriculture in the region is multi-faced and changing much faster than before. It concerns the global interactions of population, food energy and environment . This is challenge to AAAE as a professional organization for agriculture and related industries. We have to think globally and we have to work internationally in dealing with diversified issues and regional needs. We have to look for ways to promote public-private integration to facilitate technology transfer needed for the regions.

During the International Agricultural Engineering Conference 2000 on December 4-7 in Bangkok we will be holding two special events of "International Symposium on Water and Environment" and "Techno-Festa". The former is to bring scientists, industry and policymakers together to discuss sustainability issues of agricultural production systems in Asian countries. The latter will be specially designed for agricultural machinery industries including domestic manufacturers and dealers in Asian countries to exchange technical and business information as well as relevant experience of professionals concerned with machinery design, development and marketing.

For the coming years AAAE will be in close liaison with CIGR and uniting agricultural engineers from countries around the Asia into more effective whole. In all our undertakings I am confident that the agricultural engineers will produce pioneering ideas and methods that will be essential for the 21st century. It is my sincere hope that we can continue to count on you for your support and participation in our challenging task.

MESSAGE FROM AAAE

Gajendra Singh
First President of AAAE

Agricultural scientists including agricultural engineers have done an excellent job of producing enough food to meet the demand of growing population. Worldwide per capita food availability in calories has been increasing and real food prices have been decreasing over last 40 years. Although the absolute number of people engaged in agriculture globally is still increasing, the proportion of people engaged in agriculture is decreasing in all countries. In developed countries the percentage of people in agriculture is about 5% only while in developing countries it is still about 55%. Agricultural engineers can be proud of the fact that according to the American Society of Mechanical Engineers, agricultural mechanization was named as the single greatest technology of the 20th century. The professional societies play a great role in stimulating the development of appropriate technology and its dissemination to users. Through global networking the agricultural engineering organizations can contribution significantly towards making appropriate technology available to the farmers throughout the world.

The Asian Association for Agricultural Engineering (AAAE) was established in December 1990 with its office at the Asian Institute of Technology (AIT). It has established itself as professional association with regular publication of a journal and a newsletter as well as by holding international conferences regularly. The main challenge for AAAE is to become truly regional association representing agricultural engineers of the countries in the Asia and the Pacific Region. It has to expand its membership and develop close links with national agricultural engineering societies in the region.

During last decade International Commission of Agricultural Engineering (CIGR) has come a long way to become an international organization from being confined mainly to European continent. CIGR faces the major challenge of being true representative of agricultural engineers worldwide. Many developing countries do not have well-established national agricultural engineering societies. For CIGR to be effective, regional associations must be effective. The effectiveness of regional associations depends upon cooperation with national associations. Let us all work to strengthen our national societies and establish effective working relationship with our regional association. Effective national and regional associations will make CIGR a truly global organization representing agricultural engineers all over the world. This networking will facilitate dissemination of technology from one part of the world to another for the benefit of farming community as a whole and will significantly contribute towards poverty alleviation and improved food security globally.

FIELD ROBOTICS AND TECHNO-FESTA

Mikio Umeda
Vice President of AAAE (Industry)

The 21st century is an era that all creatures must co-exist in harmony on the earth. Therefore, the problems on food, environment and energy have to be reconsidered. Human beings now can easily damage and destroy the nature by using their own power and technologies. One of the ways of preserving environment is to circulate resources and materials we are using. If the circulation could be kept, the damage to environment would be minimized.

Until the middle of 20th century agriculture was sustainable in keeping the circulation of most biological materials. However excess food production in particular region and progress of transportation stimulated international food trade in the world. Japan turned to be a food importing country since 1970s. Japan's cereal food-sufficiency rate is less than 30% now. Food production takes away huge amount of water and soil nutrition like nitrogen and phosphorus compounds from food exporting countries. These compounds are being accumulated in Japan. Thus the food trade interrupts the circulation of the materials. Japanese are afraid of the food trade giving damages to environment. The precision agriculture is one of the methods to reduce the use of polluting chemicals.

In USA and European countries, the energy crisis might be more serious than the food crisis. Fossil fuel is limited, while nuclear power is still not solving problems rather than indicating difficulties and uncertainties of nuclear waste management. Therefore renewable energy source like biomass must be utilized.

The 21st century is the century of information technology. To keep sustainable agriculture based on the circulation of the materials, farm informatics such as mapping and monitoring soil, growth and yield is required. To assure the safety of food, producer must disclose the production process like soil condition, the date of fertilizer and pesticide application to consumers.

The 21st century is also the century of robot. Robot consists of body, sense and intelligence. Farm robot is one of field robots. A field robot in the 21st century will be made to combine the technology of farm machine (Body) and field sensor (Sense), and the knowledge of precision agriculture (Intelligence). Farmers in the 20th century could use farm machines completely, so that they improve labor and land productivity, and emancipate from heavy labor. Farmers in 21st century may use field robots for many operations commonly.

With the progress of economy, farm mechanization in Southeast Asian countries will be promoted rapidly in many areas. Agricultural Engineering contributes to the improvement of farming in many ways. It is very important in any company for the managers and engineers to become more acquainted each other and able to exchange information freely. For this purpose JSAM has held an annual meeting for engineers called "Techno-Festa" since 1996. AAAE will hold Techno-Festa at 10th anniversary meeting in 2000. I hope the Techno-Festa contributes to the development of farm mechanization. The farm mechanization stimulates not only machinery industry but also information technology industry.

In the 21st century, the role of Agricultural Engineering will be even more important in terms of food, environment and energy.

AAAE - TEN YEARS OF EXISTANCE

Vilas Salokhe
Secretary-General, AAAE

As a Secretary-General of the association, it gives me immense pleasure to contribute this special message on eve of 10th anniversary of the Asian Association for Agricultural Engineering (AAAE). The Association was established on December 5, 1990 by virtue of a vote of the assembly after discussion at the International Agricultural Engineering Conference at the Asian Institute of Technology, Bangkok, Thailand. AAAE was formed for the general advancement of the profession and for the practice of Agricultural Engineering in all its aspects, as it relates to the Asian Region of the influence in the world.

The major objectives were to strengthen the profession of Agricultural Engineering by promoting information exchange, improving communication, minimizing duplication of activities, and optimizing use of resources. It was also aimed at publishing a peer-reviewed international journal and newsletter. The other objective was to co-operate with national and international related organizations. While looking back after 10 years of existance, it can be realized that AAAE has achieved its objectives.

The Foundation Membership spans over 4 continents and 22 countries, the Life Members come from over all 5 continents and from 18 countries. The regular members come from over 40 countries. These numbers proves internationalism of the association. So far 9 volumes of AAAE Newsletter have been published. Similarly, 9 volumes of the International Agricultural Engineering Journal have been published. The contribution to the journal comes from different parts of the world. Subscription to AAAE journal also comes from various parts of the world.

So far, AAAE has arranged 4 bi-annual conferences. It has also co-sponsored 11 conferences arranged by others in Asia, Europe and America. It is also working closely with CIGR, EurEngg, ASAE and other national societies.

Many people have contributed directly or indirectly for the current success of AAAE. However, lot of work remains to be done. Efforts are being made to further improve the quality of the journal, increase the membership, specially life members, and journal subscriptions. During regular conferences, speciality sessions are being arranged to promote further special themes. It is also intended to work more closely with the other professional societies for the advancement of the Agricultural Engineering Profession in the current millenium.

Rice Mechanization and Processing in Thailand

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Abstract

The development of farm mechanization in Thailand started with power intensive machines such as irrigation pumps, power tillers and threshers. Most of the farm machineries used are locally manufactured except the four wheel tractors which are imported and are mostly secondhand units. The mechanization started from the Central plain region and spread to other regions. The agricultural machineries have enabled farmers to grow more than one crop a year. Moreover, the migration of labour from the agriculture sector to other sectors has continuously increased, causing labour shortage problem in the agriculture sector. Therefore, agricultural machineries have become one of the important inputs for modern agricultural production system. The mechanization is not only expanding but also changing its pattern. In the Central plain, farm mechanization has been moving from power intensive to control intensive machines. The increment of power tillers, irrigation pumps and power threshers in the Central plain region has been quite stable but rice combine harvesters have been increasing rapidly. In other regions the number of power tillers is increasing rapidly, as well as Thai-made rice combine harvesters. The mechanical dryer has played an important role in keeping and improving rice quality.

Introduction

Agriculture has long been an important sector of the Thai economy, contributing about 17 percent of the GNP (United Nations, 1997). Rice is the most important crop of the country. Even though it is declining in relative importance, rice still occupies around 51 percent of the cultivated land. Rice farmers are generally subsistence farmers, selling only their excess production. Thailand produces rice not only for domestic consumption but also for export. The country exports 4-6 million tons of white rice annually to the world market. It has a reputation for high quality, long grain white rice, which usually commands a substantial price advantage over lower grade rice. The rice export is a source of foreign exchange and a significant factor in maintaining and subsidizing economic growth.

Geography of Rice Production

Administratively as well as geographically, Thailand is divided into four regions, namely; the Northeastern, Northern, Central plain and Southern regions. Rice is grown in all regions with different rice growing environments. Approximately 75 percent of rice is grown in rainfed areas and only 25 percent is in the irrigated areas. About 11.7 percent of irrigated rice area is in the Central plain region, with 6.4, 5.0 and 1.4 percent in the Northern, Northeast and Southern regions, respectively (OAE, 1998). The Northeastern region has the largest rice area, approximately one-half of the total rice area and the farm size is also larger than in the other regions. In this region, soil erosion and drought during dry season are acute. The water holding capacity of the soil is extremely poor, which results in low yield. But the region is the largest source of high quality rice, especially the Hom Mali or Jasmine rice which is aromatic long grain. The Central plain is an intensively cultivated alluvial area. During the rainy season, rice covers the major part of the region, accounting for about one-fifth of the total cultivated rice area of the country. The central plain region has the highest yield of 2.9 and 4.7 tons/ha for major and second rice crops, respectively, (OAE, 1998). In the Northern region, upland rice is grown in the lower altitudes of high hills and in upland areas. Lowland rice is grown mainly in valleys and some terraced fields where water is available. The Southern region, touching the West and East coasts of the peninsula, constitutes about 14 percent of the total area of the country, and around 5 percent of total rice area. With limited rice fields under cultivation, there is always a shortage of rice for local consumption in the Southern

Table 1. Area planted to Rice Population and Agricultural Labour by Region, Crop Year 1996/97

Region	Total area (million ha)	Rice planted area (million ha)	Total population (million)	Agric. Population (million)	Agric. Labour (million)
Northeastern	16.89	5.18	20.66	15.49	7.76
Northern	16.96	2.32	11.90	8.35	4.59
Central plain	10.39	2.16	19.19	7.88	4.92
Southern	7.07	0.47	7.71	5.06	2.75
Whole kingdom (Total)	51.31	10.13	59.46	36.8	20.01

Source: NSO (1997). Statistical Yearbook Thailand.
OAE (1998). The Survey report of major and second rice crop, crop year 1996/1997.

region. Rice planted area, population and agricultural labour by region are shown in **Table 1.**

Rice Production

In the crop year 1996/97, the total rice area was around 10.13 million ha of which 9.18 million ha was under the major rice crop and 0.95 million ha under the second rice crop. Around 67 percent was non-glutinous and 33 percent was glutinous rice. The production was about 22.3 million tons with a yield of 2.1 tons/ha for the major rice crop and 4.5 tons/ha for the second rice crop.

Although Thailand is the world's largest rice exporter, the rice productivity is still low when compared with other countries. In the past, the increase in rice production has been due to area expansion. Since the Fourth National Economic and Social Development Plan (1976-1980), the government decided that further expansion of rice areas was not possible. Thus, the strategies were changed to increase rice production by increasing productivity and by the development and use of appropriate technology. Due to the rapid expansion of other sectors such as industry, construction and tourism, labour has been drawn from the agriculture sector, resulting in labour shortage during peak seasons, especially since the Sixth Plan (1987-1991). Agricultural mechanization had played a significant role in overcoming the labour shortage problem.

Historical Background of Agricultural Mechanization in Thailand

Traditionally, Thai farmers used simple tools, animal drawn implements and water wheels. Mechanization with power technology began in 1891 when the government imported steam power tractor and rotary hoes that were found to be unsuitable for paddy conditions and also quite expensive (Sukharumana, 1982). In 1947, a single axle tractor with rotary hoes powered by 4.4 kW gasoline engine was imported, but its low chassis was unsuitable for swampy fields (Rijk, 1989). In the early 1950's, the government Rice Experiment Station promoted the use of 4-wheel tractors by introducing contracting service. This project was unsuccessful. In 1955, 262 tractors were imported from various countries but the most popular were the Japanese model 2-wheel tractors or power tillers. During 1956-1957, the number of imported tractors increased significantly, which stimulated local workshops to begin simplifying the design of imported tractors to reduce cost and also make them suitable for local conditions.

In 1957, the Agricultural Engineering Division (AED) of the Ministry of Agriculture and Co-operative released the design of an axial flow pump, namely "Debaridhi water pump" for local manufacture. This pump was subsequently commercially produced and widely adopted. In 1958, the Division released the design of a 4-wheel tractor powered by a 25 hp engine, named "Iron Buffalo", to two private firms for commercial production. Due to the high cost of this tractor, it could not compete with imported tractors, so the firms stopped producing it. In the same year, Mr. Debaridhi Devakul designed the first prototype of a rice combine harvester in that the cutting and threshing units were connected to the tractor (25hp) and driven by a PTO shaft. This prototype was not commercially produced. In 1960 and 1964, two firms, namely Ford and Massey Ferguson, established assembly lines for four wheel tractors (Singh, 1983).

In 1964-65, workshops around the Bangkok area began to modify the design of the imported 2-wheel tractors by trial and error method. Only one workshop succeeded in simplifying the gearbox and other parts of the tractor to suite local paddy field conditions. In 1966, a few firms began producing 2-wheel tractors. The lower price of these tractors relative to the imported tractors and their suitability to local conditions made them popular, and their adoption spread to all parts of the Central plain region. The high demand for these tractors resulted in many farm machinery firms being established in this region. In 1967-69, a firm producing 2-wheel tractors in Ayudhaya province began manufacturing a simple 4-wheel tractor that was developed from the 2-wheel tractor gearbox by adding 2 more wheels and a seat. It was powered by a 15 hp single piston diesel engine (Singh, 1983).

In 1975, the AED constructed the prototype for axial flow rice thresher that received its blueprint from the International Rice Research Institute (IRRI), then released it to a selected firm in Chachoengsao province for commercial production. Ten units were immediately sold, but it still was not successful. Later in 1975, a new blueprint was released to three firms for commercial production, and it was subsequently widely adopted. In 1977, a blueprint of por-

Table 2. Distribution of Farm Machineries in Use in Thailand (Unit: numbers)

Year	Power tiller	Tractor > 45 hp	Tractor < 45 hp	Irrigation Pump	Power Thresher	Power sprayer	Rice combine harvester
1975	90,001	13,338	16,792	251,288	3,955	46,317	-
1980	280,591	37,177	36,158	517,975	18,394	131,645	-
1985	402,082	34,823	NA	614,791	29,735	123,008	-
1990	750,542	57,739	NA	1,101,850	41,876	223,433	2,250
1995	1,515,693	148,841	NA	2,038,314	68,527	390,179	2,500
1996	1,753,638	183,704	NA	2,317,392	76,386	432,767	3,000

Source: OAE. (various issues). Agricultural Statistics of Thailand.

Table 3. Percent Regional Distribution of Selected Farm Machineries

Item	Region								
	Northern		North-eastern		Central plain		Southern		Whole Kingdom
	Unit	%	Unit	%	Unit	%	Unit	%	(Total, Unit)
Power tiller	818,028	47	243,321	14	413,643	23	278,376	16	1,753,368
4 wheel tractor	47,471	26	20,032	11	111,278	60	4,923	3	183,704
Irrigation pump	566,129	25	355,846	15	1,281,849	55	113,568	5	2,317,392
Engine powered sprayer	65,316	15	25,483	6	332,888	77	9,080	2	432,767
Hand operated sprayer	4,519,791	37	3,330,606	27	2,794,099	22	1,755,691	14	12,400,187
Thresher	7,002	9	25,745	34	40,497	53	3,142	4	76,386

Source : OAE. 1997. Agricultural Statistics of Thailand, Crop Year 1996/97.

table rice thresher was sent from the IRRI and one firm produced it, but it was not widely used due to its low capacity. In the same year, the Japanese combine harvesters (head feed type) were demonstrated to Thai farmers but they were not accepted. In 1978, a rice transplanter (12 rows and power operated) was imported from China by a local firm that also produced it, but could not be sold in significant numbers. At the same time, the AED tested a Japanese reaper. During 1981 and 1982, approximately 1,000 units of Chinese reapers were imported and sold. The long stem rice varieties were not suitable for reaping and the farmers had to collect and bind harvested rice similarly to manual harvesting which required more labour. Moreover, the high weight of the machines was also a major problem during field operation. These reapers were finally abandoned. In 1985-87, local firms around Bangkok successfully developed a rice combine harvester which is being popularly used in hiring services.

Status and Trend of Mechanization in Rice Production

Agricultural mechanization in Thailand has been basically restricted to soil preparation. For dryland soil preparation mainly large four-wheel tractors with disc tillers are used while local made power tillers (8-12hp) are popularly used for the wetland cultivation. The number of farm machineries in use in selected years is shown in **Table 2**. Mechanization played an important role in agricultural production since the Sixth Plan (1987-91) which started in 1987 as the policy and strategies in agricultural production have changed to mainly increase productivity and reduce production cost. The increasing price of agricultural commodities, especially paddy and soybean during 1992-1995 also boosted the mechanization level of the country.

Farm mechanization has been expanding from mostly power intensive operation machines such as power tillers, water pumps, and threshers to control intensive operation such as rice combine harvesters (Chaisattapapong, 1997). During 1992-95, due to increase in demand and increase in price of materials and engines, the price of locally manufactured power tiller increased about 10-20%. During the same period, the production of power tiller increased approximately 40 percent (Kaittiwat, 1996). Some machines not only increased in number but also expanded in size. For example, paddy thresher in the early design had a 4-feet long cylinder and was operated by a 10 hp diesel engine with a capacity of about 1-1.5 tons per hour. Now, self propelled thresher has a 8-feet long cylinder that uses a diesel engine of the truck (about 90-130hp), and has a capacity of about 5-6 tons per hour. These large paddy threshers are mainly used for contract work. The distribution of selected farm machineries during 1996 is shown in **Table 3**. About 47% of power tillers (8-12hp) are in the Northern region which have increased from 26% in 1980. The Central plain region has about 23% while around 16% and 14% are in the Southern and Northeast regions, respectively.

In the case of the four wheel tractors (20-75hp), 60% of these are in the Central plain region, and 26%, 11% and 3% are in the Northern, Northeastern and Southern regions, respectively. The highest concentration of water pumps is in the Central plain region (55%) followed by the Northern, Northeastern and Southern regions as 25%, 15% and 5%, respectively. In the case of the threshers, 53% are in the Central plain region, followed by the Northern (34%), the Northeastern (9%) and the Southern regions (4%). Because the area of each region is different, the availability of power per unit area (kW/ha) can be used as an indicator of the degree of mechani-

Table 4. Distribution of Mechanical Power Available from Selected Farm Machineries during Crop Year 1996/97

Power source	Average size (kW/unit)	Northern (kW/ha)	North-eastern (kW/ha)	Central plain (kW/ha)	Southern (kW/ha)	Whole Kingdom (kW/ha)
Power tiller	7.5	1.46	0.24	0.80	0.77	0.69
4 wheel tractor	48.5	0.53	0.11	1.21	0.09	0.42
Irrigation pump	3.7	0.51	0.15	1.21	0.16	0.44
Powered sprayer	1.1	0.02	0.01	0.10	0.01	0.03
Rice combine harvester	126.8	NA	NA	NA	NA	0.02
Rice thresher	67.1	0.11	0.20	0.70	0.08	0.26
Total	-	2.63	0.71	4.02	1.11	1.86

Table 5. Local Annual Production of Major Agricultural Machineries

Machinery	1992	1994	1995	1996	1997
2-wheel tractor	150,000	170,000	200,000	200,000	180,000
Combine harvester	500	300	500	500	500
Land preparation Equipment					
- For large tractor	25,000	30,000	40,000	40,000	25,000
- For power tiller	180,000	250,000	270,000	270,000	200,000
Thresher	2,500	2,000	2,000	2,000	2,000
Seed drill	2,000	3,000	4,000	4,000	3,000
Sheller	600	600	800	800	600
Low-lift pump	100,000	100,000	150,000	150,000	100,000
Manual sprayer	100,000	100,000	150,000	150,000	90,000

zation for each region. The average mechanical power per hectare of farmland from various farm machines is given in **Table 4**. It is clear from the table that the Central plain region has the highest degree of farm mechanization, followed by the Northern, Northeastern and Southern region, respectively. Majority of farm machines used are locally produced. Only the large tractors, 75% of engine powered sprayers and 30-40% of irrigation pumps are imported (Kiatiwat, 1996).

Regarding the trend of farm mechanization, the expansion rate of the power intensive machineries such as power tillers and threshers in the Central plain is reaching close to saturation. This is due to the fact that the labour shortage in this region is more serious than in other regions because it is the region where a lot of factories have been established. Labour shortages with high wages of labour has forced farmers to hire rice combine harvesters for harvesting rice. The use of Thai-made rice combine harvester for custom service has become very popular and widely adopted. At present, there are about 3,000 units spread over the whole country.

It is quite obvious that agricultural mechanization in Thailand is at a turning point from labour and power intensive machines towards control intensive machineries such as planting machines, powered sprayers and combine harvesters. The use of these machines has started first in progressive farming areas; the Central plain region and the lower part of the Northern region. Appropriate combine harvesters for other important corps, namely, sugarcane, corn and soybean, will be rapidly adopted by farmers and custom hire-service contractors.

Agricultural Machinery Industry

Most of the manufacturing firms have developed from mechanic or automotive repair shop (Mongkoltanatus, 1993). The materials used are mainly mild steel stock and gray iron casting. The ball bearings, gears and engines were imported from overseas sources. The machine tools used for manufacture are simple machines such as lathes, shapers, drills, power saws, electric or gas welding and cutting equipment and air compressors. In addition, some of the bigger firms have large hydraulic presses, universal cutting and milling machines. The method of production is essentially a labour intensive technique and also their workers are unskilled labour. Some firms produce more than one kind of farm machine. This helps the firms to spread their product sales throughout the year, because most farm machines are mainly sold in one season. The production of selected farm machineries is shown in **Table 5**. The production has declined since 1997 due to financial crisis. A survey by Nakwatananukul (1998) found that the products of local farm machinery manufacturers did not follow standards and were poor in quality, resulting in unreliable products, and reducing the export potential. The problems in production of farm machineries are described as follows:

The manufacturers usually take loans from commercial banks with high interest rate resulting in high investment cost. The workers in farm machinery manufactures normally are unskilled and uneducated. The material used in production process are mild steel, steel pipes, steel sheet plate and other structure steels which have low quality, as well as no standardization. Furthermore, the machine tools used in production process are simple with low accuracy. The owners lack engineering background to develop their products in terms of design and standardization.

The sale of farm machinery manufacturers depends on various factors, especially the price of machines as well as agriculture productivity. Due to the fabrication of agricultural machineries being simple, easy to copy and not requiring advance manufacturing results in high competition of low quality machine in the market. Moreover, the tariff structure also does not support the local farm machinery manufacturers. For example, import duty on engines alone which are used as power source of local farm machinery is higher than import duty on engine with farm machinery. Therefore, the price of locally made machines is relatively high.

Government Policy on Farm Mechanization

Thailand started its first National Economic and Social Development Plan (NESDP) in 1961. Currently the country is in the Eighth Plan (1997-2001). From the First to Third Plans (1961-76), the goals for increased agricultural production were achieved by cultivated area expansion. During the Fourth to Fifth Plans (1977-86), the agriculture policies were changed to increase agricultural production by development and use of appropriate technology, increased production per unit area, improved cropping system and livestock production.

In the Sixth Plan (1987-91), the national agricultural mechanization policy was included with the general objective of developing the agricultural sector to increase productivity. In accordance with the general objective, the activities involved were expected to achieve the following:

1. Farmers will have machineries for their production at low cost;
2. Agricultural machineries must be good quality in terms of price and maintenance cost; and
3. Agricultural machineries must be appropriate for use under various conditions in the rural areas.

In the Seventh Plan (1992-96), the policy added some specific objectives such as the R&D in agricultural machineries to consider the physical characteristic of farmers, improve production quality and develop new machines suitable for farm condition in Thailand.

In the Eighth Plan (1997-2001), the mechanization policy is not explicitly stated like in the previous two Plans. The general objective of developing the agriculture sector is to improve the capacity to compete in agricultural production by promoting the replacement of human labour by agricultural machineries.

Farm Machineries Used in Rice Production

Farm machineries used in rice production in Thailand vary widely from hand tools, animal-drawn implements to tractors for land preparation, as well as from hand tools to mechanical thresher and combine for harvesting. The commonly used implements and power source in rice production are summarized below:

Land Preparation

Land preparation for rice production in Thailand is the most power-intensive operation.

Draft Animals and Implements

Swamp buffaloes are the primary draft animals for land preparation, while cattle are used primarily for transportation. Swamp buffaloes are used for single beam moldboard plough and traditional comb harrow (**Fig.1**) for land preparation, both in rice production and field crop production. Gifford (1981) reported that the area cultivated per swamp buffalo averages 1.7 ha/year ranging from 1.0 to 2.2 ha/year. The working hours average about 5 hours/day with an average capacity of about 0.1 ha/day. At present, there are only few swamp buffaloes used as power source in rice production, mainly in parts of the Northern and Northeastern regions. For the whole country, there were about 4 million head of swamp buffaloes in 1996 (OAE, 1996). The numbers of working swamp buffaloes are not known.

Fig.1 Soil preparation with swamp buffalo-drawn moldboard plow.

However, it is estimated that approximately 0.65 million heads were used as draft animals in 1996.

Power Tiller and Implements

Most of the power tillers used in the country are locally made. At present, power tillers employ steering clutch with two or more forward speeds and one backward speed (**Fig.2**). In 1997, around 1.8 million units of power tiller were in use. Most of them were used for preparation of seedbed, powering the pumps, threshing paddy and transportation. The commonly used power tiller implements are described below:

The single moldboard plough is used primarily in wetland rice production for primary tillage. A few are used in dryland, the usually for weeding. Most of the single moldboard ploughs are made of steel, having cutting width of about 15-20 cm. The two-disk plough is also used for land preparation. There are two disks of about 40 cm in diameter and one rear wheel. The harrow is used to pulverize the soil further and for land leveling after primary tillage. It looks like spike tooth harrow but it has only one row of teeth with a working width of about 120 cm. Rotary puddler is used for secondary tillage, sometimes in place of a harrow and sometimes in combination with it. The purpose is to push the weeds beneath the puddled surface. It is popularly used in the Central plain region where good land preparation is required for

Fig.2 Power tiller attached with two disk ploughs.

Fig.3 Large tractor attached with disk tiller.

Fig.4 Thai made rice combine harvester.

Fig.5 Rice threshing with axial flow rice thresher.

seeding pre-germinated seeds.

Tractor and Implements

Tractors are widely used for land preparation in the production of rice and field crops. Normally, the tractors are used in upland rice with broadcast seeding practice. Commonly used implements are the standard disk plow (3-4 disk) and the vertical disk plow or disk tiller (**Fig.3**).

Planting

Broadcasting and transplanting are common practices for rice crop establishment. Few seed drills and broadcast machines which are used for field crops are also used for rice but not popular. Rice transplanters exist in Thailand which were developed from the design of the IRRI manually-operated mat-type transplanter and imported power operated transplanters from Japan and Taiwan. These machines were not accepted by the farmers, because the manually operated mat-type ransplanter is too slow and the Japanese and Chinese power operated machines are too expensive. They also require good seedlings and well leveled seed bed preparation.

Harvesting

Harvesting and threshing of rice are the most labour-intensive operations in rice production. In many areas, especially the Central plain region, there is labour shortage during the harvest season due to rapid industrialization and withdrawal of labor from agriculture sector. The harvesting practices and existing machines are explained below:

1. Normally rice is harvested manually in Thailand. In the southern peninsula the harvesting is done by cutting the rice panicle from the stalk in a single hand operation using a special hand held blade. The other hand is used to hold and assemble the heads already cut. The estimated rate of operation is around 0.03 ha/man-day. In all other regions harvesting is done by using a sickle. The average harvesting rate is around 0.08 ha/man-day. Some farmers use a long pole to push all the crop down in one direction about 10 days before harvest to facilitate cutting and reduce tangling when the rice plants are lodged.
2. The first local combine harvester in Thailand was developed in 1987 by modifying the most widely used axial flow thresher with the transmission system of a crawler tractor. All locally manufactured combines at present are copies of the first manufacturer model. It is popularly used in all regions of Thailand (**Fig.4**). Kalsirisilp (1993) stated that the farmers were satisfied with the performance of machine but the contractors were not satisfied and wanted improvements in the machine and better availability of the spare parts. The average field capacity was 0.4 ha/hr and average total grain loss was 4.8% of grain yield.

Rice Threshing

The axial flow threshers are the most popular type (**Fig.5**). These vary in size with a capacity of about 1-6 tons/hour and 4-8 feet long cylinder, powered by 10-130 hp diesel engine. Most threshers have high threshing efficiency of more than 99%, cleaning efficiency of more than 97%, and total losses and broken seed percentage of less than 1%. These paddy threshers are mainly used for contract work and have been modified to be able to handle other crops such as soybean, sorghum, mungbean and sunflower.

Rice Processing

Drying and Storing

The major rice crop is harvested in the dry season, from November to February. It is harvested by human labour using sickle and is left in the fields for a few days to reduce the grain moisture by sun drying. After threshing it is stored or sold. This rice is of superior eating quality and fetches higher price than rice from the second crop. The second rice crop is grown in irrigated areas with high yielding rice varieties. Rice harvesting is in the rainy season, from June to the end of August. Grain is threshed as soon as possible after harvesting. The moisture content of grain varies from 20-26%, which cannot be kept for long period. The grain requires drying immediately, because the high grain moisture leads to the degrading of paddy quality by yellowing or developing mold, (KMIT Thonburi, 1984). Farmers have to sell their rice at low price after threshing. Drying is done by the middlemen and rice millers.

To raise the selling price and improve rice quality, the Government set up two main projects for the use of mechanical dryers in 1993. The objective of the first project (2 years) was to extend loans with low interest rate to the rice millers in order to purchase the LSU type dryers (120 tons/day) with a total budget of 240 million Baht. The objective of the second project (4 years) was to extend loans with a total budget of 35 million Baht for 20 units of 100 tons/day LSU type dryers to the Government Cooperative Millers and 80 units of 20 tons/day small scale dryers, which was designed and developed by the AED, for groups of farmers at the village level.

There are three main purposes for paddy storage: family consumption, sale and seed for planting the next crop. Paddy is generally stored on the farm in barns. Storage facilities may be permanent buildings constructed from wood with the floor elevated above the ground level to avoid flooding. Paddy is loaded and unloaded via the doors. Semi-permanent barns are made of bamboo-matting walls covered with a mixture of soil and dung of cattle and swamp buffalo There are roofs for protection from the sun and rain. In both barns, there is no ventilation during storage. It was found that some farmers do not store paddy due to either lack of storage facilities or a need to sell paddy straight away for financial reasons. The storage period of paddy depends on its purpose. Those who grow rice for sale store for a few months. For consumption and planting, paddy storage may be for one year or even longer. The main problems encountered during storage include the invasion of birds, insects and rodents, the yellowing of grain kernels.

Rice Milling

Most of the rice milling machineries use locally manufactured, millers based on long research and development process which could be traced back to ancient times. There are many local manufacturers who have successfully developed and produced high quality milling machineries. The equipment produced were very efficient, economical and causing minimal losses from processing. The average size of rice mills in Thailand ranges from 50 to 100 tons/day (**Fig.6**). These are situated mainly in the major rice producing areas or provinces. Most are to be found in the Central plains. These mills are exclusively powered by steam engines utilizing husk for fuel. In the remote villages, small milling machines are also powered by diesel engines of 9-12 hp. They have an average milling capacity of 3 tons/day. The efficiency is quite low. The big mills usually yield 39% head rice, 26% broken rice, 11% bran and 24% husk (Buansuwan, 1990). Generally, the essential equipment found in most rice mills in Thailand include the intake hopper, abrasive huller, abrasive whitener, blower and grading sieves. The size and number of these equipment vary from one mill to another, depending on the size and capacity of the particular mill. Approximately 97% of the paddy produced annually is milled into white rice. Head rice is used for human consumption, while the brokens are either mixed with animal feeds or further processed. The other 3% of the paddy is parboiled with most of the produce exported to Middle East countries.

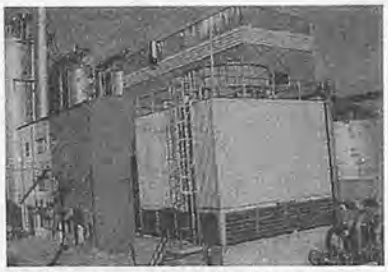

Fig.6 A large rice mill with a capacity of more than 100 tones of paddy per day, producing more than 20 tones of rice husk per day. It has a 2.5 MW cogeneration plant which utilizes rice husk as a fuel. The plant was commissioned in March 1997.

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(Continued on page 30)

Working Stability of Small Single-track Tiller

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Abstract

The small single-track tiller differs fully from the two-wheeled power tiller in having metal single-track and an alternate front plow. The single-track produced traction to push the alternate plow diving, cutting, rototilling and turning soil. The field tillage trail and mechanical analysis were carried out to study the working stability about balance, straight tilling and tilling depth, and the track wear. The results show that the technical probability of the tiller should be discussed further.

Introduction

In the hilly rural areas of Southwestern China, because of the narrow roads and small fields, the fields are tilled traditionally by manual labor or farm animals for many years. The rate of power farming using farm machineries is not more than 5%. With the deepening reforms and opening, rural labor flows to urban districts.So that less rural force and greater family income bring about the imperative requirement of the small tillers which are light in weight, cheap, and easy to move across fields.

Yao Ruo-song who is a farmer-inventor in Sichuan Province designed a new kind of cultivator—the small single-track tiller early in the 1990s. The machine was improved by the Institute of Agricultural Machinery and has been manufactured on a small scale and spread to Guongdong Province and- Chongqing City. However, the field trail shows that the quality of cultivation is unstable, the design and manufacture of the machine should be improved further, and its technical probability has been doubted to some degree.

Acknowledgement: Heartfelt thanks are due to the Senior Engineer of Chinese Academy of Agric. Mechanization Sciences, Wang Wanjun, for modifying this paper.

Structure and Principle

The tiller (model 1CZ-3) mainly consists of an engine, a speed reducer, an alternate plow, single-track, chain gearing and handle (**Fig.1**). The structure parameters are shown in **Table 1**.

When working (**Fig.2**), the engine drives the track moving. The single-track produces traction to push the alternate plow diving, cutting, rototilling and turning the soil. The track goes in the furrow and the alternate plow can be turned by the steering lever. The machine has forward and backward two speeds.

Mechanical Analysis

Vertical Stability

When the tiller is working, a horizontal forces on the unit include a horizontal component (Rxy) of soil resistance on the moldboard, the push (Px) produced by the track cut-

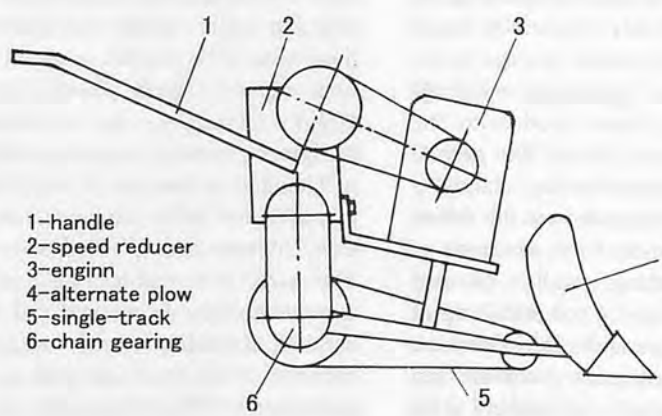

Fig.1 Structrue of single-track tiller.

Table 1. Main Structure Parameters of Single-track Tiller

Engine power (kw)	2.2
Mass of structure (kg)	104
Ground contact length of track (mm)	550
Width of track (mm)	80
Thickness of track shoe (mm)	26
Length×width×highness of tiller (mm×mm×mm)	1850 × 676 × 880

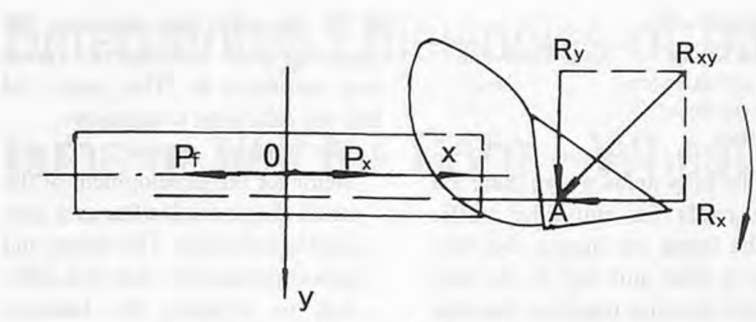

Fig.2 Analysis of horizontal forces.

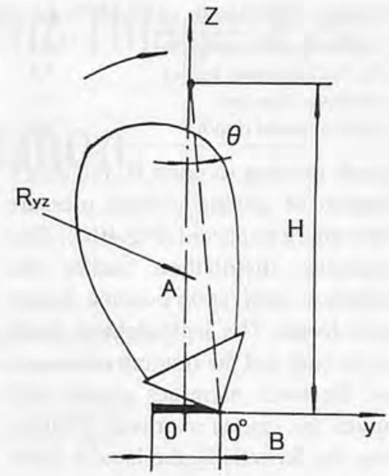

Fig.3 Vertical section of working plow.

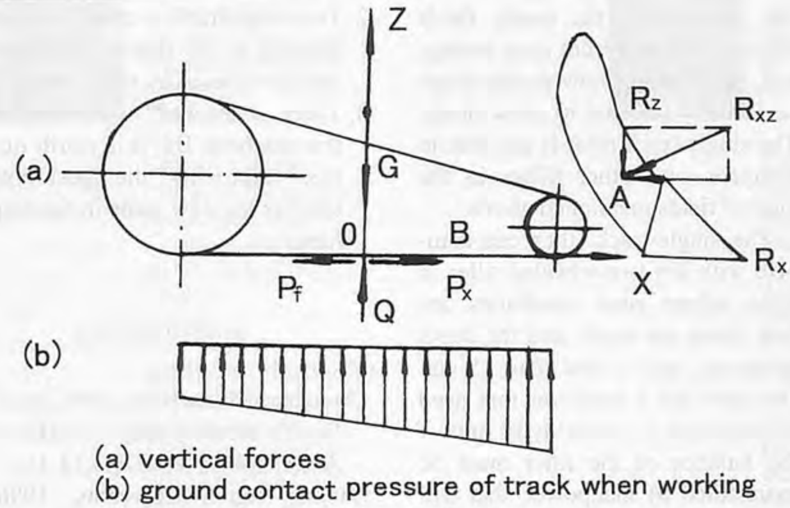

Fig.4 Analysis of vertical forces.

ting the soil, the rolling resistance of the track (P_f) and the horizontal component (T_y) of manpower T on the handle. The following is the mechanical balance formula:

P_x-R_x-P_f = 0

R_y-T_y = 0

-R_yX_A-R_xY_A+T_yX_T = 0 (1)

where

X_T = horizontal distance from action point of Ty to coordinate origin.

R_yX_A and R_xY_A are the turning moments toward the untilled soil; the reversal moment T_yX_T must be provided by the operator through the handle to control the straight stability, and keep machine straight when in motion. To reduce the power, the action line of Rx should coincide with the centre line of the track: $R_xY_A = 0$, $T_yX_T = R_yX_A$.

Balance Stability

As shown in **Fig.3**, when tilling the soil, the track moves in the furrow. Because the width of track is less than the width of furrow (only 80mm), uneven furrow pan and the action of cross component of soil resistance brings about the unit swinging (mainly tending into the untilled soil).

The maximum inclination angle (θ_{max}) of gravity centre of the machine is:

θ_{max} = arctg(B/2H)

where:

B =width of track,80 mm

H =distance of gravity centre from ground

= 400-500 mm.

The less B is and the higher H is, the easier the inclination of the unit becomes and the less allowable θ is. When the plumb line of gravity centre falls over the width of the track, the machine falls over.Taking O' as centre, stability moment equation is set up:

GB/2-R_yZ_A+T_yZ_T=0 (2)

Where

Z_T=vertical distance from O' to action point of Ty on handle

When the line of gravity centre coincides with point O', GB/2=0, the handle balance moment reaches maximum $T_yZ_T = R_yZ_A$; the maximum balance force $T_{ymax} = R_y(Z_A/Z_T)$.

Depth Stability

When working (**Fig.4**), the vertical forces on the unit include the gravity of unit (G), the reacting force of soil (Q), push force(P_x), the rolling resistance of track (P_f) and the vertical component (R_{xz}) of soil resistance on the moldboard. When the tiller is in idle motion, R_{xz} = 0, the unit is in balance, i.e.,

G-Q= 0, P_x-P_f= 0;

the ground contact pressure of the track is even distribution.

When tilling, the mechanic balance formula follows:

P_x-P_f-R_x = 0

Q_B-G-R_Z-T_Z = 0

Q_BX_B+R_xZ_A-R_ZX_A+T_ZX_T=0 (3)

Where

T_Z= vertical component of manpower T on handle.

X_T= horizontal distance from the action point of Tz to point O.

Q_B= reacting force moving to point B.

The vertical component (Rz) of Rxz must be balanced by Q, bringing about the pressure centre of

Table 2. Test Results of Single-Track Tiller (sandy loam soil)

Depth of cultivation (cm)	10-18	Productivity (ha/h)	0.033-0.053
Fuel comsuption (kg/ha)	7.5	Width of cultivation (cm)	18-25
Radius of turn (m)	1-2	Miss plowing areas (%)	1-4
forward speed (km/h)	3.7	returned slices	5

track moving to point B, the distribution of ground contact pressure becoming trapezoid (**Fig.4(b)**). This pressure distribution makes the depth of cultivation become deeper and deeper. The depth stability tends to be bad, and the running resistance of the track increases greatly and gives the engine overload. Following the formula(3),the handle force Tz must be big enough to control tilling depth and keeping the depth stability.

Testing and Results

The two tillers of model 1CZ-3 were tested in the paddy field with a moisture content of 20%-30% and the unit draft of less than 0.4kg/cm^2. The results are shown in **Table 2.**

Discussion and Conclusions

In the hilly areas where there are better roads for auto-tiller traffic and the farms are bigger, the two-wheeled tiller unit will be the first selected plowing machine, because it has plowing, rototilling and transporting 3 functions, and good working property. In the paddy fields with more than 15 cm deep spongy soil, the double-screw paddy tillers are usually selected to plow fields. The single-track tiller is not able to compete with other tillers in the kind of fields mentioned above.

The single-track tiller can compete with the two-wheeled tiller in areas where road conditions are bad, farms are small, and the depth of spongy soil is less than 15 cm. But there are 2 problems that need to be solved: (1) stability of unit: if the balance of the tiller must be maintained by manpower, that will be "liberate the swamp buffalo and tired men"; (2) the wear of track reduces greatly the working reliability of the unit and increases the operating cost and time of repair and maintenance. The study led into the following conclusions:

1. The working stability is a key factor for the development of the small single-track tiller as a new kind of cultivator. The theory and experiments show that it is difficult to improve the balance, straight tilling and tilling depth of the machine.
2. The metal track is unsuitable for moving in the paddy fields and can be replaced by rubber track.
3. There is the risk of developing this machine. But it is worth further improving the push-type tiller as the new trails in farming history.

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Determining Efficiencies of Different Tillage Systems in Vetch - Corn - Wheat Rotation

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Abstract

In Middle Anatolia, the periods necessary for tillage in the applied crop rotation for irrigated farming are relatively very short. Particularly, in systems yielding to three crops within each two years such as vetch-silage corn-wheat rotation, owing to climatological conditions these periods become more significant. By means of the tillage and seedbed preparation systems applied in this study, a solution on this issue was sought. In the first two years of the study, data concerning tillage and related management respects were assessed as well as yield tests were conducted. In the ensuing two-year yield tests will be continued. Concealing the further effects of yield test results, the cultivation of wheat or vetch stubble with one pass of rotary tiller was found sufficient. However, for corn stubble, deep plowing should be fulfilled previously to turn furrow slice and bury the stubble. Afterwards, seedbed can be prepared either with conventional system or rotary tiller.

Introduction

The increment of the irrigated area in Central Anatolia encourages crop rotation systems instead of fallowing in wheat farming. In this situation, the time needed for tillage and seedbed preparation is inevitably shortened.

Naturally, the tillage period is dependent upon the variety of the rotated crop and climatological conditions of the region. In this rather complex situation, determination of the appropriate tillage system brings about serious problems. Economical efficiency and change in the physical conditions of the soil should be considered in determining the tillage system [1].

The basic targets of conventional tillage are to form a suitable structure in upper soil layer, to provide continuous permeability in subsoil, to control weeds mechanically and to bury and mix up stubble and organic matters into soil. Currently, in addition to these, issues about economic and ecological aspects let new concerns such as sustaining soil fertility, insuring the crop yield and quality, diminishing the inputs and alleviating soil compaction to be dominant [2].

In the last few years, the use of reduced (minimum) tillage systems tended to increase as an alternative of conventional tillage. In these systems consisting of all tillage practices, less intensive than conventional tillage, the seedbed preparation is completed generally in one pass. The improvement of minimum tillage systems geared acceleration to the construction of machines reducing the intensive field traffic, minimizing power losses and more utilization of tractor power. Important studies have been carried out on rotovators and rotary tillers leading to the improvement of their contribution to tillage[3,4,5,6].

In a soil continuously cultivated with reduced or no-till systems, a hard pan restricting root growth can be formed as well as mechanical strength can be increased [1]. Hence, these problems can be alleviated by a complementary deep tillage and controlled traffic [7].

The impact of minimum till on crop yield should not be so negative as to eliminate the profits obtained in other respects. The previous studies on this issue reflected significant differences. Some studies affirm the significant influence of tillage system on crop yield of which moldboard plowing had the greatest yield. [8]. On the other hand, some studies report the insignificant effect of reduced tillage systems on crop yield [9,10,11], whereas some indicate significant increment in yield [12,13].

Considering the fuel and time consumption for seedbed preparation, reduced till systems had the most successful results. Studies reported significant superiority of these systems in economical respects [10,11,14].

In this study carried out in Middle Anatolia conditions, tillage systems that can be used in vetch-corn-wheat rotation were examined concerning the machinery management characteristics. The effects of tillage on soil properties were not profoundly inspected. However, the variation in crop yield due to tillage system is under investigation. The data for mechanization were collected in 1996 and 1997. The yield tests will last until the summer of 2000.

Materials and Method

Materials

The research was conducted at the research farm of the Ankara University, approximately 40 km south of Ankara. The altitude of the research field was 1050 m and the size of the complete experimental area was 500 × 150 m. The length of the plots was 100 m each. The site was a typical clay of Middle Anatolia with an increment of 0...1%.

Some specifications of the tractor and field equipment used in the experiments are given in **Tables 1** and **2** For an accurate comparison of the results, all field operations utilized by a new 70 HP Fiat 70-56 tractor.

A volumetric fuel meter of 0.1 *l* sensitivity were used to determine the fuel consumption. Since the engine speed was calculated from P.T.O. speed, an electrical speed meter was used to measure P.T.O. speed. A hand chronometer was used during the calculation of fuel consumption, P.T.O speed, working speed and idle times.

The assessment of working depth utilized a special wooden depth compass. Samples taken from the prepared seedbeds were subjected to sieve analysis with square hole sieves.

At the first stage of the rotation, the Hungarian vetch variety was drilled in mid-October 1996 after seedbed preparation. The Arifiye corn variety was rotated in mid-June 1997 immediately after forage harvesting and subsequent tillage operations. After harvesting the silage corn in mid-October 1997, Bezostaja-1 wheat variety was rotated at the beginning of November 1997. Drilling of the seeds were made on time at the research farm. All other applications after drilling such as irrigation and maintenance were complied with the research farm's own procedures.

Table 1. Some Specifications of the Test Tractor

Power (DIN - kW)		51.52 (70 HP)
Nominal engine speed (min^{-1})		2500
P.T.O transmission rate (engine / P.T.O)		3.65
Tire sizes (in.)	Front	7.50 - 16 (6 kat)
	Rear	16.9 / 14 - 30 (6 kat)
Gear box		8 forward / 3 backward
Total transmission rates in the gears used in experiments and teoretical speeds (m/s) at 1970 (min^{-1}) engine speed		
	slow 2	145,875 / 0,97
	slow 3	99,595 / 1,42
	slow 4	27,664 / 1,83
Total mass (with ballast) (kg)		2750

Table 2. Technical Features of the Field Equipment

Parameter	Plough	Horizontal rotary tilller	Vertical rotary tiller	Disc harrow	Combine harrow
Theoretical width (cm)	96	180	200	240	300
Working depth (max - cm)	25	20	16	16	-
Working speed (m/s)	1.39	1.00	1.00	1.94	1.94
Total mass (kg)	440	770	510	480	660

Method

As the objective of the study was to determine the management data, the size of the plots were selected as the most appropriate ones. Beyond this, the impact of the tillage sys-

Table 3. Seedbed Preparation Systems

Field operation	Sys. No.	Field machinery				
		Plow	Disc harrow	Combine harrow	Horizontal rotarytiller	Vertical rotarytiller
Seedbed preparation for	1	+	+	+		
vetch on wheat stubble and	2-a				+	
for corn on vetch stubble	3-a					+
Seedbed preparation for	1	+	+	+		
wheat on corn stubble	2-b	+			+	
	3-b	+				+

tems on the aggregate size and crop yield was also studied. The values concerning management and aggregate stability were taken once during the seedbed preparation for each crop. The yield tests will be reviewed twice.

Experimental Plan

The seedbed preparation was accomplished for the three different systems as indicated in **Table 3**. In the conventional system (first system), plough + disc harrow + combine harrow were used. For the second and third systems; the seedbed preparation for vetch and corn was performed by only one pass of rotary tiller. However, for wheat seedbed deep tillage was required, hence plowing was performed before rotary tilling.

The experimental area was divided into 12 plots each measuring 100m × 50 m. The tests were done in a randomized complete block design with four replications. During the assessment of management data, each plot was divided into two subplots and the field operations were completed in 100m × 25m field sizes. The measurements were replicated three times for each subplot, thus a total of six replications were provided for each plot and the average values were taken into account.

Determination of Work and Fuel Inputs

Care was taken for the matching of the tractor and implements. The selection of working speeds were made as to the optimal speed of field equipment. Care was also taken for the engine speed to provide the standard P.T.O. speed (540 min^{-1}). Further, the impact of wheel slip on working speed were considered.

The theoretical speed (v), was calculated from rear wheel speed and effective dynamic wheel radius. The assessment of rear wheel speed depended on P.T.O speed and transmission rate. These calculations followed the following equations:

$$n_t = (n_k . i_k) / i_v$$

$$v = (2 . \pi . R . n_t) / 60$$

where; n_t is the rear wheel speed of the tractor (min^{-1}), n_k is the measured P.T.O. speed (min^{-1}), i_k is the transmission rate, i_v is the total transmission rate in the operated gear, v is the theoretical working speed (m/s) and R is the effective dynamic wheel radius (m).

The effective working speed (v_f) was calculated after running for 50 m. Afterwards, the wheel slip (P) was calculated as follows:

$$\% P = \left[(v - v_f) / v\right] . 100$$

where; P is the wheel slip (%) and v_f is the effective working speed (m/s).

The theoretical work rate (S_t) was found after the effective working speed and working width. Considering the time needed to cultivate a 0.25 ha-field, the effective work rate (S_e) was computed. Afterwards field efficiencies (k) of the tillage equipment were calculated as follows:

$$k = S_e / S_t$$

The fuel consumption for the cultivation of a plot was determined directly by the difference of the initial and values of the fuel meter. The fuel consumption per ha (y_t) was computed by dividing the difference by the area of the cultivated field.

Five kg soil samples were spread to a 12-cm depth of prepared seedbeds after the soil was sieved in order to determine the aggregate size distribution. The sieve size ranged from < 5 mm, 5...10 mm, 10...22 mm and > 22 mm.

The evaluation of the results was performed using the analysis of variance and least significant differences where necessary within TARÝST statistical program.

Results

Work and Fuel Inputs

The average measured working width and depth of the field equipment are shown in **Table 4** Since the climatological and soil conditions are notably different among the periods of tillage operations for different crops, the results were evaluated for tillage periods independently.

At the start of the experiments, the field conditions were worse than anticipated owing to fairly high cutting of wheat by a combine harvester. This situation caused problems especially in rotary tilling. Nevertheless, the experiments were continued without taking any precaution and surmounting this problem on grounds that this is one of the most common issues in Turkish agriculture. Harvesting of the subsequent crops were also completed.

The average results of the seedbed preparation for vetch on wheat stubble are shown in **Table 5**.

Immediately after the forage harvesting of vetch, the seedbed prepa-

Table 4. Average Working Width and Depth of Field Equipments

Item	Plow	Disc harrow	Combine harrow	Horizontal rotarytiller	Vertical rotarytiller
Effective width (m)	1.036	2.150	3.050	1.912	1.865
Working depth (cm)	21.21	14.81	-	11.70	11.97

Table 5. The Results of Tillage Operations for Seedbed Preparation of Vetch on Wheat Stubble

Sys. No.	Field work	Speeds (m/s) V	V_f	P (%)	Work rate (ha/h) S_t	S_e	k	Z (h/ha)	y_t (l / ha)
	Plow	1.584	1.342	15.3	0.500	0.392	0.786	2.56	17.24
1	Disc h.	2.030	1.795	11.6	1.389	1.176	0.848	0.85	5.99
	Com. h.	2.011	1.747	13.2	1.919	1.453	0.759	0.69	4.40
2-a	H. rot.	1.044	1.039	1.1	0.715	0.540	0.759	1.85	17.29
3-a	V. rot	1.046	1.019	2.6	0.683	0.533	0.781	1.88	17.88

Table 6. The Results of Tillage Operations for Seedbed Preparation of Corn on Vetch Stubble

Sys. No.	Field work	Speeds (m/s) V	V_f	P (%)	Work rate (ha/h) S_t	S_e	k	Z (h/ha)	y_t (l / ha)
	Plow	1.566	1.375	12.20	0.510	0.411	0.807	2.43	15.11
1	Disc h.	2.044	1.815	11.18	1.405	0.911	0.649	1.10	5.11
	Com. h.	2.060	1.775	13.85	1.948	1.307	0.672	0.77	4.09
2-a	H. rot.	1.023	0.998	2.44	0.687	0.533	0.781	1.86	19.70
3-a	V. rot	0.985	0.958	2.73	0.643	0.503	0.783	1.99	19.53

Table 7. The Results of Tillage Operations for Seedbed Preparation of Corn on Vetch Stubble

Sys. No.	Field work	Speeds (m/s) V	V_f	P (%)	Work rate (ha/h) S_t	S_e	k	Z (h/ha)	y_t (l / ha)
1	Plow	1.509	1.074	28.78	0.400	0.278	0.694	3.58	28.11
2-b	Plow	1.514	1.077	28.91	0.401	0.283	0.706	3.53	28.00
	H. rot.	1.036	0.964	6.95	0.663	0.509	0.768	1.97	17.40
3-b	Plow	1.523	1.098	27.91	0.409	0.284	0.695	3.52	28.10
	V. rot	1.035	0.970	6.26	0.651	0.556	0.855	1.80	13.82

ration of corn was started. However, due to the late regional precipitation the tillage operations were likewise delayed. The results of tillage for corn on vetch stubble are shown in **Table 6**.

The preliminary tests after the corn harvest showed that rotary tilling would not be sufficient for a classical grain drill. Hence, all plots were plowed to remove heavy corn stubble. Afterwards, the seedbed preparation was done by conventional system in plots 1.1...1.4, by horizontal axis rotary tiller in plots 2.1...2.4 and by vertical axis rotary tiller in plots 3.1...3.4. The results of tillage operations on corn stubble for wheat seedbed is shown in **Table 7**. Management data for the second and third operations of conventional tillage were not taken at that time since they indicated a very similar trend in the previous two tillage practices. In case of any requirement, the average of the previous measurements were used.

Discussion

According to the results of all the experiments, the average values of effective work time and fuel consumption per hectare are exhibited in **Figs. 1** and **2** which show that the conventional system had higher effective work time and fuel consumption than the rotary tilling on wheat and vetch stubble.

Statistical analysis indicate insignificants differences between rotary tillers (neglecting vetch stubble) whereas it was significant between the conventional and rotary till systems ($p<0.01$). The maximum effective work time was observed at system 2-b (plow + horizontal rotary harrow) on corn stubble. Nonetheless, statistical analysis showed it was not significant between the systems ($p>0.05$). Also, fuel consumption of the 2-b system was maximum followed by the systems 3-b (plow + vertical rotary harrow) and 1 (conventional). The tillage system had significant impact on fuel consumption ($p<0.01$) and all systems differed significantly from each other in mean comparisons.

Further, the impact of stubble type on the effective time and fuel consumption was examined which showed that wheat and vetch stubble exhibited very close values. In contrast, the values obtained in corn stubble was high yielding to a sig-

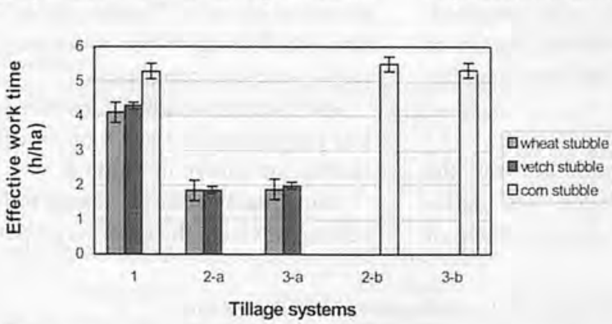

Fig.1 Effective work time per hectare in each tillage system and stubble conditions (Error bars indicate $LSD_{0.5}$= 0.29, 0.1 and 0.22 respectively for wheat, vetch and corn stubble conditions).

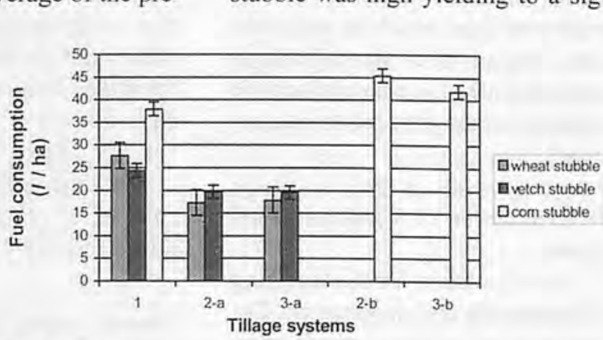

Fig.2 Fuel consumption per hectare in each tillage system and stubble conditions (Error bars indicate $LSD_{0.5}$= 2.86, 1.5 and 1.53, respectively, for wheat, vetch and corn stubble conditions).

Table 8. Particle Size Distribution of the Experimental Plots (Unit:mm)

Stubble type	System no	Particle size distribution (%)*				$LSD_{0.5}$
		< 5	5...10	10...22	> 22	
	1	67.22 b	14.37 a	12.34 a	6.07 a	
Wheat	2-a	71.20 a	14.38 a	10.19 a	4.23 a	2.91
	3-a	73.17 a	13.66 a	9.93 a	3.24 a	
	1	62.15 c	14.01 a	12.48 a	11.36 a	
Vetch	2-a	69.27 b	13.12 a	11.96 a	5.65 b	3.56
	3-a	73.40 a	12.36 a	9.29 a	4.95 b	
	1	44.26 b	11.95 a	14.06 a	29.73 a	
Corn	2-b	51.63 a	13.89 a	13.14 a	21.34 b	5.79
	3-b	51.77 a	12.23 a	13.81 a	22.19 b	

* Numbers in a column within a stubble range followed by the same letter are not significantly different at 0.05 confidence level.

nificant difference from the other stubble conditions ($p<0.01$).

The statistical evaluation of the particle size distribution of the cultivated plots is shown in **Table 8**.

The rate of particles below 5 mm is the lowest in the conventional system on all stubble conditions differing from other tillage systems ($p<0.01$). The tillage systems do not differ from each other in the 5...22 mm particle size. Concerning the particles greater than 22 mm, no significance between the systems was recorded on wheat stubble. However, the analysis of variance on vetch and corn stubbles indicate a significant effect on tillage system on this particle size range ($p<0.01$) which accounted for the significant difference of conventional system from the other two systems as to mean comparisons.

Conclusions

Pending the results of the yield tests the following conclusions can already be drawn:

1. The collected data about fuel consumption, work rate...etc. proved adequate to the requirements in this study.
2. Rotary tilling in one pass is appropriate regarding work rate and fuel consumption. In using the rotary tiller as primary tillage, the working depth remained at 10 to 12 cm instead of the expected 16 cm.
3. The impact of stubble conditions and soil compaction is excessive for the primary till using the rotary tiller. Otherwise, such seedbed preparations cannot be successful.
4. Since rotary tillers use from both drawbar power and P.T.O. power, the wheel slip values was found fairly low.
5. In conventional systems, the percentage of particle size ≥ 5 mm was lower and <22 mm was higher conflicting with the requirements of other experiments [15].
6. One pass rotary tilling is suggested for the tillage operations performed on vetch and wheat stubble. On the other hand, on corn plant one plowing is necessary to remove corn stubble. Afterwards, the seedbed can be prepared either by conventional or rotary tilling.

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(Continued on page 40)

Field Performance of Bullock-Drawn Puddlers

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Abstract

Puddling is an important field operation for transplanting paddy. About 40 million ha area in the country are planted to paddy mostly by transplanting method. The puddling operation facilitates the transplanting of paddy, creates favourable plants growth, mixes fertilizer thoroughly and suppress the weeds. It is generally done by bullocks using indigenous plough at the level of small and marginal farmers. It is required to be operated several times to get the desired quality of puddling. Moreover, weeds are not completely buried even after many operations of indigenous plough. Hence, the existing six different types of implements were used for puddling operation in the actual field and their comparative performance were evaluated. The study reveled that the use of rectangular bladed puddler of blade size 225 × 140 × 3 mm with a provision for operator seat arrangement.

Introduction

Rice is an important staple food in India. It is grown on an area of about 40 million hectares which amount for almost 30 % of the total rice area in the world. However, the average yield of rice in the country is barely 50 % of the average yield of 2.82 t/ha. This may be due to poor management and cultivation practices of the paddy crops in the country. About 30 % of total planted to rice had direct sowing as method of planting. The direct sown paddy gives about 20% less yield than the transplanted paddy but less expense. Some farmers grow paddy by transplanting method to get a higher yield. Puddling is an important field operation carried out for transplanting paddy as it facilitates transplanting easier, creates favourable physical and bacterial condition for plants growth, mixes the fertilizer thoroughly and suppress weeds. Puddling is generally done by bullocks using indigenous plough. It is required to be operated several times to get the desired quality of puddling. Moreover, weeds are not completely buried even after many operations of the indigenous plough. Various designs of bullock- drawn puddlers are available in the market but not popular among the farmers. At the same time the comparative performance of the puddlers is also not known for different soil conditions. The present study evaluates the working performance of these puddlers available in the Faculty of Agricultural Engineering, R.A.U., Pusa. The economics of their use was also studied out for the prevailing local conditions in Bihar.

The comparative performances of puddling implements were also studied by many research workers. Sinha (1964) conducted an experiment using indigenous plough, mehur plough, rotary type rectangular bladed puddler, modified improved puddler and the voltas puddler. There is no significant difference in grain yield of paddy obtained by using different puddling implements.

Bandyopadhya et al. (1966) studied the effect of different methods of puddling using country plough, M. B. plough, disc harrow, power tiller rotavator and their different combinations for two to five times. He observed that the treatment T_2, ploughing followed by running a puddler i.e., total three operations appeared to be optimal as inferred from data on moisture holding capacity and pore space.

Reddy and Rao (1971) compared the performance of APAU puddler, Voltas puddler and Swastic puddler. They reported that the APAU 750 mm puddler was superior to Voltas and Swastic puddler. It reduces time and cost of puddling and increases grain yield.

Tiwari and Singh (1984) studied the effect of blade angle and width of tractor operated rotary puddler on puddling quality. Four puddlers with blade angles of 0^0, 15^0, 30^0 and 45^0 blade angle, respectively. Shaft direction were fabricated and the blades of 50, 75 and 100 mm width were used on each puddler. Two and three puddling operation were performed with all puddlers. Puddling quality was adjudged on the basis of puddling index, bulk density, percolation loss and hydraulic conductivity. It was concluded that the blade angle of 30^0 and blade width of 75 mm is best for puddling.

Jain et al. (1991) conducted a comparative field performance evaluation of different bullock drawn puddling equipment, i.e., rotary blade puddler, disc harrow and harrow cum-puddler in comparison with indigenous plough. The performance of the rotary blade puddler was found to be superior to other implements. It was very effective in reducing percolation loss as it provides good puddle with puddling index of 49.10 % to 57.02 % in clay loam soil. The average depth of puddling was 110-150 mm under different condition. They also found higher yields in the case of rotary blade puddler when operated twice.

Thus, it is evident from the foregoing literature that the rotary blade puddler gives better quality puddling than other implements. The size and shape of these puddlers vary to a great extent.

Materials and Methods

The experiment was carried out at the research farm of R.A.U. Pusa. Six different types of bullock-drawn puddlers were selected for performance evaluation. The detail specifications of the puddlers are given in **Table 1** and a view of the same has been shown in **Figs. 1** and **2**. The draft measurement test was conducted with the help of hydraulic dynamometer. A cone penetrometer was used to measure the penetration resistance (cone index) and depth of puddling. The field capacity of each implement was calculated based upon their actual coverage in the field. Thus, the various parameters like draft of implement, puddling index, cone index, bulk density, hydraulic conductivity, puddling time for a particular area and effective working width and depth of an implement were recorded. Based upon these parameters the specific energy was calculated. The puddling index was also evaluated by soil dispersion method as given below:

$$Pd.I. = \frac{Volume\ of\ sattled\ soil}{Total\ volume\ of\ sample} \times 100$$

The actual decision was based upon the performance index, which was calculated as follows:

Performance Index =

$$\frac{\left[1-\frac{\partial D}{D_P}\right] E_f.\eta_f \left[1-\frac{1}{Pd.I.}\right]\left[1-\frac{\partial B}{B_E}\right]\left[1-\frac{\partial P}{P_D}\right]\frac{1}{K}}{Specific\ Energy}$$

Where,

∂D = Standard deviation for depth, mm

$$= \sqrt{\frac{(D_O \approx D_P)^2}{n-1}}$$

Do = observed depth of working, mm

$\approx$ = Symbol indicates difference of

Dp = desired depth of working, mm

n = no. of observations

E_f = effective field capacity, ha/h

η_f = field efficiency in fraction

$Pd.I.$ = puddling index

∂B = standard deviation of bulk density

$$= \sqrt{\frac{(B_O \approx B_E)^2}{n-1}}$$

Bo = observed bulk density, kg/m^3

B_E = expected bulk density, kg/m^3

∂P = standard deviation for cone penetrometer reading, MPa

$$= \sqrt{\frac{(P_O \approx P_D)^2}{n-1}}$$

P_O = observed cone index, MPa

P_D = desired cone index, MPa

K = hydraulic conductivity, mm/h

Specific energy was calculated based upon the requirement of pulling power and volume of soil tilled per unit time. Pulling power was measured by multiplying the draft of implement to the working speed of bullocks. The volume of soil tilled per unit time was calculated by multiplying the working width of an implement to the working depth and working speed. Thus, the following relationship was used to measure the specific energy requirement of each puddling implement:

Specific energy =

$$\frac{Pull\ Power,\ N.m/s}{Volume\ of\ soil\ tilted\ per\ unit\ time,\ m^3/s}\quad J/m^3$$

The actual selection of implement was based upon their working performance and their economics

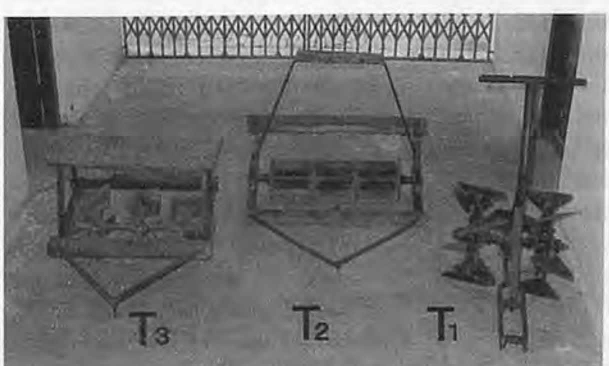

Fig.1 A view of puddling implements(T_1, T_2 & T_3).

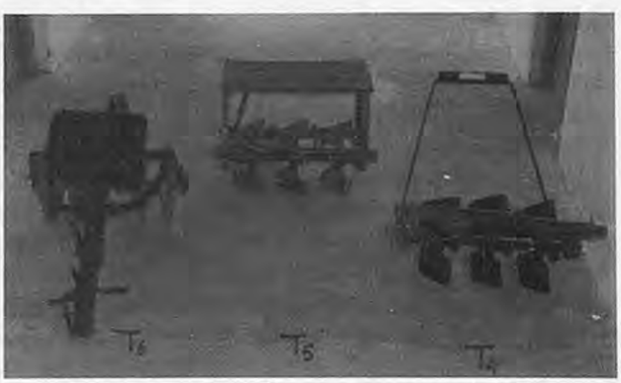

Fig.2 A view of puddling implements(T_4, T_5 & T_6).

of use. The cost of use of animal power was evaluated by adopting the standard procedure for cost analysis. Thus, the selection was made giving equal weights to the performance index and cost of their use.

$$Selection\ Index = \frac{Performance\ Index}{Cost\ of\ use,\ Rs/ha}$$

Test Performance

The test was conducted in the field flooded with water. The average value of the draft was recorded through hydraulic dynamometer. The results reveal that the triangular bladed puddler (T_1) a requires a minimum draft of 348.2N. This was followed by treatment T_4 where rectangular bladed puddler was used. The highest draft of 687.9 N was recorded with disc harrow (T_6). This was probably due to its highest working depth actually observed in the actual field.

Looking to the specific energy requirement pattern the straight ribbed puddler (T_2) gave minimum value. The effect of different implements on specific energy requirement was also highly significant (**Table 2**). The minimum value of specific energy requirement with treatment T_2 may be attributed to the fact that the width of puddler was comparatively high, creating minimum time loss for a specific area.

As indicated earlier, the puddling index was recorded by soil dispersion method immediately after operation of the implements. This was considered as a yardstick for measurement of quality of work done. The effect of all the treatments was found to be highly significant on the puddling index. The highest value of puddling index was observed with treatment T_3 where rectangular angle bladed puddler with operator seat with blade size 225 × 140 × 3 mm. This was followed by treatments T_4 and T_5. The treatment T_1 gave a minimum value of puddling index indicating poor churning of soil. The highest value of puddling index with treatment T_3 may be due to the fact that the soil was rotated to a greater period of time due to its angular design and

Table 1. Specification of Bullock-Drawn Puddling Implements

Treatment No.	Name of puddling implements	Specifications					
		Blade angle with the Shaft	No. of blades in each set	No. of blade set per gang	Blade size, mm	Width of implements, mm	Weight of implements, kg
T_1	Triangular bladed puddler	20^0	6	2	225 × 155 × 2	550	36
T_2	Straight rib puddler	0^0	6	3	230 × 55 × 3	720	44
T_3	Rectangular angle bladed puddler with provision of operator seat	45^0	4	3	225 × 140 × 3	620	49
T_4	Rectangular angle bladed puddler	45^0	4	3	215 × 145 × 3	580	34
T_5	Rectangular angle bladed puddler with provision of operator seat	45^0	4	3	205 × 85 × 3	590	45
T_6	Disk harrow	$0\text{-}30^0$ adjustable	2	2	410 disk dia	560	51

Table 2. Performance Parameters of Different Puddling Implements

Treatment No.	Name of puddling implements	Draft (N)	Sp. Energy requirement (kJ/m^3)	Puddling index	Cone index (MPa)	Depth of puddling (mm)	Bulk density (kg/m^2)	Hydraulic conductivity (mm/h)	Effective field capacity (ha/h)	Field efficiency (%)
T_1	Triangular bladed puddler	348.2	7.300	19.74	0.074	86.83	1426	0.6410	0.0997	72.80
T_2	Straight rib puddler	503.5	6.543	26.53	0.064	107.18	1430	0.5580	0.1440	80.00
T_3	Rectangular angle bladed puddler with provision of operator seat	609.2	8.792	32.00	0.063	112.52	1496	0.2200	0.1260	81.29
T_4	Rectangular angle bladed puddler	388.9	6.631	31.33	0.063	103.30	1482	0.5472	0.1200	82.75
T_5	Rectangular angle bladed puddler with provision of operator seat	575.0	8.563	31.15	0.059	114.60	1513	0.2397	0.1150	78.36
T_6	Disk harrow	667.9	9.035	29.31	0.054	132.33	1467	0.3197	0.1060	77.57
F- Value		729.08	483.64	31.37	120.2	391.46	235.8	188.811	372.512	
Std. Error (MN)		3.04	0.4927	0.831	0.001	0.7558	2.280	0.0132	0.6721	
CD at 5%		9.16	0.1544	2.505	0.002	2.277	6.872	0.0399	0.4629	

Table 3. Analysis of Performance Parameters

Treatments	Depth of puddling, mm			Cone Index, MPa			Bulk Density, kg/ m^3			Puddling index %	$1-\frac{1}{Pd.I.}$	Hydraulic Conductivity, mm/h	$\frac{1}{K}$
	Averrage observed values	$\partial D = \sqrt{\frac{(Do \approx Dp)^2}{n-1}}$	D= $1-\frac{\partial D}{Dp}$	Average observed values	$\partial D = \sqrt{\frac{(Po \approx P_D)^2}{n-1}}$	CI= $1-\frac{\partial P}{P_D}$	Average observed values	$\partial B = \sqrt{\frac{(Bo \approx B_E)^2}{n-1}}$	B.D.= $1-\frac{\partial B}{B_E}$				
T_1	86.83	54.64	0.593	0.074	0.0249	0.530	1426	107	0.929	19.74	0.9493	0.641	1.50
T_2	107.18	31.102	0.768	0.064	0.0130	0.754	1430	99.4	0.934	26.53	0.9623	0.558	1.75
T_3	112.52	24.944	0.814	0.0633	0.0119	0.775	1496	24.3	0.984	32.0	0.9687	0.219	4.55
T_4	103.30	35.583	0.734	0.063	0.0115	0.783	1482	39.1	0.974	31.33	0.9680	0.547	1.83
T_5	114.60	22.543	0.832	0.059	0.0076	0.856	1513	5.71	0.996	31.15	0.9678	0.239	4.17
T_6	132.33	2.712	0.979	0.054	0.0014	0.973	1467	57.4	0.962	29.31	0.9650	0.319	3.13

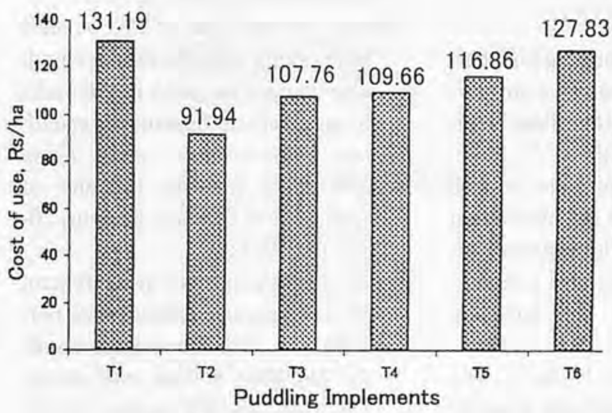

Fig.3 Cost of use puddling implements.

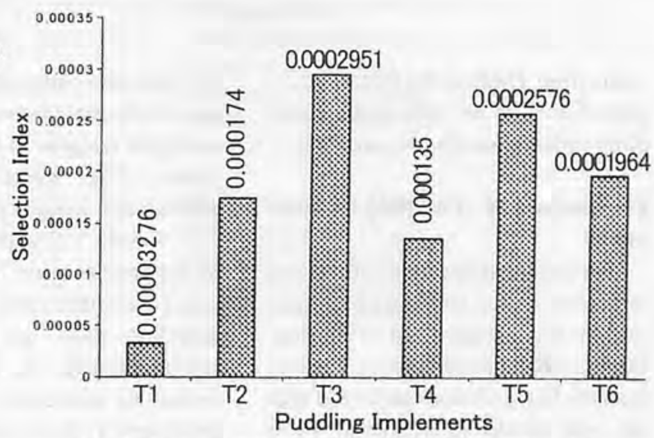

Fig.4 Selection index of different puddling implements.

thus indicating 2.7 % to 62.10 % greater puddling index than other treatments.

The penetration resistance/cone index was measured with the use of cone penetrometer. The quality of puddling was inversely proportional to the cone index recorded just after puddling. Thus, the minimum value of cone index was recorded with treatment T_6 where disk harrow was used and thus indicating its superiority over other treatments in the range of about 8.47 % to 27.51 %. Similarly, the highest depth of puddling was also recorded with disk harrow (T_6). The lowest depth of working was with treatment T_1 which was due to its least weight and wider blade size. The effect was also highly significant.

The bulk density and hydraulic conductivity, as recorded in the actual field, gave a significant effect on the different treatments. Looking to the bulk density, the treatment T_5 gave the highest value showing its superiority. This was followed by treatment T_3 and T_4. The higher value of bulk density with treatment T_5 indicated its better quality of churning of the soil. Although, hydraulic conductivity supported the treatments T_3 followed by treatments T_5 and T_6.

Field Capacities and Field Efficiencies of Puddling Implements

The highest field capacity was observed with treatment T_2 where straight ribs puddler was used. It was followed by treatments T_3 and T_4. The highest value of field capacity with treatment T_2 may be attributed to the fact that the working width of the puddler was relatively high, requiring minimum time to cover a specific area. Looking to the field efficiency of different puddling implement, the treatment T_4 gave the maximum value where rectangular angle bladed puddler was used. The treatment T_1 gave the minimum value of field efficiency due to its lower working width.

Performance Indices of Puddling Implements

Performance index of different puddling implements was calculated on the basis of quality and quantity of work done, and energy requirement of the implements. The quantity of work done was considered as depth of puddling, effective field capacity and field efficiency of different puddling implements. The quality of work done was based upon the cone index, puddling index, hydraulic conductivity and bulk density observed during the experimentation. The performance index of different puddling implements was evaluated as shown in **Tables 3** and **4**. As ob-

Table 4. Performance Index of Different Puddling Implements

Treatments	$P.I. = \frac{D \times C.I. \times B.D.(1\text{-}1/Pd.I) \times 1/K \times h_f \times E_f}{S.E.}$	Performance Index
T_1	$\frac{0.593 \times 0.530 \times 0.929 \times 0.9493 \times 1.56 \times 0.728 \times 0.0997}{7.3}$	4.299×10^{-3}
T_2	$\frac{0.768 \times 0.754 \times 0.934 \times 0.9623 \times 1.752 \times 0.80 \times 0.144}{6.543}$	0.016
T_3	$\frac{0.814 \times 0.775 \times 0.984 \times 0.9687 \times 4.547 \times 0.8129 \times 0.126}{8.792}$	0.0318
T_4	$\frac{0.734 \times 0.783 \times 0.974 \times 0.9680 \times 1.827 \times 0.8275 \times 0.120}{6.631}$	0.0148
T_5	$\frac{0.832 \times 0.856 \times 0.996 \times 0.9678 \times 4.171 \times 0.7836 \times 0.115}{8.563}$	0.0301
T_6	$\frac{0.979 \times 0.973 \times 0.962 \times 0.9650 \times 3.127 \times 0.7757 \times 0.106}{9.035}$	0.0251

vious from **Table 4**, the treatment T_3 gave 5.35% to 86.48% higher puddling index than other treatments.

Economics of Puddling Implements

The cost analysis was carried out to determine the economics of their use in the actual field condition. Details of their cost of use may be seen in **Fig.3**. It was observed that the cost of use of treatment T_2 is lowest among all. This was due to a wider working width of the implement which ultimately resulted to higher field capacity.

Selection of Puddling Implements

The appropriate selection was done by considering the value of performance index and cost of their use. Both the parameters were given equal weights to take final decisions. The treatment T_3, i.e. rectangular bladed puddler of size 225 × 140 × 3 with operator's seat arrangements gave the highest value of Selection Index (S.I.) recommending their use for puddling operations(**Fig. 4**). This was followed by treatments T_5 & T_6. The treatment T_1 gets the least priority. Comparing the values of performance index, the priority order of their selection remains the same as in the case of selection index. Thus the cost of use could not make any impact in the order of their priority of selection.

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(*Continued from page 35*)

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A Comparative Study on the Crop Establishment Technologies for Lowland Paddy in Bangladesh: Transplanting vs. Wet Seeding

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Abstract

Experiments were conducted to identify the advantages and disadvantages of the existing crop establishment techniques for the cultivation of lowland paddy in Bangladesh. The work rate of random seeding by hand was nearly 100 times faster than that of hand transplanting. However, the economic analyses revealed that hand transplanting can earn approximately 30 US dollar net profit per hectare over hand seeding method; and machine transplanting can earn about 27 US dollar per hectare net profit compared to machine seeding method. Machine transplanting can earn 13 US dollar net profit per hectare compared to hand transplanting while machine seeding can earn about 53 US dollar net profit per hectare compared to hand seeding method.

Introduction

Rice is a staple food for half of the world's population, about 90% of which live in Asia. The rice crop may be planted by direct seeding or transplanting. In the beginning, many farmers produced rice by direct seeding with traditional varieties. However, with the introduction of high yielding varieties (HYV), the production practice shifted from direct seeding to transplanting. Some specific studies confirmed that transplanting rice produced 10 to 20% more yield than broadcast rice (Ramiah and Hanumontha, 1936; Bautista, 1938; Ghose et al., 1960 and IRRI, 1970). Devasundrarajah (1971) reported that there are two clear advantages in transplanting the rice seedings: transplanted paddy occupies the field with lesser time compared to direct seeded paddy and it facilitates the control of weeds. Rice transplanting is a highly labour intensive operation which requires about 30% of the labour needed for rice production. According to Islam (1993), about 400-450 man-hr/ha were necessary for hand transplanting in rows, but in the case of random transplanting, the labour requirement was 300-350 man-hr/ha.

Some recent studies show that there is no yield difference between the direct seeding and transplanting practices of rice production provided that the other production factors are applied effectively and identically. The adoption of direct seeded rice culture is gradually increasing in some parts of the rice growing areas in the world in order to minimize production cost (Flin and

Mandac, 1986). Due to rapid industrialization in Thailand and Malaysia, the labour cost has increased substantially and farm labour has become scarce. To reduce the cost of cultivation in some of the irrigated areas, direct seeding is being practiced extensively and it is expected that most farmers in the area will eventually switch to direct seeding (De Datta and Nantasamsaran, 1991).

In Central Luzon, Philippines, where rice has been traditionally grown in transplanted condition, however, the adoption of broadcast seeding is rapid, from less than 2 percent in 1979 to 16 percent in 1982 (Moody Cordova, 1985). Erguisa et al. (1990) reported that farmers who in 1980 were practicing a combination of transplanting and wet seeding had shifted entirely to broadcast seeding by 1986. In Malaysia during the 1987 off season, 99 percent of the planted area in the Muda irrigation scheme was direct seeded (Ho et al., 1990). Even when direct seeding is practised by the rice farmers anywhere in Asia, transplanting is still popular.

This study was undertaken: (a) to identify the advantages and limitations of the existing crop growing techniques for lowland paddy; (b) to determine the field performances of different crop establishment techniques; and (c) to compare the economics of transplanting and wet seeding methods of rice production.

Materials and Methods

A manually operated transplanter and a drum type seeder for lowland paddy were imported from the International Rice Research Institute (IRRI) by the Bangladesh Rice Research Institute (BRRI) in Gazipur in Bangladesh. Both machines were modified in order to adapt them to local conditions. Two experiments viz. (a) experiment I for seedling transplanting; and (b) experiment II for wet seeding were conducted at the silty clay loam soil of the BRRI farm.

Treatments for Experiment I

T_1 = Transplanting by IRRI designed transplanter
T_2 = Transplanting by BRRI modified transplanter
T_3 = Hand transplanting in rows

Treatments for Experiment II

T_1 = Seeding by drum type seeder at the rate of 60 kg/ha
T_2 = Seeding by drum type seeder at the rate of 80 kg/ha
T_3 = Hand broadcasting at the rate of 100 kg/ha

Design of Experiment

Both experiments were conducted under Randomized Complete Block (RCB) design and the treatments were replicated thrice in each block.

Experimental Procedure

Before the field test, the transplanter and drum seeder were tested in the laboratory in order to confirm the workability of all the functional components. Two experiments were conducted in the adjacent fields. The paddy seeds for transplanting and wet seeding experiments were soaked in water in the same day. When the pre-germinated seeds were sown in the nursery to raise seedlings for Experiment I, the seeds from the same lot were sown directly in the field of Experiment II. For machine transplanting, the seedlings were raised in the dapog bed while for hand transplanting they were raised in wet bed. Fourteen to 16 day-old seedlings were used for transplanting experiment. During planting, the field capacities and efficiencies of different crop planting/seeding methods were calculated from the collected data. The crop stands after 20 days of planting were also recorded. Both experiments and treatments within an experiment were managed identically in terms of irrigation, drainage, weeding, fertilizer and insecticide application. Finally they were harvested, threshed, cleaned and dried; and the yields were expressed in mt per hectare at 14% moisture content. The data recorded from the experiments were subjected to analysis of variance and DMRT by using IRRISTAT package. The partial budget analyses were conducted between transplanting and wet seeding practices for both traditional and mechanized system in order to determine the economically viable technology for crop establishment in lowland paddy.

Results and Discussion

Field Performances of Transplanting and Seeding Machines

The effective field capacities of the IRRI-designed transplanter, BRRI modified transplanter and hand transplanting method were 0.0155 ha/hr, 0.0191 ha/hr and 0.0023 ha/hr, respectively (**Table 1**). The results reveal that about 20% working capacity was increased in BRRI modified transplanter compared to IRRI designed transplanter, though the difference was not statistically significant. The transplanting capacities of the machines were almost 7 to 8 times greater than that of the hand transplanting method. The results were statistically significant at 5% level. The average seedling per hill in IRRI, BRRI and hand transplanting methods were 8.10, 6.16 and 4.16, respectively. The number of seedlings per hill in the machine transplanting method was significantly higher than that of hand transplanting. The field efficiencies of IRRI and BRRI transplanters were 76.83 and 78.90 percent, respectively, which were statistically not different. That of hand transplanting method was 91.40 percent and significantly higher at 5% level than

Table 1. Field Performance of Different Transplanting Methods (Unit: ha/hr)

Operation	Transplanting Methods		
	IRRI designed transplanter	BRRI modified transplanter	Hand transplanting
Effective field capacity (ha/hr)	0.0155 a	0.0191 a	0.0023 b
Theoretical field capacity (ha/hr)	0.0200 a	0.0242 a	0.0025 b
Field efficiency (%)	76.83 b	78.90 b	91.40 a
Planting distance, hill to hill (cm)	16.16 a	15.16 a	15.10 a
Standing angle (deg)	65.83 b	66.26 b	72.00 a
Seedling per hill	8.10 a	6.16 b	4.16 b
Missing hill at planting in 50 m^2 (%)	3.81 a	3.66 a	0.00 b
Missing hill after 15 days in 50 m^2 (%)	4.60 a	4.76 a	0.25 b

In a row, means followed by a common letter are not significantly different at the 5% level by DMRT.

Test conditions:

Soil type	:	Silty clay loam	Parameter	:	LSD (5%)
Plot size	:	2.4 m × 20 m	Theoretical FC (LSD 5%)	:	0.00481
Variety	:	BR1	Effective FC (LSD 5%)	:	0.00365
Water depth	:	2-3 cm	Field efficiency (LSD 5%)	:	2.40
Age of seedling	:	16 days	Planting distance	:	2.40
Seedling height	:	9 cm	Standing angle	:	3.12
Seedling density	:	5.78 nos/cm^2	Seedling/hill	:	2.68
Plant spacing	:	20 cm × 15 cm	Missing hills at planting	:	74
			Missing hills after 15 days of planting	:	0.47

Table 2. Field Performance of Drum Seeder Compared to Hand Broadcasting Method

Operations	Different methods of seeding		
	BRRI drum seeder (60 kg/ha)	BRRI drum seeder (80 kg/ha)	Hand broadcasting (100 kg/ha)
Effective field capacity (ha/hr)	0.153 b	0.117 b	0.223 a
Theoretical field capacity (ha/hr)	0.207 ab	0.150 b	0.257 a
Field efficiency (%)	73.91 b	77.777 ab	87.307 a
Plant population (no/m^2)	238.3 c	358.3 b	502.5 a
Average plant spacing (cm)	5.86 a	5.73 b	8.30 a
Average plant height (cm)	23.27 a	22.60 a	23.72 a
Average root length (cm)	4.41 a	5.53 a	5.20 a

In a row, means followed by a common letter are not significantly different at the 5% level by DMRT.

Test conditions:

Soil type	:	Silty clay loam	Theoretical FC	:	0.07149
Plot size	:	4 m × 20 m	Effective FC	:	0.3998
Variety	:	BR1	Field efficiency	:	10.37
Seeder speed	:	16.95 m/min	Plant population	:	63.83
Walking speed	:	40 m/min	Average plant spacing (cm)	:	1.72
Parameters	:	LSD (5%)	Average plant height (cm)	:	2.03
			Average root length (cm)	:	1.6

those of machine transplanting.

The effective field capacities of the BRRI modified drum seeder with seeding rates of 60 kg/ha and 80 kg/ha were 0.15 ha/hr and 0.12 ha/hr, respectively, and were not statistically significant. However, the field capacity of the hand-broadcasting at the rate of 100 kg/ha was 0.22 ha/hr which is significantly higher than drum seeder seeding at both rates (**Table 2**). The field efficiencies of the drum seeder at the rate of 60 kg/ha and 80 kg/ha were 73.91 and 77.77 percent, respectively. That of the hand broadcasting at the rate of 100 kg/ha was 87.30 percent. The result show that the field efficiency of hand broadcasting was significantly higher than those of machine seeding at both seed rates as no time was lost in turning in the case of hand-seeding. The average plant population, 18 days after seeding in the drum seeder plot at the seeding rate of 60 kg/ha and 80 kg/ha were 238.33 and 358.33 m^2, respectively; and that of the hand broadcasting at the rate of 100 kg/ha was 500 m^2 which were significantly different at 5% level (**Table 2**). For the drum seeder plot, the distance between rows was 20 cm, however, the distance between hills along the rows varied with the seeding rate. In drum seeder seeding at the rate of 60 kg/ha and 80 kg/ha, the hill-to-hill distances were 5.86 cm and 5.73 cm which were not statistically different, but at higher seeding rate, the seedling per hill was higher. The job of random wet seeding by manual labour is nearly 90 times faster than hand transplanting of paddy in rows. On the other hand, the job of wet seeding in rows by machine was approximately 8 times faster than machine transplanting in rows.

Economic Performances of Transplanting and Seeding Methods

Hand Transplanting vs. Hand Seeding

The partial budget analysis between manual transplanting and manual seeding shows that if a farmer wants to shift from the existing transplanting practice to the direct seeding practice, there will be a net loss of about 30 US dollar per hectare (**Table 4**). In the existing transplanting practice, the seedlings are being planted in rows. Therefore, the rotary type weeding machines used for weed control costs only 6.84 US dollar per hectare. On the other hand, in the case of the manual seeding, the seeds were broadcast at random. Therefore, mechanical weeding was not possible. In this situation, the farmers are compelled to adopt hand-weeding which costs about 56 US dollar per hectare.

It is worth mentioning that the weed control operations use agrochemicals, but not advisable as it is hazardous to the environment. For direct seeding nearly 10 US dollar/ha extra cost was necessary for additional levelling and land partitioning in order to maintain uniform water level throughout the field which was inevitable for uniform crop stand. Besides, some of 80 US dollar/ha was estimated as a yield-loss penalty in direct seeding method for uneven crop stand. However, a sum of 40 US dollar/ha was estimated as a timely planting benefit in the case of hand seeding because it was nearly 100 times faster than the hand transplanting method.

Machine Transplanting vs. Machine Seeding

The partial budget analysis between machine transplanting and machine seeding shows that there is a net loss of about 27 US dollar/ha if a farmer would shift from transplanting to wet seeding method (**Table 5**). In this analysis, the weeding cost was not considered because the crops were planted in rows and hence, the operation of rotary type weeder was possible for both methods. The fixed and variable costs for both machines were considered in the analysis.

The results in **Table 6** shows that the machine transplanting earned a net benefit of 13 US dollar/ha compared to hand transplanting. On the other hand, the result in **Table 7**

Table 3. Basic Assumptions, Labour Wage Rate and Prices of Goods

Price of seed paddy	:	US$0.23/kg
Price of non-seed paddy	:	US$0.16/kg
Labour wage for machine operation	:	US$1.36/day
Helpers's wage	:	US$1.14/day
Yield loss due to uneven crop stand in the hand seeding field	:	0.5 ton/ha
Yield benefit from timely planting in hand seeding field	:	0.25 ton/ha
Transplanter price	:	US$ 113.64/piece
Drum seeder price	:	US$ 68.18/piece
Rotary weeder price	:	US$ 6.82/piece

Note: Labour wage and prices of goods are based on Dhaka market, Bangladesh in 1998.

Table 4. Partial Budget Analysis Between Hand Transplanting and Hand Seeding in Lowland Rice Cultivation

Added return	(US$/ha)	Added cost	(US$/ha)
(A) Extra Revenue:		(B) Extra Costs	
Yield benefit from timely seeding	39.77	Extra levelling and land partitioning in seeding field	9.12
		Cost of seed	22.70
(C) Saving in Costs:		Cost of labour for seeding	0.92
Cost of seedling production for transplanting method	19.32	Cost of manual weeding	56.82
Labour cost saved for seedling uprooting and transplanting	73.86	(D) Loss in Revenue:	
Cost saved for machine weeding in transplanting method	6.84	Yield loss due to uneven crop stand in hand seeding	79.55
Total	139.79	Total	169.11
Net benefit from hand transplanting over hand seeding (US$/ha)		= Added return - Added cost	
		= (A + C) - (B + D)= 139.79 - 169.11	
		= (-) 29.32	

Table 5. Partial Budget Analysis Between Machine Transplanting and Machine Seeding in Lowland Rice Cultivation

Added return	(US$/ha)	Added cost	(US$/ha)
(A) Extra Revenue:		(B) Extra Costs	
Benefit from drum seeder renting	1.53	Extra levelling and land partitioning in seeding field	9.12
		Cost of drum seeder (FC + VC)	16.14
(C) Saving in Costs:		Cost of seed	13.63
Cost of seedling production (seed)	12.50	Cost of labour	1.71
Cost of seedling production (labour)	7.88		
Cost of wooden frame, plastic sheet, straw etc.	25.74	(D) Loss in Revenue:	
Cost of transplanter (FC + VC)	4.03	Yield loss due to uneven crop stand in machine seeding	79.55
Cost of transplanter operation (operator and helper)	10.80	Revenue loss from transplanter renting	9.10
Yield saved for transplanting missing hills	39.77		
Total	102.25	Total	129.25
Net benefit from machine transplanting over hand seeding (US$/ha)		= Added return - Added cost = (A + C) - (B + D)= 102.25 - 129.25 = (-) 27.00	

Table 6. Partial Budget Analysis Between Machine and Hand Transplanting for Lowland Rice Cultivation

Added return	(US$/ha)	Added cost	(US$/ha)
(A) Extra Revenue:		(B) Extra Costs	
1. Yield benefit from timely planting	11.93	1. Cost of transplanter (FC + VC)	14.83
2. Benefit from machine renting	9.10	2. Cost of wooden frame (FC + VC)	18.92
		3. Cost of seedling production	27.21
(C) Saving in Costs:		(D) Loss in Revenue:	
1. Labour saved in seedling uprooting and hand transplanting	73.86	1. Yield loss for missing hills	39.77
2. Cost saved in wet bed seedling production	19.32		
Total	114.21	Total	100.73
Net benefit from machine transplanting over hand seeding (US$/ha)		= Added return - Added cost = (A + C) - (B + D)= 114.21 - 100.73 = 13.48	

shows that the machine seeding can earn a net benefit of approximately 53 US dollar/ha. Therefore, shifting from the traditional to the mechanized practices for transplanting and seeding operations was economical and profitable at the minimum use levels of 1.8 ha and 0.3 ha, respectively.

Conclusions

1. For direct seeding, approximately 10 US dollar/ha additional cost was necessary for land levelling compared to the transplanting method.
2. In the field of wet seeding by hand, the operation of rotary weeder was not possible due to lack of specific rows in the plants.
3. The work rate of random seeding by hand was approximately 100 times faster than that of hand transplanting.
4. In overall consideration, hand transplanting is still economical on the part of the farmers compared to the hand seeding method.
5. For both transplanting and seeding operations, a shift from the traditional to the mechanised practice was economical and profitable.

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Table 7. Partial Budget Analysis of Seeding and Weeding Costs Between Machine and Hand System

Added return	(US$/ha)	Added cost	(US$/ha)
(A) Extra Revenue:		(B) Extra Costs	
1. Benefit from drum seeder renting	1.53	1. Cost of drum seeder (FC + VC)	16.14
		2. Cost of rotary weeder (FC + VC)	12.24
(C) Saving in Costs:		(D) Loss in Revenue:	
1. Labour saved from hand seeding labour	0.64		
2. Cost saved from seed in hand seeding	22.73		
3. Cost saved from hand weeding	56.82		
Total	81.72	Total	28.38
Net benefit from machine seeding over hand seeding (US$/ha)		= Added return - Added cost = (A + C) - (B + D)= 81.72 -28.38 = 53.34	

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(*Continued from page 56*)

Development and Performance of 2-unit Diggers for Cotton Stalks Uprooting and Groundnut Lifting

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Relating Corn Yield to Water Use During the Dry-season in Port Harcourt Area, Nigeria

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Abstract

One of the major problems facing farmers in the humid tropics of Nigeria, and particularly Port Harcourt Area, is the lack of proper knowledge on the relationship between crop yield and water use under varying climatic conditions. This has resulted in the fact that farmers have only one cropping season, whereas with good understanding it is possible to have more through irrigation and proper crop management. This research, carried out within 2 years, aims at establishing, for the first time, a functional relationship between crop yield and amount of water use in Port Harcourt area, Nigeria. Corn (zea maize) was the study crop and water use at various levels of irrigation between permanent wilting point and field capacity of the soil was investigated. Corn was both planted in field plots and non-weighing water table lysimeters. The latter were used as controls. Results showed that yield was not proportional to the level of crop water use. Maximum corn dry matter yield ranged between 18.28 and 19.84t/ha, while grain yield is between 8.20 and 8.63t/ha. The optimum seasonal ET was about 470-490mm. A threshold ET value of 180 – 200mm was obtained for both dry matter and grain yield.

Introduction

For several years now, much research has been carried out on a variety of problems associated with the role of water in aiding growth and enhancing the yields of plants. These studies have yielded many perceptions into the relationship between plants and water. The findings, in turn, have played an important role in helping to improve agricultural productivity in arid and semi arid regions throughout the world. According to Vaux and Pruitt (1983), though the totality of knowledge about the role of water in agriculture is impressive, it is neither complete nor comprehensive.

Many factors serve to limit crop growth including soil type, nutrient content and climate but water has been observed to be the principal yield-limiting factor. Historically, research aimed at determining the relationship between crop yield and water has been guided by various notions of what constitutes a "desirable" level of water use. The work of agronomists and other crop-oriented researchers is often directed at establishing the level of water input necessary to achieve maximum yield per hectare. A desirable level of water use in the perception of the economist is that water, when efficiently applied, should be to a point where the price of its last unit is just equal to the revenue obtained as a result of its application.

Crop water use or consumptive use is the sum of two terms: evaporation, which is water evaporating from soil surface and surfaces of the plants; and transpiration, which is water entering plant tissue or being passed through leaves of the plants atmosphere (Hansen et al 1979). Consumptive use can apply to water requirement of a crop, a field, a farm, a project, or a valley. When consumptive use of a crop is known, the water use of larger units can be estimated. The volume of water taken by the plant is influenced by factors such as temperature and humidity, wind movement, intensity and duration of sunlight, stage of development of the crop, type of foliage and nature of leaves; These factors differ from one part of the world to the other. Hence it is important to estimate crop water needs for irrigation purpose.

The increasing scarcity of water all over the world, especially in the humid tropics of Nigeria, vis-à-vis Port Harcourt area is on the brink of bringing great changes in irrigated agriculture. Port Harcourt, the capital city of Rivers State of Nigeria which is situated on latitude 4.9°N and longitude 7.0°E, has two distinct climatic seasons; rainy season and the dry season. The rainy season with its attendant rainfall is between the months of May and October, while the dry season with virtually no rainfall, occurs for the rest or the remaining 6 months. Most often than not, the inadequate water supply situation in Port Harcourt, especially during the dry season could be likened to a state of drought. This drought results from changes in the weather, increased demand for water and scarcity of rainfall to supplement water supplies. Majority of the farmers do no farming during this time of the year because of inadequate moisture that cannot support plant growth. At the present time, farmers in Port Harcourt only have one cropping season all year round, but it will be possible to have more through irrigation and/or proper management of water requirement relationship under different climatic conditions. It is only when farmers have this knowledge will they be able to confidently apply whatever available quantity of water in the dry season with the goal of maximizing crop yield per unit water input. In other words, a relationship that can predict all year round crop water use to yield is important. This can only be attained for particular crops, especially corn, if necessary steps are taken in research to estimate the crop water use pattern.

Therefore, the ultimate aim of this study is to establish a functional relationship between corn yield and amount of water use in Port Harcourt area during the dry season.

Material and Methods

Between February, 1993 and December, 1994 an experiment was conducted to study the relationship between crop yield and water use at the Rivers State University of Science and Technology, Port Harcourt, research farm. Although, the study recognized that there are other factors that may limit crop yield, water was identified as the principal yield limiting factor. Rivers State is characterized by a humid tropical climate, with 70% of the annual rains falling between April and August, while 22% is spread in the 3 months of September to November. The driest months are from December to March. During the rainy season the land is productive, especially with corn, but diminishes from September when late rains are about to begin until virtually no corn is seen in the field in November. It is, therefore, of utmost importance to determine if irrigation can be used to supplement rainfall; and how much land should be irrigated most efficiently with the limited available supply of water starting from September.

The crop under study was *Zea corn maize*. The only single independent variable or factor that was investigated was water use in terms of irrigation depth. Water use at various levels of irrigation between field capacity and the permanent wilting point of the soil were determined in the experiment. Consideration was also given to water level applications in literature before final selection. According to Stewart and Hangan (1973), irrigation treatments are always expressed in terms of the total depth of irrigation water from planting to maturity ranging from zero to 600mm. Hence in this experiment levels in depth of irrigation per day chosen were 8.5mm, 6.5mm, 5.0mm, 3.5mm, 2.0mm, 1.0mm and 0mm. The response variable was production as grain yield. The other plant growth response measured was total dry matter production. The experiment was divided into plots which were randomly assigned to various application levels: a total of 24 flat beds arranged 3 beds per row of 1m by 1m in area and raised to 0.6m height. Eight lysimeters representing the eight application levels served as controls to these field plot experiments. The soil used in both field plots and the lysimeters were collected from the top 0.4m of the field soil profile, thoroughly mixed into an homogeneous sample before use in the experiment. After this, both the soils in the field plots and the lysimeters were subjected to three wetting and

Table 1. Mean Daily Air Temperature, Solar Radiation and Rainfall at the Study Area (1983 - 1992)

Month	Average Temperature (^oC)	Solar Radiation ($ca/cm^2/day$)	Rainfall (mm/day)
JAN	27.0	737.4	17.9
FEB	28.4	778.7	54.6
MAR	28.3	741.6	107.2
APR	28.0	769.7	138.6
MAY	27.3	730.3	230.9
JUN	26.5	680.8	271.7
JUL	25.8	524.7	346.1
AUG	25.8	537.5	323.2
SEP	26.2	612.3	352.5
OCT	26.4	654.0	217.4
NOV	27.3	720.4	73.4
DEC	26.3	720.5	24.3

Table 2. Growing Season Average Temperature, Solar Radiation and Precipitation at the Study Area (1983-1992)

Parameter	Growing Season	
	1st	2nd
Temperature, ^oC	27.8	26.6
Solar radiation, $Cal/cm^2/day$	7.515	676.8
Precipitation, mm/day	109.8	169.9

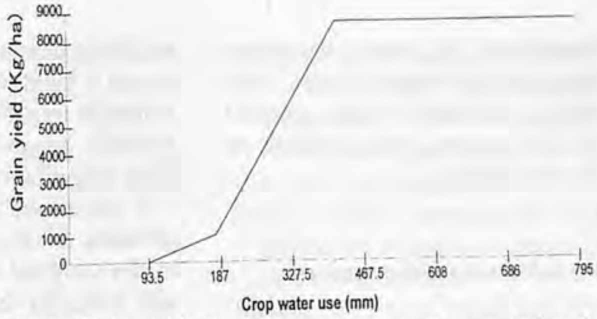

Fig.1 Grain yield of corn in relation to water use during the first planting periods (1993-1994) of the experiment.

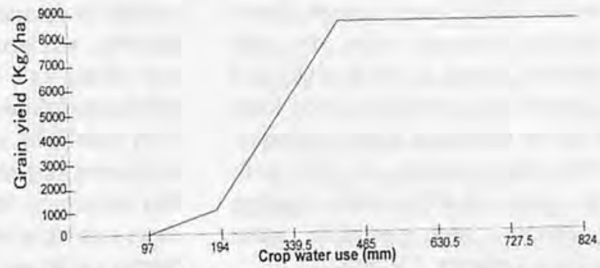

Fig.2 Grain yield of corn in relation to water use during the second planting periods (1993-1994) of the experiment.

drying cycles to permit settling of the material so as to simulate the natural soil profile, in accordance with methods described by Musick and Dusek (1980) and Steward and Hagan (1973).

During the initial stages of the research, soil samples were collected in each of the 24 beds and lysimeters at varying depths of 0.1m, 0.2m, 0.3m and 0.4m. They were immediately sun-dried and passed through 2.0mm sieve. Particle size analysis were obtained by the hydrometer method (Lambe, 1951).

The field capacity, wilting point and bulk density test were carried out by methods described by Hansen et al (1979) and Michael, (1978).

Prior to planting, pre-plant irrigation was applied (first irrigation after seed preparation), to each plot to compensate for residual differences in profile moisture content to a depth of 1m in order to bring all plots to a more or less uniform initial root zone moisture content. Fertilizer (NPK), 180 g dissolved in 6 litres of water were applied uniformly to all experimental plots and lysimeters. Pest and weed control were based on prevailing practices in the region. Four and two crops were respectively planted in each plot and lysimeter which translated into crop density of 40,000 plants/ha. This adequate planting rate will allow for uniform and optimum plants at harvest (FAO, 1980). In line with normal experimental procedure, the crops were allowed to grow up to 0.4m height (about a month after planting) with uniform daily application, before the 8 different depths of irrigations were started in the field and the control lysimeters. In the field measured application was done by surface irrigation using watering cans. In the lysimeters, application was done both at the water table level (bottom) and on the surface depending on depth of application and crop root zone depth which is invariably related to the age of the plant.

Additional water from time to time during rain was recorded by a rain gauge located in the field. Planting was carried out twice in the year as follows:

(i)January/February to April/May – first planting period; and
(ii)September to December – second planting period.

The eight weighing water table galvanized cubical steel lysimeter tanks have dimensions of 0.7m by 0.7m. In the design, gravels were used to maintain the water table at the bottom of each tank before soil was placed on the gravel. The tanks were fitted with about 0.6m long and 0.15m diameter PVC pipe, which was connected to the water control system designed for the tank. The water supply and drainage arrangement in this research were similar to that reported by Shih and Synder (1985), Benz et al (1985), Reichman et al (1979), and, Williamson and Schilgaade (1965); although the dimensions of the lysimeter were different because water table depths differ with different climates, different soils and crops (Benz et al. 1985). For instance, the depth of corn root zone from research findings in Port Harcourt area ranges between 0.29m and 0.35m. In order to simulate normal conditions in the soil environment, the tanks were installed 0.6m to the ground with 0.1m protruding above the ground.

Measurements were also made of soil moisture in field plots using gravimetric method. Crop, dry-matter and marketable yield, were determined by hand harvesting from each lysimeter or plot, oven dried to constant weight, adjusted to 12.5 percent grain moisture on dry weight basis.

Results and Discussion

Laboratory analysis, using the United States Department of Agriculture (USDA) soil textural classification, showed that the soil samples tested in both field and lysimeter are generally sandy loam with the following mean characteristics: field capacity, 14.14%; wilting point, 6.43%; bulk density, $1.68g/cm^2$, and available water holding capacity, 130mm.

Long term (1983-1992) mean daily air temperature, solar radiation and precipitation in the study area is given in **Table 1. Table 2** gives the average values of the above parameters during the crop growing period of the research, i.e., the dry season. Values of leaf area and plant height in the corn growth periods of establishment, vegetation, pollination or flowering, and grain production stages of this work are detailed in Ayotamuno et al, (1997).

Given in **Table 3** are the values of yield obtained relative to the amounts of water used in irrigation in the first and second planting periods of 1993 and 1994; and the water use efficiency.

Eight irrigation treatments (T_o – T_7) were applied in each of the four planting periods. The treatments ranged from 0 to 971mm and 833mm, respectively, for the first and second irrigation periods in 1993 and 0 to 799mm and 816mm, respectively, for the same irrigation periods in 1994. These irrigation treatment levels were designed both to allow the development of water deficits in some crops and to provide adequate irrigation in others. The curves (**Figs. 1** and **2**) obtained from this table relates grain yield to irrigation depth. It shows rapid increase in yield with each increase in irrigation treatment until the rate of increase began to diminish with large irrigation treatment levels.

A close look at the yield pattern of **Table 3** will shows that the dry matter yield did not exceed 60kg/ha and 140kg/ha for T_o and T_1 in all the seasons. The crops that received this irrigation treatments were observed to be generally stunted in growth, no teaseling, pollination and silting and, therefore, no grain production. Grain production began with treatment T_2 with some plots producing just about 1ton/ha. From this treatment level and upwards, there was rapid increase in both dry matter yield and grain yields with each level of treatment until T_5 when the rate of increase in yield began to show signs of diminishing returns. The mean of maximum dry matter yield in both plots and control lysimeters ranged between 18,280 – 19,840 kg/ha, while grain yield ranged from 8,200 – 8,630 kg/ha. From **Table 3** the above level of yields are noticeable in treatments T_4-T_7, but not in any specific treatment level. But in **Figs. 1** and **2** the optimum grain yield and water use values were obtained in the four seasons by locating the points immediately before the maximum crop yield boundary (T_4-T_7) and projecting it, respectively, to the y- and x-axis. This being in agreement with methods described by Michael (1978). In other words, yield will decrease when treatment level is below the optimum irrigation and maximum crop yields are possible above the optimum water use. From **Fig. 1** and **2** the optimum water use realized in this experiment were 470mm and 490mm for the first and second irrigation seasons, respectively.

Furthermore, an examination of the regression curves show that yield is not proportional to water applied as it is sometimes assumed (De Wit, 1958). A further examination of the curves reveal that the function does not begin at the origin. This finding is supported by Hillel and Guron, (1973) who observed a distinct intercept or threshold valve of crop water use below which corn production is negligible. The threshold crop water use valve may be due largely to the water loss caused by direct evaporation from the soil surface, particularly during germination and establishment stages of the corn as well as, perhaps, to occurrence of some transpiration from senescing plants after cessation of growth. The threshold crop water use value of 180-200 mm was obtained for grain yield in this experiment. In other words, irrigation application below this level could cause corn crop in Port Harcourt area to be irrevocably stressed.

A very important result of the experiment is the systematic increase in crop water efficiency (ratio of crop yield to crop water use) with increase in quantities of irrigation to a maximum value before decreasing at higher irrigation levels. The highest water use efficiencies of 160-180 kg/ha-mm were obtained at seasonal irrigation levels that ranged between 460-490mm (**Table 3**). That is, any additional millimeter of irrigation water above this level on the soil may be tending towards waste, especially during the dry seasons in Port Harcourt.

Conclusions and Recommendations

The problem of inadequate water supply in Port Harcourt, especially during the dry season coupled with the dearth of information on the proper management of crop water requirement relationships, has resulted in the fact that majority of the farmers have only one cropping season all year round. This research was geared towards solving this problem by relating corn water use to yield within a period of 2 years.

Table 3. Yield Response to Water Application and, Water Use Efficiency During the Dry Season in Port Harcourt Area, 1993 - 1994

Treatment (mm)	Irrigation water (mm)	Dry Matter (t/ha) Plots	Dry Matter Lysimeter control	Dry Matter Mean	Grain Yield (t/ha) Plots	Grain Yield Lysimeter control	Grain Yield Mean	Water use efficiency (× 1000)
			Feb to	May.	1993			
T_0	0.0	0.04	0.03	0.04	0.00	0.00	0.00	0.00
T_1	93.0	0.04	0.13	0.14	0.00	0.00	0.00	0.00
T_2	186.0	3.50	4.10	3.80	1.00	1.38	1.19	0.64
T_3	326.0	13.62	13.75	13.69	4.63	4.01	4.32	1.33
T_4	465.0	17.11	17.21	17.16	7.17	7.65	7.41	1.60
T_5	605.0	16.82	17.81	17.32	7.80	8.10	7.95	1.31
T_6	695.0	17.74	18.60	18.28	7.92	8.40	8.16	1.17
T_7	791.0	17.72	18.00	17.86	8.16	8.23	8.20	1.04
			Sept to	Dec.	1993			
T_o	0.0	0.07	0.03	0.05	0.00	0.00	0.00	0.00
T_1	98.0	0.13	0.12	0.13	0.00	0.00	0.00	0.00
T_2	196.0	3.26	3.90	3.58	0.95	1.45	1.20	0.60
T_3	343.0	14.19	13.85	14.02	4.61	4.00	4.31	1.26
T_4	490.0	18.01	19.09	18.55	8.50	8.40	8.45	1.72
T_5	637.0	18.75	18.80	18.87	8.52	8.50	8.51	1.33
T_6	735.0	18.86	19.00	18.93	8.49	8.38	8.44	1.20
T_7	833.0	18.57	18.83	18.70	8.14	8.25	8.20	1.00
			Jan to	Apr.	1994			
T_o	0.0	0.05	0.06	0.06	0.0	0.00	0.00	0.00
T_1	94.0	0.11	0.11	0.11	0.0	0.00	0.00	0.00
T_2	188.0	3.27	3.75	3.51	1.09	1.63	1.36	0.72
T_3	329.0	13.81	13.60	13.71	4.15	4.40	4.28	1.30
T_4	470.0	17.96	18.20	18.08	7.60	8.20	7.90	1.64
T_5	611.0	17.69	18.65	18.17	7.78	8.11	7.90	1.29
T_6	705.0	17.87	18.65	18.60	7.60	7.80	7.90	1.12
T_7	799.0	18.43	17.80	18.12	8.10	8.40	8.25	1.03
			Sep to	Dec.	1994			
T_o	0.0	0.01	0.02	0.02	0.0	0.00	0.00	0.00
T_1	96.0	0.12	0.16	0.14	0.0	0.00	0.00	0.00
T_2	192.0	3.28	3.60	3.44	1.16	1.48	1.32	0.69
T_3	336.0	14.22	14.31	14.27	4.40	5.25	4.83	1.44
T_4	480.0	19.52	19.11	19.32	8.36	8.68	8.52	1.78
T_5	734.0	20.78	18.90	19.84	8.86	8.58	8.63	1.40
T_6	720.0	18.89	19.55	19.22	8.47	8.73	8.60	1.20
T_7	816.0	18.41	19.30	18.86	8.00	8.00	8.00	0.98

T_o = 0mm/day T_2 = 2mm/day T_4 = 5.0mm/day T_6 = 7.5mm/day
T_1 = 1mm/day T_3 = 3.5mm/day T_5 = 6.5mm/day T_7 = 8.5mm/day

Generally, the results showed that yield was not proportional to ET as it is sometimes assumed. A further examination of the curves reveal that the function does not begin at the origin. Maximum corn dry matter yield ranged between 189.28 – 19.84t/ha, while grain yield is between 8.20 – 8.63t/ha. The optimum seasonal water use rate was about 470 – 490mm. A threshold value of 180 – 200mm was obtained for both dry matter and grain yield.

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Development and Performance of 2-unit Diggers for Cotton Stalks Uprooting and Groundnut Lifting

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Abstract

Mechanical uprooting of cotton stalks and lifting groundnut in Sudanese irrigated schemes are of vital importance. Therefore, a 2-unit digger was developed and compared with traditional methods at different dates for uprooting cotton stalks and lifting groundnut.

No significant differences between the fabricated 2-unit digger and manual cotton stalks puller were detected in uprooted cotton root length in the first week of May for the two seasons and fourth week of May for the second season. Nevertheless, a significant longer root was obtained with the 2-unit digger in the fourth week of May in the first season.

For lifting groundnut, the results indicate that the performance of the developed 2-unit digger on crop loss percentage was similar to the digger –shaker for the two seasons of study. Both diggers resulted in significantly and very highly significantly lower crop loss percentage in the first and second seasons, respectively, in comparison with the manual lifter. However, crop lifting at 21 and 14 days from the final crop watering was the optimum time for mechanical digging and manual lifting, respectively.

As the performance of the 2-unit digger was quite satisfactory, it was recommended for cotton stalks uprooting and groundnut lifting.

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Introduction

Cotton (*Gossipium barbadense* L. and *G. hirsutum* L.) is the backbone of Sudanese wealth. It is grown in irrigated and rain-fed areas at different localities in the country. In irrigated schemes it occupies 143,000 ha in the Gezira: 28,000 ha in the Rahad; 25,000 ha in the New Halfa; and 8,000 ha in the Suki. The manual for puller cotton stalks that was introduced into the Gezira in 1930s is the common implement used in these pulling schemes. Cotton stalks operation is usually carried out in the summer months, during which temperature is very high and labour output is very low. This operation is very slow and requires an expert and strong labour.

During the past few years, cotton stalks were observed to remain in the fields up to the first rain showers in June in order to moisten the soil for easy pulling. During this time, cultural practices for groundnut crop start. However, the stalks remaining in the fields may contribute to transferring disease and insects to the newly sown cotton in July, especially after ratooning.

Many trials were carried out to mechanize uprooting of the cotton stalks. Testing was normally done in narrow ranges and the devices used were faced with technical difficulties which stopped their use (Dawelbeit, 1994).

On the other hand, groundnut (*Arachis hypogea* L.) is another important cash crop in the Sudan. In 1986/87, it occupied 496,440 ha that produced 399,500 tons (Ishag, 1986). The Sudan's irrigated area has a stabilizing effect on groundnut production that does not occur in other groundnut producing areas of the world (Ishag et al. 1985). Dafalla et al. (1992) reported that the average contribution of groundnut to the total export value during the period 1980-1985 was between 1.7 and 18.6% and about 15% of the total area under cultivation are irrigated, producing 40% of the total crop.

Under irrigated schemes, groundnut is grown in the Gezira (90,000 ha), Rahad (27,000 ha), New Halfa (17,000 ha) and Suki (5,000 ha). The crop was faced with many mechanization problems such as lack of spare parts, inadequate training on the part of the operator, insufficient workshops equipment, absence of support

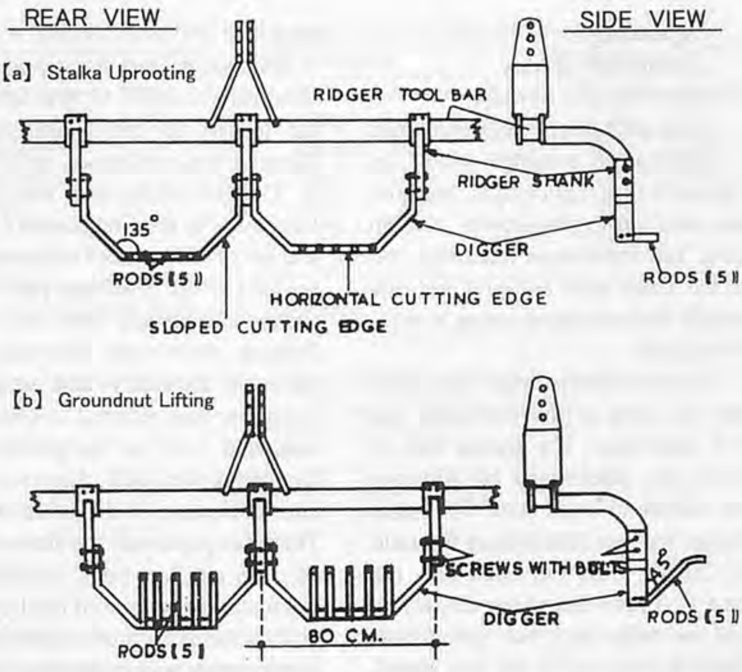

Fig.1 Shape and attachment of 2-unit digger for cotton.

services, poor management and maintenance of machinery, selection of unsuitable machinery and poor infrastructure (Dawelbeit, 1991). Groundnut harvesting which is a labour intensive operation is considered one of the major factors contributing to groundnut low yield.

A few digger-shakers and combine threshers have been introduced in irrigated schemes by the government in order to attract farmers towards groundnut production. Unfortunately farmers did not respond positively. They accepted threshers instead to be used as stationary machines. They think that the use of digger-shaker results in high crop loss. Moreover, farmers are used to growing miscellaneous cash crops on top of bunds ties across the groundnut fields, such as Pigeon pea (*Cajanus cajan* L.) and Roselle (*Hibiscus sabdariffa* L.).

The harvesting dates and methods of these crops are different from that of groundnut. Hence, based on these two reasons, manual lifting is the more common method of groundnut harvesting. This method requires optimum soil moisture content to facilitate lifting and to reduce crop loss under heavy clay soils. Therefore, watering before lifting is an essential technique. However, groundnut harvest time coincides with cotton picking and both are labour intensive operations. Labour prefers collections of groundnut and digging for lost pods to cotton picking as the former is quick in cash return.

Therefore, to solve the problems of uprooting cotton stalks and groundnut lifting, 2-unit diggers were developed to perform these two field operations under irrigated schemes of heavy clay soils in the Sudan. This was to save time and manual labour for other coincident cultural practices, to reduce field operation drudgery and to minimize groundnut losses.

Materials and Methods

Digger Development

A 2-unit digger consists of two digger units. Each unit was made of one hard steel piece, with thickness of 1.3 cm and width of 6 cm. The steel piece was available from a scraped lorry rear shock absorber spring. The unit of the digger consisted of a horizontal cutting edge of 40 cm in length, after sharpening by grinder. This is because cotton and groundnut are usually grown on the top of 80 cm spaced ridges and the normal width of the ridge is 40 cm. Then the steel piece was bent at an angle of 135° to the vertical at both sides to a length of 27 cm each. After sharpening they became two sloped cutting edges. The function of the sloped edges is to help in digger penetration of about 19 cm below the ridge height. The average ridge height from the bottom to the top was about 15 cm, giving a total penetration depth of about 34 cm.

Also, it helps in keeping the horizontal cutting edge inside the soil, as a result of its inclination and as the soil slides down. Then the two sides are bent vertically to a length of 22 cm, giving a distance of 78 cm from outer sides. The distance from the centre of one shank to the centre of the other was 80 cm. This distance allows the passage of cotton stalks branches and groundnut plants without getting stuck. At each side a hole of 1.3 cm in diameter which was drilled at a distance of 10 cm from the point of vertical bending and another hole at both sides, was drilled at a distance of 10 cm from the first hole. The purpose of these holes is to facilitate the proper position of the digger unit using screws with bolts to the shanks of the body ridger. The positioning of the digger has to be done after the detachment of the lower part of the ridger which consists of cutting share, frog and wings.

Five metal rods were welded 10 cm apart to the rear of the horizontal cutting edge. For uprooting cotton stalks, rods were welded perpendicular to the edge. Each rod was 10 cm long. Whereas, for groundnut lifting, the five rods were welded to the rear of cutting edge at an angle of 45° vertical. Each rod was 40 cm long and with slight bending at 10 cm from the end (**Fig. 1 (b)**). The function of the rods for uprooting cotton stalks, was to help in breaking and detaching the soil clods from the cotton root system. That leaves the uprooted cotton stalks standing upright so as to be easy for quick manual collection. In the lifting of the groundnut, the functions of rods were to lift the plants gently upwards, so as to allow for the soil particles to fall while being lifted. The slight bending at the end of the rods facilitates a smooth crop slipping-off.

Each fabricated digger unit was made to be simple in design, easy to fabricate locally, needs no spare parts and light in weight (about 88 Neutons).

Thereafter, the 2-unit digger was assembled and attached to the tractor by 3-point linkages to work as a fully mounted 2-unit digger for uprooting cotton stalks (**Fig. 1 (a)**) and for lifting groundnut (**Fig. 1 (b)**).

For performance evaluation, the 2-unit digger for cotton stalks uprooting was compared with the traditional manual cotton stalks puller at different uprooting dates (Experiment 1). For lifting groundnut, the 2-unit digger was compared with digger-shaker and manual lifting at different lifting dates after the final crop watering (Experiment 2).

Experiment 1 (Uprooting Cotton Stalks)

The experiment was carried out during 1988/89 and 1989/90 seasons in the Gezira scheme. The climate is semi-arid and the soil is a Vertisol which is characterized by swelling when it is wet and shrinking when dry. It contains 50-60% clay and it is of difficult physical conditions.

Comparative performance test was carried out in farmers' fields in which cotton (*Gossipium barbadense* L.) local variety (Shambat B) was grown. Treatments included two uprooting devices:

1- The developed 2-unit digger (**Fig. 1 (a)**).
2- Manual cotton stalks puller. and two dates of cotton stalks uprooting:
1- First week of May.
2- Fourth week of May.

These treatments were combined in randomized complete block design with five replications. Sub-plot size was 1.6 m (two rows) × 20m long. Ten stalks were randomly collected from each sub-plot for root length determination using a measuring tape.

The 685-International Case tractor was used in the test using the first high gear. The tractor rate of work was determined by allowing the tractor to work with the 2-unit digger for four times along the field of 280 m long. For each run, the time was recorded using stopwatch and the mean time was calculated. Then the rate of work was determined according to Hunt (1979) equation, by assuming 80% field efficiency (E), as follows:

Rate of work (ha/h) =
Implement width of cut (m) × Number of digging
(bodies × actual tractor speed (m/s) × 3600 (s/h) × E (0.8)) ÷ 10,000 (m^2/ha)

Experiment 2 (Lifting Groundnut)

The experiment was carried out during 1992/93 and 1993/94 seasons, at New Halfa Research Station (15° 05′ S, 15° 30′ N). The soil type is a Vertisol with 45- 60% clay content (Blokhuis, 1962).

Treatments for groundnut lifting included the following:

1-The fabricated 2-unit digger (**Fig. 1(b)**).
2-Digger-shaker: chain type digger-shaker inverter, model No. CD-80-2, tow row.
3-Manual lifting.

Four lifting dates that started 14 days from the final crop watering (FCW) at intervals of 7 days, which were: 14, 21, 28 and 35 days from the FCW.

The resulting 12 treatments were laid in randomized complete block design, with four replications. Subplot size was 3.2 m (4 rows) × 10.5 m long.

Groundnut (*Arachis hypogea* L.) local variety (MH383) was sown on the top of 80 cm spaced ridges. Planting was performed on 15th July. The first lifting date was on 5th December in the first season (1992) and on 28th December in the second season (1993). The lifted pods were separated manually from the vines. Missing pods were also dug and collected manually and weighed. Crop loss was referred to pods that remained in or on the ground surface or mixed with disturbed soil after collection of the lifted plants. The total yield was the sum of lifted, plus and lost pods which were calculated as percent of total yield.

The comparison of means for the experiments was performed using Duncan's multiple range test (LeClerg et al. 1962).

Results and Discussion

Experiment 1 (Uprooting Cotton Stalks)

The means of the uprooted root length for the two seasons (1988 and 1989) and tractor rate of work, that was determined in the first season only are shown in **Table 1**.

There was no significant difference in root length between the 2-unit digger and manual cotton stalks puller in the first week of May for the two seasons. The fourth week of May recording in the first season (1988) showed that some stalks were broken at the grasp point of the manual puller with the stalks, leaving the lower stalks portion and root system in the soil. This could be attributed to the relatively dry and brittle stalks and the relatively dry and hard soil. Such left portion of stalk is prohibited according to the crop protection local law, lest they may germinate during the rainy season. The stalk breakage was probably due to the great pressure applied to overcome the adhesive forces between soil particles and root system,

Table 1. Values of Uprooted Root Length (cm) and Tractor Rate of Work

Uprooter Type	Rate of Work (ha/h)	1988/89 Season 1st Week of May	4th Week of May	Average	1989/90 Season 1st Week of May	4th Week of May	Average
2-unit digger	1.2	27.0	24.0	25.5	32.0	24.0	28.0
Manual puller	-	26.0	14.0	20.0	30.0	24.0	27.0
Average	-	26.5	19.0	22.8	31.0	24.0	27.5
SE ±	-	0.4 (NS)	2.0 *		1.0 (NS)	2.0(NS)	
LSD (P=0.05)			5.6				

NS = Not significant.
* = Significant at 5% level of significance.

Table 2. Values of Uprooted Root Length (cm) Over Two Years Old

Uprooter Type	Means, 1988/89, 1989/90 1st Week of May	4th Week of May	Average
2-unit digger	29.5	24.0	26.8
Manual puller	28.0	19.0	23.5
Average	28.8	21.5	25.2

and also due to the angular pulling action with puller. Therefore, the 2-unit digger was found to result in significantly (P = 0.05) longer root in comparison with manual cotton stalks puller. For the second season (1989), the two devices resulted in similar root length in the fourth week of May. This was probably due to the infestation of experimental land by Bermuda grass (*Cynodon dactylon* L.) that restricted the development of secondary root system which resisted the root pulling. However, the comparison of the means for root length over the two seasons of study (**Table 2**), showed that more root length was obtained using the 2-unit digger than using the manual cotton stalks puller with the two dates of cotton stalks uprooting.

In some roots a mark at contact point of the digger edge with lower portion of the root a mark had been noticed indicating that the root had slipped over the cutting edge to give a complete root length. This was probably due to the stronger attachment of root parts to each other, compared to adhesive force of soil particles on them, or could be due to the soil breakage lines created by the digger under dry heavy clay soil. These lines might pass through the root system zone causing a reduction in adhesive soil forces on the lower root portion. However, the 2-unit digger was observed to cut and fractionate the top of the ridge without disturbance leaving the stalks standing upright. This situation eased the quick collection of uprooted stalks manually.

The recommended plant population for cotton is 76,000 to 80,000 per ha (Technical packages, 1991). The manual cotton stalks puller requires 24 man-hour /ha to pull that huge number of stalks one by one (Dawelbeit, 1994). The use of the 2-unit digger resulted in a rate of work of 1.2 ha/h which is equal to about 0.8 hour/ha (**Table 1**). This indicated how fast the uprooting of cotton stalks could be completed using the 2-unit digger.

The attachment of the digger units to the ridger shanks that are extended to the rear of the tool bar (**Fig. 1 (side view)**), allows the tool bar to pass over non-uprooted stalks before the cutting edges thereby preventing the sweeping of uprooted stalks by the tool bar. Hence, the digger being stuck and over-riding non-uprooted stalks have been avoided.

Experiment 2 (Lifting Groundnut)

The means and average crop loss percentage in the two seasons of study are shown in **Table 3**.

There was a significant difference (P = 0.05) between treatments in the first season (1992). After 21 days from the FCW, the 2-unit digger and digger-shaker resulted in significantly lower crop loss percentages compared to manual lifting 6 and 7%, respectively. The overall average crop loss percentage with the two digger types (2-unit digger and digger-shaker) was similar (11%) and significantly lower in comparison with the manual lifting method (15%).

Results of the second season (1993), showed a very highly significantly difference (P = 0.001) between the treatments. Here again, the 2-unit digger resulted in very significantly lower crop loss percentage (23%) after 21 days from the FCW, while the same result was obtained with the digger-shaker after 14 days. The average crop loss percentage was also similar with the two digger types (28 and 29%) and very significantly lower than with manual lifting of about 10%.

The LSD test at 5% significance level (LeClerg et al. 1962) indicated that the two digger types resulted in consistent significantly lower crop loss after 21 days from the FCW for the two seasons (**Table 3**). The manual lifting consistently gave the highest crop loss percentage which appeared that lifting after 14 days from the FCW resulted in consistent significantly lower crop loss percentage compared to the rest of the manual lifting dates for the two seasons.

The overall average of the two seasons (**Table 4**) showed that the overall lifting dates of the 2-unit digger and digger-shaker were similar and resulted in lower crop loss percentage (20%) in comparison with manual lifting (27%). Therefore, lifting at 21 and 14 days from FCW resulted in the lowest crop loss percentage by using the two digger types and manual lifting, respectively.

Table 3. Effect of Lifting Device and Lifting Time on Groundnut Loss %

Lifting Device	Days From Final Crop Watering 14	21	28	35	Average
		1st Season (1992)			
2-unit Digger	11ab	6a	15b	13b	11a
Digger- Shaker	14 b	7a	13b	10a	11a
Manual Lifting	13 b	12a	17b	16b	15b
Average	13 b	8a	15b	13b	12a
SE	= ± 3.0 *				
LSD (p = 0.05)	= 6.1				
		2nd Season (1993)			
2-unit Digger	35b	23a	31a	24a	28a
Digger-Shaker	23a	28a	31a	34b	29a
Manual Lifting	32b	39c	46c	39c	39c
Average	30a	30a	36b	32b	32b
SE	= ± 4.0 **				
LSD (P = 0.05)	= 8.1				

* = Significant at the 5% significance level.
** = Significant at the 1% significance level.
For each season, means followed by the same letter are not significantly different at P=0.05 according to Duncan's multiple range test.

Table 4. Effect of Lifting Device and Lifting Time on Groundnut Loss over Two Years Old

Lifting Device	Means, 1992 and 1993 Days From Final Crop Watering 14	21	28	35	Average
2-unit Digger	22	15	23	19	20
Digger-Shaker	19	18	22	22	20
Manual Lifting	23	26	32	28	27
Average	22	20	26	23	22

The crop loss percentage in the second season (1993) was higher than in the first season (1992) (**Table 3**). This was probably due to the delay in crop lifting, which was done after 166 days from the crop emergence while the recommendation for groundnut lifting is 120-140 days after sowing (Technical packages, 1991). The deliberate delay in crop lifting was due to the easy detaching for pods from the plant. Therefore, the very significant lower crop loss percentage that was obtained with the two digger types in the second season, was probably due to the reduction of soil adhesion forces on groundnut pods, by soil clods fractionation when the diggers were used in comparison with manual lifting.

It was noticed that the lost pods in digging operation with the 2-unit digger and digger-shaker were scattered on the soil surface and mixed with disturbed soil which were easily and quickly collected manually. The lost pods with manual lifting required manual devices for digging to expose pods from the underneath of the dry and hard soil. Because of the appearance of lost pods on the soil surface in mechanical digging, farmers were of the opinion that the use of the digger-shaker results in high crop loss than manual lifting. The study revealed the reverse.

Conclusions and Recommendations

Experiment 1 (Uprooting Cotton Stalks)

Manual pulling of cotton stalks operation is a tedious and slow work which is exacerbated with a very hot weather in the summer months. The study indicated the importance of mechanical uprooting of cotton stalks before the rainy season. The fabricated 2-unit digger resulted in slightly longer root in the first week of May for the two seasons. Similar root lengths were obtained in the fourth week of May for the second season, whereas a significantly longer root was obtained in the fourth week of May for the first season in comparison with manual cotton stalks puller. The 2-unit digger solved the problem of cotton stalks uprooting with satisfactory performance and in a short time hence, recommended for uprooting cotton stalks in irrigated heavy clay soils.

Experiment 2 (Lifting Groundnut)

The performance of the developed 2-unit digger on lifting groundnut was similar to that of the digger-shaker and the use of both resulted in significant lower crop loss in the first season and very significant lower crop loss in the second season compared to manual lifting.

Groundnut lifting at 21 and 14 days from the final crop watering (FCW), were found to be the optimum times for groundnut mechanical digging and manual lifting, respectively.

Thus, the developed 2-unit digger is recommended for lifting groundnut.

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Availability of Custom - Hire Work for Vertical Conveyor Reapers

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Abstract

The studies were conducted on availability of custom-hire work for vertical conveyor reapers through field interviews using a sample size of 51 machines spreading over 37 villages in Hisar and Sirsa districts of Haryana, India.

Introduction

Harvesting is an important activity in crop production. Today's intensive agriculture leaves only a very limited time between harvesting of one crop and sowing of the next one. Optimum period for harvesting a crop is at its biological maturity. At this stage, yield is maximum and losses are minimum, crops are susceptible to shattering if harvesting is delayed. Timely harvesting of the crop is, therefore, very important.

Fig.1 Front view of tractor front mounted vertical conveyor reaper.

Acute labour shortage is felt during the harvesting season because time available for harvesting is limited and the operation is generally manual.

In order to circumvent the labour scarcity in the harvesting season of paddy and wheat, the intermediate technology between sickle and combine harvesters in the form of vertical conveyor reaper commonly called VCR was developed by International Rice Research Institute (IRRI), Manila for harvesting of paddy, wheat, gram and fodder crops.

Materials and Methods

Data on use patterns of tractor-drawn vertical conveyor reaper was collected through field a survey in Hisar and Sirsa districts of Haryana. Since the number of machines available in these two districts was not very large, an effort was made to study all the machines in the area of study. Only a limited number of machines operating in the selected districts might have been missed the study. The study was started from a particular village known to have some number of machines operating there. All the machine owners were interviewed for the study. The study was extended to other two districts by each time obtaining information

Table 1. Village-wise Distribution of Vertical Conveyor Reapers

District	Block	Village	Number of machine
Hisar	Hisar-I	Dabda	1
		Dev Muklan	1
		Kaimri	1
		Mirka	1
		Kharar Alipur	2
		Shahpur	3
	Fatehabad	Dhani Nanaksar	1
		Daryapur	2
		Nakhatia	1
		Hazranva Kala	1
		Bigher	2
		Ahlisadar	3
		Jhalnia	1
		Gorkhpur	2
		Mahmmadpur Rohi	1
		Haripura	1
		Shahindawali	1
	Adampur	Kali Ravan	1
		Siswal	1
	Bhuna	Jandlikalan	1
	Hansi-I	Pehni Amirpur	1
	Hansi-II	Jamavari	2
		Shekhpura	1
	Tohana	Baliawali	1
		Samen	1
	Ratia	Hansga	1
Sirsa	Sirsa	Paniwari	1
		Maujukhera	2
		Patli Daber	1
	Chopta	Jodhnka	4
		Ding	1
	Baragudha	Phaggu	1
		Malri	2
	Odhan	Rohanwali	1
		Kalanwali	1
		Paniwala Mota	1
	Rania	Bani	1

about the machine owing villages from the farmers. Thus a total of 51 machine-owners spreading over 37 villages were studied. Village-wise distribution of machinery is given in **Table 1**. The number of tractors purchased by the farmers' during different years is given in **Table 2**.

The front view of a tractor front-mounted vertical conveyor reaper is shown in **Fig.1**.

Annual Use

The annual use of the machine by the owners was recorded for self work on the owners' own farm and for custom work on others' farms for each year.This information was obtained by discussion with the farmers' based on their memory and cross checking the information with the other details, annual use for self work and custom work was summed up to find the machine's total annual use for each year.

The mean annual use of machine both in terms of: a) hours of use; and b) hectares harvested was determined for: i) self-work i.e., use on owners' own farm, ii) custom work and iii) total use.

1) Year-wise of Annual Use:

Form 1987 to 1995, the mean annual use of the machine was determined separately for years to see wether there was any increase in the average use of the machine as the awareness about the utility of machine increased with time. From year-wise the mean annual use was susequently the overall mean use as determined by simple airthmatic mean.

Table 2. Year-wise Population of Vertical Conveyor Reapers (VCR)

Year	No. of Machines	Comulative No. of Machines
1987	2	2
1988	1	3
1989	3	6
1990	10	16
1991	9	25
1992	6	31
1993	7	38
1994	9	47
1995	4	51

Table 3. Year-wise Annual Use, hrs

Year	Annual use, hrs									Per cent custom work use
	Self-use			Custom work			Total use			
	Mean use	S.D.	C.V.	Mean use	S.D.	C.V.	Mean use	S.D.	C.V.	
1987	15.00	10.00	0.66	20.00	0.00	0.00	35.00	10.00	0.28	57.00
1988	20.50	7.50	0.36	27.50	5.00	0.18	47.50	12.50	0.26	57.80
1989	20.00	15.90	0.79	38.00	29.25	0.77	60.00	45.15	0.75	63.00
1990	18.00	9.32	0.51	43.90	31.14	0.71	61.92	40.45	0.65	70.89
1991	16.50	12.67	0.76	44.92	44.63	0.99	61.42	57.30	0.93	73.13
1992	17.00	9.22	0.54	46.00	36.06	0.78	63.00	45.28	0.72	73.00
1993	17.25	9.73	0.56	47.89	27.65	0.57	65.14	37.38	0.57	73.51
1994	20.68	20.35	0.98	48.05	40.87	0.85	68.73	60.22	0.87	69.91
1995	24.47	22.01	0.89	42.44	39.51	0.93	66.91	61.52	0.91	63.42
Overall Mean	18.82	2.70	0.14	39.85	9.24	0.23	58.84	10.18	0.17	66.85

Table 4. Year-wise Annual Use, ha

Year	Annual use, hrs								
	Self-use			Custom work			Total use		
	Mean use	S.D.	C.V.	Mean use	S.D.	C.V.	Mean use	S.D.	C.V.
1987	6.00	4.00	0.65	8.00	0.00	0.00	14.00	4.00	0.28
1988	8.20	3.00	0.35	11.00	2.00	0.18	19.00	3.00	0.26
1989	8.00	6.24	0.80	15.20	11.70	0.77	24.00	11.41	0.75
1990	7.20	3.72	0.51	17.56	12.45	0.72	24.76	20.54	0.65
1991	6.60	5.06	0.75	17.96	17.85	0.98	24.56	18.14	0.92
1992	6.80	3.69	0.54	19.60	14.42	0.79	25.20	12.48	0.71
1993	6.90	3.89	0.55	19.15	11.06	0.56	26.05	12.66	0.57
1994	8.27	8.14	0.98	19.22	16.34	0.85	27.49	18.74	0.87
1995	9.78	8.80	0.90	16.97	15.80	0.94	26.76	16.60	0.92
Overall Mean	7.52	1.08	0.14	16.07	3.80	0.23	23.53	4.07	0.17

Results and Discussion

It was observed that none of the farmers' comparing the sample used the vertical conveyor reaper for harvesting any other crop except wheat. However, it can be used for harvesting paddy, mustard, gram and fodder crops.

Year-wise Annual Use

Tables 3 and 4 show that the total annual use of the machines was 58.84 hrs. and it harvested an average of 23.53 ha area in a year. The annual use of the machine increased gradually from 35 hrs. and 14 ha in 1987 to 66.91 hrs and 26.76 ha in 1995. The proportion of use of the machine for custom-work increased from 57.00 per cent in 1995 with a peak of 73.00 per cent in 1993. The decrease in availability of custom-work after 1993 was perhaps due to the use of combine-harvesters by the farmers. On an average, the proportion of custom work was 66.85 per cent. Average annual use of the machine by owners on their own farm was 18.82 hours or 7.52 ha which roughly amounted to one-third oh the total- use

Conclusions

1. The average annual use of vertical conveyor reaper was 58.84 hours and it harvested an average area of 23.53 hectares, out of which 66.85 per cent annual use was for custom-work.
2. The fee of custom-work and its percentage of in crop production cost was Rs.650/per hectare and 4.96 percent, respectively, for wheat crop only.
3. Future prospect of custom-work for vertical conveyor reaper are very bright as it provides employment and also generates income. ■■

Development and Testing of a Prototype Fibre Scutching Machine

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Abstract

A power-operated flax fibre scutching machine was developed with the help of Jay Shree Textiles. Prior to conducting the evaluation of the machine, the flax stem was retted with three methods, viz., warm water, free flowing water and dew retting. The warm water (controlled) retting resulted significantly in high fibre yield and fibre percentage. The machine has an average capacity of 35 kg of stalk per hour with variation in the range of 32-38 kg/h. The machine scutched approximately 7 kg/h fibre from the stalks. The extraction and cleanliness efficiency of the machine was 87.5 and 80-85 per cent, respectively. The machine produced slightly longer fibre (2.5 mm) than the CIAE make. The net profit with the fibre scutching machine was Rs. 112 per hour.

Introduction

Flax or linseed (***Linum usitatissium L.***) is an important oilseed of India occupying 1180 thousand hectares and producing 342 thousand tonnes of seed (Anonymous, 1992) which yields oil of immense industrial value. In addition, the crop also produces more than 700 thousand tonnes of straw but it is going as waste due to non-availability of suitable device for proper extraction of fibre from the straw. At present, the specific varieties of linseed exclusively grown for fibre in Western countries are called "flax ".

Every part of the linseed plant can be utilized commercially either directly or after processing. The fibre of flax is important textile fibre because it has great strength, fineness, durability and better resistance to environmental fluctuations. It is stronger than cotton, rayon or wool. The fibre which is extremely porous, absorbs moisture rapidly and makes excellent towels, drying cloths and water holding articles. Short fibres are used as raw pulp for making paper for quality and strong fibre can effectively be used for low cost roofing tiles based on convertible polymers and for fibre reinforced plastics (Singh et. al., 1996).

Now-a-days, dual purpose varieties of linseed have been developed after realising the importance of both seed and fibre. In India, there is no appropriate machine available for fibre scutching at present. A small power-operated and hand-operated prototype scutching machine was developed by the Jute Technological Research Laboratory and Central Institute of Agricultural Engineering, respectively, but the capacity of the machine was very low. It is labour intensive and not very efficient. Therefore, a study was taken especially to develop a prototype of fibre scutching machine which suits farmers' need for successful extraction of fibre at the lowest operational cost. The steps to develop the machine were taken by the Jay Shree Textiles and the HPAU did the design, evaluation, etc.

Materials and Methods

The process of transforming the linseed plant into fibre requires a series of steps after harvesting of crop (Dempsey, J.M., 1995).

Retting of Straw

The concept of flax retting allows certain micro-organisms in the presence of moisture to form enzyme which attack the non-cellulosic portion of the flax straw that are rich in pectins for liberating the fibre elements from the surrounding parenchyma. There are two basic methods of retting of flax straw, i.e., dew retting and water retting of which the latter is popular in the country.

In the present study, the straw was retted using cold and warm water as follows:

Cold Water Retting

Cold water retting is the most primitive form of retting. The loosely bound bundles of straw are weighted with stones to submerged then in slow streams or static water for 2-3 weeks depending on the temperature of water. Temperature below 15 °C inhibits the bacteria responsible for retting. The faster retting takes place in stagnant water.

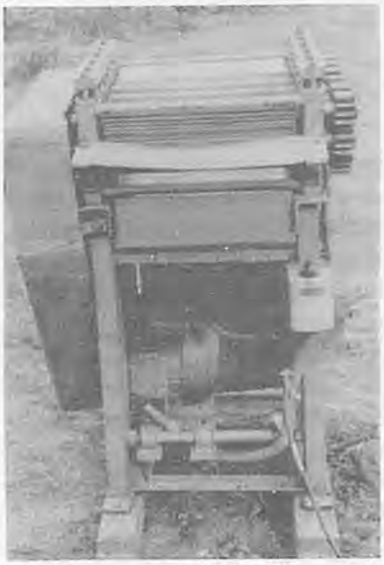

Fig. 1 Power-operated flax fiber scutching machine.

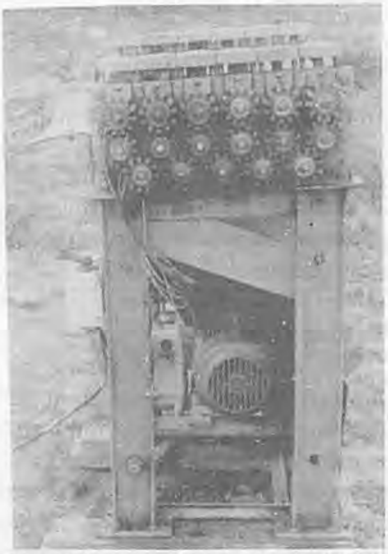

Fig. 2 Side view of flax fibre scutching machine.

Warm Water Retting

The bundles of straw are placed in well-equipped retteries with a controlled water tank to produce uniform fibre. This method is quick, efficient and requires less space for the crop. The retting phase begins when fresh water at 25 °C is added to the tank and adding warm water through an inlet pipe at the bottom of the tank until at uniform temperature of 28 °C is reached. This temperature is maintained throughout the retting period by adding warm water which should not be hot more than 80 °C. The amount of water added at interval of 8-12 hours during the entire period is sufficient for a complete change. The duration of the retting period for a single ret is approximately 5-6 days. Once the retting is completed the stalks are taken out and dried in the open before extraction of fiber.

Scutching

Scutching is the process by which the fibres from the retted straw are separated. Proper scutching determines the quality of fibre, viz., cleanliness, length of reed, broken fibre etc.

Hence, a suitable prototype of fibre scutching machine was developed on the basis of above concept, knowledge and experience with old prototype of JTRL and CIAE.

Design and Development of the Machine

The basic design considerations in developing the machine were:

1. The machine should be suitable for extracting fibre of good quality with minimum wastage/breakage,
2. The machine should have provision for electrical engine with fibre extracting capacity of 5-7 kg/h, and
3. The machine should have back and fourth movement of rollers to prevent the fibres from sticking.

Keeping in view the design considerations, a power-operated flax fibre scutching machine was fabricated with the help of the Jay Shree Textiles (**Fig. 1**). It consists of a main frame, rollers with teeth of various size and shape and power transmitting unit. The series of rollers were mounted on top of the main frame enabling drive the for 3-phase motor mounted at the bottom of the main frame connected to the belt and pulley. All rollers were at uniform speed. The rollers of 70 mm diameter and 280 mm length are so designed to enable the dried flax straw stem to be broken with 1^{st} and 2^{nd} roller feeding at end and separating from the fibre at the 3^{rd} and 4^{th} stage and falls after cleaning with help of the 5^{th} and 6^{th} roller in the tray. To obtain better results, the top rollers of the machine can be adjusted by increasing or reducing the spring pressure on the bottom roller as well as at both ends of the rollers. The tension of the spring should also be so adjusted that it gradually reduces from the first rollers at the feeding end to the last roller at the receiving end (Gilbertson, 1994).

One end of all the rollers has gears of 11 teeth for driving the roller (**Fig.2**) and the other end of the roller is mounted with the pulley of size 228 mm and gear of 23 teeth. The transmission unit is covered with the help of the safety guard.

Evaluation of the Machine

Prior to conducting the evaluation of the machine, the flax stem was retted using the three methods mentioned earlier. Initially the machine was operated in idle condition for proper adjustment of rollers. The machine performance parameters such as scutching capacity, extraction efficiency, cleanliness percentage, number of labourers required, speed of gear and test duration were recorded. Cost calculations were also carried out based on the procedure given in IS Code (Anonymous, 1979). The annual use and life of the machine was assumed to be 1500 hours and 10 years.

Results and Discussion

Effect of Retting Method

The results of retting methods on fibre yield and percentage of fiber yield are given in **Table 1** with water temperature of 28-30 °C providing a significantly high fibre yield. In the case of dew retting, the process took a long time which brought above low fiber yield.

Performance of the Scutching Machine

The machine was tested for 250 hours which gave an average capacity of 35 kg of stalk per hour varying at 32 to 38 kg/h at a flywheel speed of 70 rpm. The variation was influenced by manual feeding of straw leading to non-uniform feeding. The extraction and cleanliness efficiency of the machine was 87.5 and 80-85 per cent, respectively. The machine scutched approximately 7 kg /h fibre from the stalks.

Comparative Performance of the Machines

Table 3 shows a comparative performance of the CIAE and the developed prototype machines with respect to fibre yield, fibre length and fibre fineness. **Table 3** shows that fibre yield is 17 times higher using the JST machine compared with the CIAE performance. The JST machine produced also slightly longer fibres (2.5 mm) than that of the CIAE. The fineness of fibre was also measured using a gravimetric method showing more fine fibre yield for the developed JST machine.

Cost of Operation of the Machine

The cost of operation of the machine was considered all different cost components (**Table 4**). The machine can scutch about 50 mt of stalks per year. The total cost of operation (fixed + variable) per hour was Rs. 27.88 and machine will scutch 35 kg of stalks/hour which yields 7 kg of fibre per hour and cost Rs. 210. The total cost of raw material and its processing per hour was approximately Rs. 98. The net profit with the fibre scutching machine was Rs. 112 per hr. the material.

Table 1. Retting Methods on Fibre Yield and Fibre Percentage

Method of retting	Duration in winter	Temperature (°C)	Scutched fibre yield (kg/ha)	Fibre (%)
Warm water (control)	7 days	28-30	626	29.4
Free flowing water	20-25 days	18	616	27.6
Dew retting	30 days	10	389	25.3
LSD	-	-	36	3.62

Table 2. Test Results of Flax Fibre Scutching Machine

Parameter	Mean Value
Speed of flywheel, rpm	70
Scutching capacity, kg stalks/h	35 (32-38)
Number of labour required	2
Quantity of fibre scutch, kg/h	7
Extraction efficiency, %	87.5
Cleanliness efficiency,%	80-85
Test duration, h	250

Table 3. Comparative Performance of Flax Fibre Scutching Machines

Parameter	Type of Machine	
	CIAE	JST
Fibre yield, kg/h	0.42	7.14
Fibre length, cm	60.1	62.6
Fibre fineness	2.39	2.10

Table 4. Economics of Jst Flax Fibre Scutching Machine

Parameter	Cost, Rs
Initial cost of machine	80,000
Cost of raw material required per hour	35
Cost of retting of raw material per hour	35
Fixed cost per hour	14.58
Variable cost per hour	13.30
Total cost of raw material & its processing	97.88
Total cost of fibre produced per hour	210
Net profit per hour	112.12

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Processing of Niger Seed in Small Mechanical Expellers as Affected by Post Harvest Storage and Pre-extraction Treatments

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Abstract

Niger seed is a local oil crop that in widely grown in Ethiopia. Two experiments were conducted to study the effects of three post-harvest storage periods and each of two pre-extraction treatments (heating, roasting) on oil recovery, extraction efficiency, expeller cake and the processing characteristics of the Niger seed. In each experiment, the treatments were assigned to seed samples of 7 kg. in completely randomized design with 4 replications and then subjected to extraction using a small mechanical expeller. The results obtained showed that longer storage resulted in significant deterioration and negatively affected ($p<0.01$) the recovery and efficiency indicating the need for proper post-harvest storage and handling or extraction from freshly harvested seeds. There was a significant improvement in extraction efficiency as a result of heat treatment applications ($p<0.01$). Slightly roasting improved the overall performance. However, medium and high level roasting negatively affected the performance with frequent blockage of the expeller and occurrence of higher process losses.

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Introduction

The cells of oil seed embryo contain oil in an extremely fine emulsion (Asedu, 1990) which when broken or bruised become injured to cause tiny drops of free oil to ooze out and collect on the surface. This oil could be extracted either by presses (hydraulic or mechanical screw) or by the use of solvent. The later is capable of extracting nearly all the available oil from the oilseed and the efficiency of extraction is assumed to be100%. This method of extraction generally requires higher capital expenditure and is not feasible for the small scale rural oil extraction. In contrast, mechanical screw presses are cheaper, because it is just friction and pressure that cause the heating of the mass which facilitates oil extraction (Asedu, 1990). Most small scale expellers in Ethiopia are of the screw press type. Unlike solvent extraction, oil extraction by means of expellers is naturally associated with losses and a certain percentage of the oil remains in the cake, even with the most efficient expeller.

There has been shortages of edible oil and dependence on foreign aid in many rural areas of Ethiopia. Unlike developed countries, the diets of the rural Ethiopian population could benefit from increased inclusion of oils to ensure adequate supplies of essential fatty acids (Swetman,1992) and raise calorie intakes. The high demand for edible oil in rural areas could better be met through the development of appropriate small scale oil extraction systems suitable for the local oil seeds, and through the formulation of improved extraction procedures. These would greatly help to optimize the overall efficiency of the system and good quality edible oil cheaper and readily available to the rural population. Niger seed (*Guitozia abbyssinica*) is an important local oil crop which accounts for more than half of the oil seeds processed by the small scale sector. The processing characteristics of this important oilseed have not been well studied and information in this regard is scarce. Some of the available reports indicate that low processing efficiencies are attributed to the quality of the raw material and the degree of post harvest deterioration (Tadewos, 1989, Asedu 1990). The results of experimental studies conducted on the extraction of oil from ground nut, macadamia and other oil seeds have indicated that the rate of oil recovery, extraction efficiencies and qualities of the resulting oil are affected by moisture content, quality of the seed and the type and level of pre-extraction treatments applied to the seeds prior to extraction (Macfarlane et al., 1981,Head et al., 1987, Southwell et al., 1989, Swetman et al.,1989). The operational temperatures, applied pressure and holding time also affect the extraction of oil from oil seeds (Asedu,1990). In Ethiopia efficiencies of small expellers are not usually satisfactory and the application of pre extraction treatments is not well exercised.

The objectives of this study were to investigate the effects of post-harvest storage deterioration and pre-extraction treatments (heat conditioning, roasting) on oil recovery, extraction efficiency expeller cake and related processing parameters of Niger seed using a small mechanical screw press (Tiny Tech., India).

Materials and Methods

Extraction Sample Preparation

In this study three extraction trials were conducted on a variety of Niger seed locally known as *Fogera* with mean oil content of 39.5%. Newly harvested seeds were sieved and temporarily stored in bulk at ambient conditions. The seeds were divided into three batches and randomly assigned to three different storage periods of 6, 9 and 15 months. Each of these different batches were further subdivided and put into sixteen boxes. In trial 1 four different heat conditioning treatments were assigned to each of the sixteen boxes of the three batches in Completely Randomized Design (CRD) with four replications. The heat treatments used were: control, heating in an over for 30 minuets at temperatures of 60°C, 90°C and 105°C. In trial 2, similar procedure was repeated except that heat conditioning treatments were replaced by four roasting treatments. Roasting treatments were conducted by roasting samples on an open fire of equal intensity at low, medium and high levels which correspond to 3,5 and 8 minutes of roasting time.

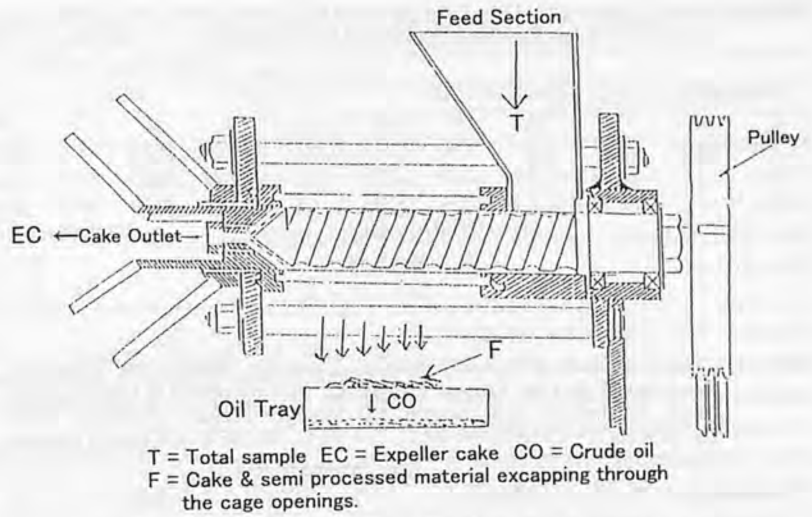

Fig.1 Section through the expeller showing the processing.

Extraction Procedures

The extraction was made using a small mechanical screw press (Tiny Tech., India) the operation of which is similar to the type of oil expellers used by small scale oil producers in Ethiopia (**Fig.1**). The expeller was powered by 5.5 kW 3-phase electric motor giving a worm shaft speed of 35 rpm. Before feeding experimental samples, the expeller was warmed up and brought to steady state operation with non-experimental sample. Cake thickness at the chock ring was adjusted to 1.5 mm at a throughput of 47 kg/hour.

The extraction was made in three batches with the application of treatments to 7 kg sub-sample prepared from each of the sixteen boxes. All trials were replicated four times and provided with untreated control treatments. Data on weight of crude oil (CO), expeller cake (EC), cake and semi-processed material escaping through the cage bar openings (F) were recorded for each treatment within each batch. The oil extraction efficiencies for different treatments were calculated for crude oil as (Head, 1990):

$$\text{Oil Extraction Efficiency (\%, OEE)} = \frac{\text{Total oil recovered (kg)}}{\text{Total oil in feed stock}} \times 100$$

The total available oil in the experimental sample was determined by multiplying the mean percent oil content of the seed with the weight of the sample. The total available oil determined by this method was 2.77kg. The recorded and calculated data were analyzed using Minitab Statistical packages. Foots content in the crude oil were also examined by monitoring the settlement of the crude oil in 1000 ml measuring cylinders over a period of 10 days for representative samples.

Results and Discussion

Heat Conditioning (Trial 1)

The mean values of crude oil recovery, oil extraction efficiently and expeller cake weight of Niger seed subjected to three different storage periods and three different

Table 1. Crude Oil Recovery (kg), Oil Extraction Efficiency (Oee) and Expeller Cake (kg) as Influenced by Heat Treatments and Length of Storage Periods (Batches). Heat Treatments: 1= Control, 2= 60°C, 3= 90°C , 4= 105°C All for 30 minutes

Batches(B)	Heat Treatments (H)											
	Crude oil (CO)				OEE %				Expeller Cake (EC)			
	1	2	3	4	1	2	3	4	1	2	3	4
1 (6 months)	2.31	2.41	2.43	2.43	83.39	87.00	87.73	87.73	4.12	4.04	4.00	3.99
2 (9 ")	2.22	2.30	2.39	2.39	80.14	83.03	86.28	86.28	4.12	4.14	4.05	4.05
3 (15 ")	2.07	2.10	2.34	2.33	74.72	75.81	84.47	84.12	4.08	4.07	4.10	4.12
	LSD (0.05):H/B = 0.02				LSD (0.05):H = 0.59				LSD (0.05):H = 0.04			
	H × B = 0.04				B = 0.51				B = 0.02			
					H × B = 1.01				H × B = 0.06			

Table 2. Cake and Semi Processed Material Escaping Through the Cage Bar Openings (F, kg) and Process Loss (P, kg by Difference) as Influenced by Heat Treatments and Length of Storage Periods (Batches) Heat Treatments :1= Control, 2= 60°C, 3 = 90°C, 4=105°C All For 30 minutes

Batches(B)	Heat Treatments (H)							
	F (kg)				P (kg)			
	1	2	3	4	1	2	3	4
1 (6 months)	0.39	0.39	0.39	0.38	0.18	0.16	0.18	0.20
2 (9 ")	0.40	0.39	0.40	0.38	0.27	0.17	0.17	0.18
3 (15 ")	0.56	0.48	0.46	0.41	0.29	0.35	0.11	0.14
	LSD (0.05):H/B = 0.01				LSD (0.05):H/B = 0.04			
	H × B = 0.01				H × B = 0.03			

Data are means of 4 replicates.
The process loss, P = T - EC - CO - F.

heat conditioning treatments are shown in **Table 1**. The lowest value for oil recovery and efficiency was recorded from the batch stored for 15 months whereas the highest value was recorded from the batch stored for 6 months. The results obtained showed that the recovery and efficiency were significantly influenced by the length of storage and heat treatments ($P<0.01$). In addition, the extent to which recovery and efficiency were influenced by increasing heat levels differed in the batches as evidenced by the existence of a significant ($P<0.01$) heat × batch interaction. All the heat treated samples gave higher recovery that the control samples. However, there was no statistically significant difference between 90°C and 105°C heat treatments in recovery and efficiency within all the batches. Optimum performance was observed for the samples heated to 90°C. This result agrees with that of Head et al. (1987) who reported optimum oil recovery from ground nut heated for 27.4 minutes at 95.6°C. Thermal treatments are reported to have the advantage of making the mass more permeable to oil flow (Asedu, 1990). At higher temperatures, evaporation within the cage is expected to result in the loss of oil with the cake, due to the high lubricating action of the oil. This phenomenon was observed when seeds heated to 105°C were processed. The observed post-harvest deterioration and the consequential loss of dry matter and decline in the quality of the seeds could be the reasons for the observed differences in oil recovery among batches.

The proportion of the weight of cake (**Table 1**) obtained from the total sample is important because some oil usually escape with the cake and affect the extraction effi-

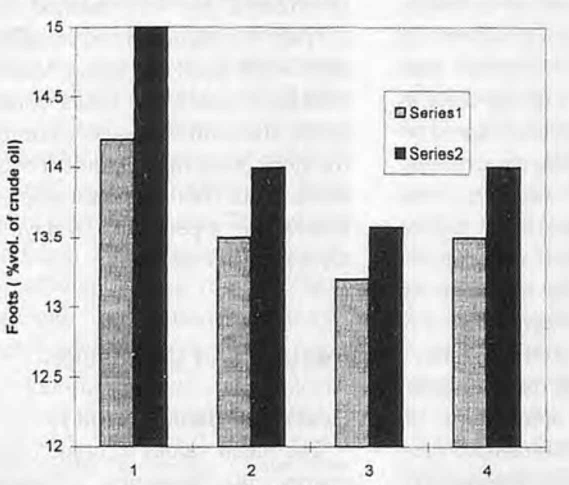

Fig.2 Foots content (% vol. crude oil) for heat treatments series. (1=batches 1 & 2, series 2=batch 3)

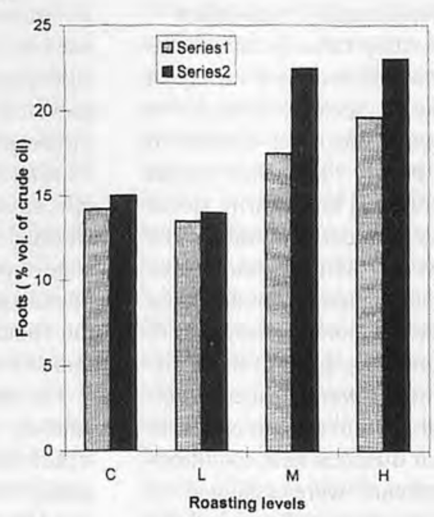

Fig.3 Foots content for roasting treatments. Roasting level: C=contraol, L=low level, M=medium level and H=high level roasting

Table 3. Crude Oil Recovery (kg), Oil Extraction Efficiency (%) and Expeller Cake (kg) as Influenced by Roasting and Length of Storage Periods / Batches Roasting Treatments : C = control, L= low, M = Medium, H = High

Batches(B)	Heat Treatments (H)											
	Crude oil (CO)				OEE %				Expeller Cake (EC)			
	C	L	M	H	C	L	M	H	C	L	M	H
1 (6 months)	2.30	2.39	2.23	1.92	83.21	86.19	80.60	69.31	4.12	4.02	3.81	3.18
2 (9 ")	2.22	2.26	2.18	1.90	80.14	81.68	78.52	68.68	4.19	4.18	3.77	3.18
3 (15 ")	2.06	2.13	2.04	1.61	74.64	76.98	73.74	58.21	4.18	4.31	3.77	3.21
	LSD (0.05):R/B = 0.02				LSD (0.05):R = 0.80				LSD (0.05):R/B = 0.03			
	R × B = 0.12				B = 0.70				R × B = 0.06			
					R × B = 1.36							

Table 4. Cake and Semi-processed Material Escaping Through the Cage Bar Openings (F, kg) and Process Losses (P, kg) by Difference) as Influenced by Roasting and Length of Storage (Roasting : C= Control, L= Low, M= Medium, H= High)

Batches(B)	Heat Treatments (H)							
	F (kg)				P (kg)			
	C	L	M	H	C	L	M	H
1 (6 months)	0.40	0.39	0.57	1.27	0.18	0.21	0.36	0.63
2 (9 ")	0.42	0.39	0.47	1.09	0.19	0.17	0.59	0.82
3 (15 ")	0.40	0.36	0.57	1.33	0.35	0.20	0.62	0.84
	LSD (0.05):R/B = 0.04				LSD (0.05):R/B = 0.05			
	R × B = 0.07				R × B = 0.08			

Data are means of 4 replicates.
The process loss, P = T - EC - CO - F.

ciency. Proper operation of the expeller is noted when cakes are escaping through the choke ring without any blockage. Thus, the amount of cake obtained could be considered as one of the basic parameters to evaluate the processing characteristics. The expeller cake (**Table 1**) was affected by storage period, heat treatment and their interaction ($P<0.01$). The batch stored for 15 months had the highest mean expeller cake weight whereas the batch stored for 6 months had the lowest value. The foots content (% volume of crude oil) of representative samples given in **Fig.2** tended to indicate that foots content increase with an increase in the length of storage period.

From the data in **Table 1**, it can be seen that the corresponding values of actual weights of expeller cake plus crude oil do not equal to the total weight of the sample processed.

This could partly be due to the evaporation of moisture during continuous expelling and the residual cake and oil remaining behind in the expeller after the completion of each run. This difference represents a process loss (**P**) considered to be important when small quantities of the raw material are processed. Since the sample processed in this study was (7 kg), the expected process loss was computed from the mass balance equation shown in foot note of **Table 2**. As shown in **Table 2**, the processing characteristics of Niger seed as measured by the process loss (**P**) and the weight of cake and semi-processed material escaping through the cage bar openings (**F**) were found to be affected by the length of storage and level of heat treatments. No blockage of the expeller was observed during the processing of heat heated samples.

Roasting (Trial 2)

The mean values of crude oil recovery, extraction efficiency and expeller cake weight of Niger seed roasted are shown in **Table 3**. There was no difference between the untreated and sample roasted at low level in moisture content. However, medium and high level roasting resulted in the reduction of the moisture content to 6.4 and 5.5%, respectively. The results obtained show that oil recovery, extraction efficiency and expeller cake weight were significantly influenced by storage period, roasting treatments and their interaction ($P<0.01$). An increase of 3.1%, 1.5% and 2.3% in extraction efficiency were obtained as a result of slightly roasting of batches of seeds stored for 6, 9 and 15 months, respectively. Batches of seeds stored for 15 months had the lowest recovery and efficiency compared to the batches stored for 9 and 6 months. Medium and high level roasting negatively affected the overall performance. Such a difference could be attributed to low moisture content, loss of oil through roasting and high fiber content remaining. The processing characteristics (**Table 4**) were not satisfactory as indicated by relatively higher process loss, frequent blockage of the expeller, reduced cake at the choke ring and decreased throughput. Furthermore, medium and high level roasting negatively affected the volume of clarified oil after gravity settlement as evidenced by high proportion of foots observed (**Fig.3**).

Conclusion

The results of this study clearly showed that extraction of oil from Niger seed using a small expeller could be improved significantly through the applications of pre-extraction heating and roasting treatments. However, proper storage and handling of the raw material or the use of freshly harvested seeds are equally recommended. Niger seed is peculiar to Ethiopia and widely grown in most parts of the country and deserves further study in the area of developing appropriate extraction technology and reducing post harvest and processing losses. Results obtained with Tiny Tech. oil mill have been found to be comparable with relatively larger size expellers around Jimma town. From a raw material of 39.5% oil content, nearly 87% of the available oil has been recovered as crude oil after heating the sample to 90 °C in the first batch. This figure corresponds to about 30 kg of clarified oil from 100kg seed. The net difference in income for the producer when applying this treatment would, therefore, be significant as large quantities are processed.

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Modification of Grain Thresher to Work with Groundnut

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Abstract

There is an acute shortage of groundnut threshers in the Sudan irrigated schemes. This situation is associated with lack of spare parts and shortage of hard currency to introduce new threshers. The delay in threshing the stacked heaps of groundnut results in the delay of the following cotton land preparation. Moreover, the groundnut heaps may act as source of rats to attack groundnut pods as well as wheat crop before combine harvesting.

A large number of stationary grain threshers had been introduced to the Sudan. This work was carried out to modify the grain thresher for groundnut threshing, in order to enhance groundnut threshing operation to mitigate the associated problems with the delay in threshing operation. The modification comprised parts that affect groundnut threshing operation (concave, soil particles sieve, seed sieve, aspirator fan pulley, threshed raw material delivery gate and bagging system (optional)). The modified parts were made to be replaceable. Their specifications and objectives were mentioned and the procedure of groundnut threshing test was explained. The modified grain thresher was found to work successfully and with high quality of groundnut yields. Its field capacity was found to be about 41% in comparison with Lilliston combine thresher capacity. Suggestions to increase the modified thresher field capacity were stated.

Introduction

Groundnut (*Arachis hypogea* L.) is an important cash crop in the Sudan. The total area under cultivation in irrigated and rainfed sector is about 1.04 million hectares (Ishag et al. 1987). About 15% of which is under irrigation yielding about 40% of the total national groundnut production (Dawelbeit, 1991).

Groundnut production is mechanized at various levels in irrigated schemes. It was reported by Dafalla et al. (1992) that about 24% of groundnut area in Rahad scheme (27,000 ha) is mechanically lifted and about 62% of the area is mechanically threshed. In New Halfa scheme (25,000 ha), 100% of the groundnut harvesting is manually lifted, but it is 100% mechanically threshed. Farmers in New Halfa scheme have been refused to accept mechanical lifting method. They think the use of digger-shaker results in high crop loss than hand lifting, but research work reveals the reverse (El-Awad, 1997). In the Gezira scheme (90,000 ha), as well as Suki scheme (5,000 ha), the groundnut is usually lifted and threshed manually. This is due to the scarcity of crop harvesting machines in these two schemes. Therefore, the groundnut is threshed using wooden threshing paddles that are obtained from the local market.

The groundnut digger-shakers and the trailed Lilliston Model 1580, PTO shaft driven combine threshers were introduced by government to New Halfa and Rahad schemes, to mechanize groundnut harvesting operations. This should make the crop more attractive and rewarding to the farmers and to alleviate the harvesting problems. Loss of optimum soil moisture content for manual lifting under heavy clay soils makes lifting difficult as plenty of pods are left in the soil. In general, the mechanization problems faced by the schemes, as reported by Dawelbeit (1991), include lack of spare parts, inadequate training, insufficient workshop equipment, absence of support services, poor management and maintenance of machinery, selection of unsuitable machinery and poor infra structure.

Farmers use Lilliston combine threshers as stationary threshers on stacked groundnut heaps (normally four heaps per field of 2.1 ha), for easy collection and bagging of crop residue as an important animal feed stuff. These machines become obsolete, and faced by lack of spare parts in the local market, contributed with shortage of hard currency to import new ones.

All irrigated schemes are of intensive cropping system. Groundnut follows wheat and precedes cotton crop in rotation. Although groundnut lifting usually starts in November, the threshing operation extends through April, particularly in New Halfa scheme, which is of 100% mechanical threshing. Generally, the delay in groundnut threshing in all irrigated schemes is due to the scarcity of groundnut threshers, high operation cost (mechanical or manual), high price of bagging sacks and lower price of the crop in local markets at the beginning of harvesting season. In effect, the delay in crop threshing may lead to the following problems;

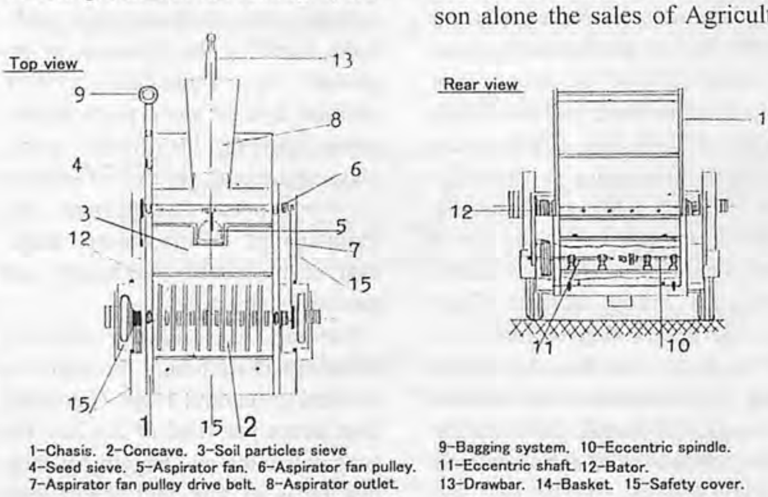
1. Delay in the following cotton deep ploughing and, consequently, delay in subsequent land preparation operations, that often leads to the delay in cotton sowing date in July;
2. The stacked groundnut heaps in fields become source of rats outbreak, that attack groundnut pods, in addition to wheat crop before combine harvesting in March, resulting in great postharvest loss in yield for the two crops; and
3. The groundnut harvesting operations coincides with the early cotton picking time (with high quality of seed cotton). Laborers prefer to work in groundnut harvesting to cotton picking. There is usually a shortage of farm labour during this period.

Therefore, mechanical threshing of groundnut would solve the above mentioned problems and would save hand labour for cotton picking, which is a backbone of Sudanese wealth.

Due to the shortage of hand labour in irrigated schemes, and for the optimization of different cultural operations, the general trend is towards the mechanization of all field crops. One of the mechanical operations, that had been accepted and adopted by farmers is the mechanical sorghum threshing, which has to be done after manual heads cutting (using sickles) and collection of naturally dried heads in heaps. Mechanical threshing is carried out using stationary thresher, driven by the tractor PTO shaft. It is a quick operation with high quality grain in comparison with manual threshing (using paddles), which depends on unpredictable natural air velocities for grain and straw separation. Therefore, the Sudan Agricultural Bank and other agencies introduced a large number of Turkish stationary grain threshers, driven by tractor PTO shaft, and sold to the farmers. In the 1997 season alone the sales of Agricultural Bank, showed that 1,553 grain threshers were bought by the farmers. Then these machines became available throughout all agricultural schemes. The machine was designed to work with a wide range of grain crops, but not with groundnut.

The starting sequence of sorghum and groundnut threshing is in October and December, respectively. Therefore, the proper modification of grain thresher would make it to work also with groundnut. Hence, it would be more profitable to the farmer and would enhance groundnut mechanical threshing with high quality of groundnut yields.

For the above reasons, the available grain thresher was modified to meet the requirements of groundnut threshing. This is necessary in order to alleviate the problems associated with the delay in threshing operation, and to compare the modified thresher capacity with the Lilliston combine thresher as a commercial groundnut thresher in irrigated schemes.



1-Chasis. 2-Concave. 3-Soil particles sieve 4-Seed sieve. 5-Aspirator fan. 6-Aspirator fan pulley. 7-Aspirator fan pulley drive belt. 8-Aspirator outlet. 9-Bagging system. 10-Eccentric spindle. 11-Eccentric shaft. 12-Bator. 13-Drawbar. 14-Basket. 15-Safety cover.

Fig.1 Main parts of modified grain thresher. (Oztarim, Dis. Ticaret A.S.)

Modified Parts

The Oztarim grain thresher, Model HMT-1200-SPX, was chosen for the modification work in the 1996/97 season. Some parts that affect groundnut threshing operation were identified prior to the machine test, while others were identified and adjusted throughout the micro-threshing tests. Finally, the following parts were designed and assembled to suit the groundnut threshing requirements (figures in parenthesis represent the serial number of the modified part as shown in **Fig.1**):

1. The concave (2);
2. The soil particles sieve (3);
3. The seed sieve (4);
4. Aspirator fan pulley (6);
5. The threshed raw material delivery gate (not mentioned in the drawing); and
6. Bagging system (optional) (9).

The thresher main parts and the modified parts locations are shown

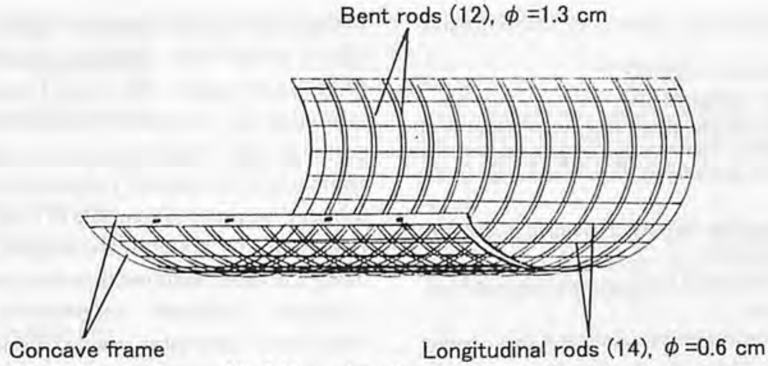


Fig.2 Groundnut threshing concave.

in **Fig. 1**.

The concave

The dimensions of the locally made groundnut concave (**Fig. 2**) were similar to the grain crops' concave. It consisted of a metal frame with dimensions of 118.5 × 119cm. The cross sectional area of the metal was 0.6 × 3.8cm, in order to withstand the welding heat without irregularity in the normal shape of concave frame. Before welding, the two sides of the frame (119cm) were bent in half a circle of 78 cm in diameter. Then 12 metal rods, each of 1.3 cm in thickness, were bent in parallel to these two bent frame sides and welded in spacing of 9 cm, to the inner surface of the two horizontal sides (118.5cm) of the concave frame. The 14 metal rods of 0.6 cm thickness were welded longitudinally in spacing of 8 cm, to the inner surface of the two curved sides. The purpose of the formed 9 × 8 cm network was to facilitate smooth and quick delivery of the threshed raw material from the threshing unit and to avoid the breakage of groundnut pods. Moreover, it helps in breaking the dry crop vines into small pieces for easy and quick propelling by the aspirator fan.

The soil particles sieve

The soils of irrigated schemes contain about 50-60% clay. Therefore, to facilitate crop lifting with minimum crop losses, a light watering before manual lifting is essential. Consequently, clay particles adhere to groundnut pods. The main objective of this sieve was to separate the soil particles after the detachment from pods in the threshing process. The sieve was provided from storage tank of scraped Lilliston combine thresher. The openings of the network were diagonal with diameters of 2.5 and 1cm. It was laid in the middle of the shaker. Its dimensions were 95 × 115cm.

The seed sieve

This sieve was located after the aspirator fan area. Its dimensions were 47 × 115cm. It consisted of a metal frame similar to that in the concave frame. Eight metal rods of 0.6 cm thickness were welded longitudinally and crossed by 22 welded rods, forming a network of 4.5 × 4.5cm. Its function was to allow the delivery of the clean pods to the bagging system and to prevent the passage of longer vines.

Aspirator fan pulley

For clean pods without trashes and with the least vines, the original pulley, which was of 20 cm in diameter, was replaced by a smaller one of 15 cm diameter. The small pulley was of a single belt grove and provided from scraped Lilliston combine thresher. The objective was to increase the fan speed and, consequently, the air velocity suction in order to result in clean pods. Then a 118B-drive belt was purchased from the local market.

The threshed raw material delivery gate

This is a gate that allows the passage of the threshed raw material from the threshing unit to the soil particle sieve. Because groundnut crop is bulky and light in weight, then the gate between the sieve and the lower end cover of the threshing unit was increased vertically by 14 cm more. This was done through the cutting of the sheet cover at the two end sides and bent upwards. This was to result in a total vertical distance of 27 cm from the surface of the soil particle sieve. This could be made as an adjustable flap, to be razed for groundnut threshing and lowered for other grain crops.

Bagging system (optional)

The principle of the design was similar to the original one, but it differs in the shape and dimensions. In this system the chute was made of barrel sheet with a cross sectional area of 15 × 15cm. The purpose was to facilitate quick propelling of large quantities of crop pods, in addition to the passage of vines, if any, without clogging. Some stationary grain threshers are not provided with bagging system and, consequently, no propelling fan. The clean grain seeds have to be collected on ground placed burlap and then to be bagged manually. The same could be applied to the modified thresher by disconnecting the bagging system when it is used for groundnut threshing.

Placement of Groundnut Threshing Parts

All the designed and assembled parts to meet the requirements of groundnut threshing were made to be replaceable. Therefore, the parts for grain threshing were removed and replaced by the adapted parts for groundnut threshing.

Testing Procedure and Analysis

The modified groundnut thresher

Table 1. Groundnut Threshing Operation Performance as Affected by Tractor Engine Speed

Tractor engine Speed (r.p.m.)	Observation on threshing operation performance
800	Slow movement of shaker that did not allow forward movement of threshed raw material. As a result, there was a blockage at delivery gate by the threshed material, and grinding of the raw materials in the threshing unit.
900	The movement of shaker facilitated the forward movement of threshed raw materials and clean collected pods.
1,000	The rate of forward movement of threshed raw materials was increased, and with cleans collected pods also.
1,100	Faster movement of threshed raw materials that facilitated high feeding rate and clean collected pods. No groundnut pods breakage was observed.
1,200	Very high movement of shaker did not permit clean pods to pass from aspirator fan area to the seed sieve. This speed caused the appearance of broken groundnut pods and seeds.

Table 2. Technical Data on Thresher Shafts Speed in Relation to Tractor Engine Speed (r.p.m.)

Tractor engine	PTO shaft	Bator shaft	Shaker shaft	Aspirator fan shaft	Propelled fan shaft
900	465	403	280	900	2955
1,000	513	430	310	970	3145
1,100	560	450	320	1022	3525

Table 3. Effects of Modification on Groundnut Threshing with Reference to Threshed Farmers' Samples

Tractor engine	Sample	% age by weight			% age by volume		
Speed (r.p.m.)	Weight (kg)	Pods	Soil	Vines	Pods	Soil	Vines
900	33.5	70	26	4	82	9	9
1,000	35.9	71	24	5	82	8	10
1,100	22.7	70	26	4	82	9	9
Thresher means	30.7	70.3	25.3	4.3	82	8.7	9.3
* F. S. (1)	53.7	38	57	5	60	27	13
F. S. (2)	42.0	60	37	3	79	14	7
F. S. means	47.9	49	47	4	69.5	20.5	10

*F.S. = Farmer's sample.

was tested with groundnut of 6% moisture content, for mixed sample of pods and vines. The moisture content was determined using an electric oven for six hours at 130℃. Then the following observations were recorded on the thresher performance:

Threshing Operation Performance

After assembling all the adapted groundnut threshing parts, a 685-International Case tractor was used for operating the modified thresher. The tractor engine speed, (using engine revolution gauge), was taken as a reference for thresher shafts speed, including the tractor PTO shaft. Different engine speeds were tested to identify the suitable speeds of thresher shafts for high crop delivery rate and high quality of threshed pods. The observations on groundnut threshing performance are shown in **Table 1**.

Threshing results indicated that the suitable tractor engine speeds were in the range of 900-1,100 r.p.m. Then the corresponding speeds of thresher shafts were determined using a tachometer. The technical data are presented in **Table 2**. However, in fields, the optimum threshing operation speed could be achieved through the observation of high delivery rate of threshed raw material and clean collected pods without breakage.

Comparative Threshing Performance

The effect of each tractor engine speed, of the three selected speeds (900, 1,000 and 1,100 r.p.m.) was evaluated on threshing operation performance. Then the results were compared with randomly chosen two farmers' samples (F. sample (1) and F. sample (2)), which were threshed using Lilliston combine threshers as stationary threshers (commercial threshers). Each sample was of one full sack and its weight was determined. The custom among farmers is to sell and buy groundnut by volume (full sack) and not by weight. Hence, in addition to the evaluation of threshing performance by weight, it was also evaluated by volume. Therefore, the comparison criteria comprised the percentage by weight and by volume for clean pods, mixed soil particles and vines for each sample, after manual separation in the laboratory.

The three selected tractor engine speeds were found to result in similar threshing performance (**Table 3**). Therefore, for economic fuel consumption, the tractor engine speed should be increased with the increased thresher-feeding rate and vice versa. The comparison of threshed samples by the modified thresher with that threshed by the commercial threshers indicated that the modified thresher resulted in high percentage of net clean pods and lower percentage of mixed soil particles by both weight and volume. The percentage of mixed vines were found to be similar by weight and volume for both thresher types. These results indicated the superiority of the modified thresher over the commercial threshers in relation to yield quality. However, for a given crop volume, the lower percentage of mixed soil particles, the greater percentage of crop pods by both weight and volume (**Table 3**). The lower percentage of mixed soil particles with the use of modified thresher, could probably be due to the strong action of hitting by bator that would result in the detachment of consider-

Table 4. Thershers' Capacity (time taken to fill one sack)

Machine type	Reps.	Time taken		Remarks
		Min	Sec.	
Modified thresher	1	4	00	(Untrained daily labores for threshing operation. They used hands for feeding).
	2	3	36	
	3	3	36	
Average time		3	44	
Lilliston 1580	1	1	31	(Trained labores for threshing operation. They used wooden forks for feeding.)
	2	1	45	
	3	1	17	
Average time		1	31	

able amount of adhered soil particles to the pods. On the other hand, the similarity in the results of mixed vine percent for both threshers indicated the suitable revolutions of aspirator fan of modified thresher for groundnut cleaning in comparison with the commercial threshers. However, results obtained with the commercial threshers agree with Dawelbeit (1991) who concluded that the mechanical threshing using Lilliston combine thresher requires a supplementary cleaning.

The obtained results indicated the success in the modification of the grain thresher to work successfully with groundnut and with higher quality of collected pods in comparison with commercial threshers.

Modified Thresher Capacity

For the modified thresher capacity determination, the moderate tractor engines speed of 1,000 r.p.m. was selected. Seven daily laborers were used in the threshing operation. Three of them were for crop collection from the heap, two for thresher feeding and two for filling and moving sacks and also for displacement of separated soil particles from underneath the soil particle sieve, to prevent the blockage of sieve openings.

According to the above-mentioned conditions, the thresher capacity was expressed in time required to fill one sack, which replicated three times. The length of time was determined using a stopwatch. Moreover, to ascertain the modified thresher capacity, it was compared with Lilliston combine thresher as stationary thresher also (commercial thresher). The modified thresher capacity was expressed as percentage of the commercial thresher. Data on commercial thresher were provided by Sir El Khatim (1998) (personal communication) at Rahad irrigated scheme. The commercial thresher was used with a Fiat tractor and also with seven laborers also. Three of them were used for displacement of crop from the heap. Three others were for pushing the displaced crop towards the thresher pickup cylinder. All of were using long wooden forks in the operation. The seventh laborer was used to detach the filled sack and attach the empty one to the thresher chute. Here again, the time taken to fill one sack was recorded and replicated three times. Results are shown in **Table 4**.

The modified thresher capacity percent as compared to commercial thresher (Lilliston 1580) was determined by dividing the average time for commercial thresher to fill one sack (91 sec.) by the average time for the modified thresher to fill one sack (224 sec.) multiplied by 100%. Then the modified thresher capacity was found to be about 41% in comparison with commercial thresher capacity.

Other Characteristics of Modified Thresher

1.One of the merits of the modified thresher in comparison with a commercial thresher is that considerable amount of groundnut heap remainder, that contains a mixture of pods, soil and trashes could easily and efficiently be separated when fed by carry baskets or hessian cloth to the modified thresher, even if it is placed on the soil particles sieve. With the commercial thresher, the separation of pods from the heap remainder that could not be removed by wooden forks, hence had to be done manually. This operation is very slow, time consuming and costly.

2. After the end of sorghum threshing season, the grain threshing parts could easily be replaced by the designed and assembled parts for groundnut threshing and vice versa.

Future Investigations

The major area for future investigations is the increase of modified thresher capacity. This could be increased as follows;

1. By increasing the basket feeding area horizontally to occupy more than two feeding labours;

2.By connecting the crop elevator to facilitate quick and smooth feeding operation;

3.For quick and easy displacement of separated soil particles from underneath the sieve, an inclined sheet metal could be fixed to the shaker and below the soil particle sieve, in order to direct the separated soil particles to the side of the thresher for further removal by the laborers spade. This method permits the thresher to work for a longer period of time without changing its position.

(Continued on page 74)

Optimal Farm Plans for Tractor Capacity and Analysis of Tractor Use in Vegetable Farms, Bursa Province, Türkiye

by
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Abstract

The purpose of this research was to determine the optimal farm-size in order to maximize farm income and to investigate whether the tractors were used rationally or not in the Bursa province of Turkey.

It was known that a lot of factors affect optimum farm-size, such as farm structure, technical specifications of the farm machines, land irrigation status, soil type, farm mechanization level in using farm machines efficiently or not.

The main data for this study was collected through interviews from 183 farmers, selected by sampling of tractor-owner farmers in Bursa province.

In the research area, the tractors work about 362 hours in a year. The findings show that, the power of tractors in a unit area was 4.78 hp/ha and one tractor works in approximately 11.72 hectares of farmland in the research area. The tractors are used for an average of 259 hours (71.54%) at the agricultural work 48 hours (13.26%)non-agricultural work and 55 hours (15.12%) for works of others.

The required acreage was determined at 32.6 hectares for a tractor capacity under optimal farming conditions, taking consideration available production possibilities and resource restrictions, by using linear programming (LP) method. The findings also found that the farmers with larger than 21 hectares used their tractors rationally.

Introduction

Turkish agriculture has emerged from a traditional structure to an industrialized one and farms have become more market-oriented rather than being subsistence ones as family farms, especially in the planning period since 1960.

As a result of intensive farming a 2-10 fold increase has been achieved in the yields of most agricultural products. In spite of this considerable progress, Turkish agriculture still has important problems which generally seems common in most developing countries, i.e., farm lands are always divided into small parts from generation to generation because of inheritance laws. In Turkey, mainly due to the inheritance laws, most farms are very small in size and farm lands are scattered and fragmented. This structure of agriculture creates difficulties using modern technology such as irrigation, plant protection, fertilizer use, and especially agricultural mechanization.

It seems clear that these factors (technical, structural and economics) have negatively affected the economic efficiency of the farm units and the use of tractor and other equipment.

Materials and Methods

The study areas were Karacabey, Yeni ehir and M.Kemalpa, districts of Bursa province, where intensive farming is observed, especially for vegetable growing. The results of some previous studies have been used as reference materials in addition to the data were collected in a field survey with the 183 farms selected by random sampling.

In order to make a comparative analysis of vegetable growing economy farms under both current and after planning conditions, linear programming (LP) technique was used to determine optimal production patterns and economic evaluation of tractor-use.

Linear programming deals with

the problem of determining feasible plans which are optimal with respect to a certain agreed-upon linear objective function; in particular, it determines a plan which maximizes or minimizes some linear function over all possible feasible plans. The feasible plans are those that satisfy certain restrictions which are usually in the form of a system of linear inequalities. Hence linear programming is defined in terms of a mathematical model composed of linear functions, in which programming is used as a synonym for planning; linear programming involves choosing activities in such a way as to obtain an optimal program. An optimal program is defined as a feasible plan which maximizes (or minimizes) some linear function, or objective function, from among all possible feasible plans.

The maximization (or minimization) of the objective function is subject to certain linear constraints. The usual way of writing a maximization problem in a matrix form is

Maximize $Z=C'X$

$AX \leq, \geq$ or $= B, \quad X \geq 0$

Where A is an m × n matrix of technical coefficients, C is an n × 1 vector of prices or other weights for Obj. Funct. X is an n × 1 vector of activities,

B is an m × 1 vector of resource or other restraints, and a $C'X=Z$ is the objective function. This problem can be written as:

Maximize $Z= C_1X_1+C_2X_2+........+C_nX_n$ subject to

$a_{11}x_1+a_{12}x_2+..............+a_{1n}x_n \leq b_1$

$a_{21}x_1+a_{22}x_2+..............+a_{2n}x_n \leq b_2$

. . .

. . .

. . .

$a_{m1}x_1+a_{m2}x_2+...........+a_{mn}x_n \leq b_m$

$x_1 \geq 0, x_2 \geq 0.................x_n \geq 0$

In a compact form the problem can be rewritten as

Maximize $Z=\sum_{j=1}^{n} c_j x_j$ subject to

$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \qquad x_j \geq 0$

where

$i=1,2,...,m$; and $j=1,2,...,n$

In designing the linear programming models for these farm production plans, I used both the average values of the data collected from our sample and the findings of former studies related to the subject (1,2,3).

In the construction of the farm models, I accepted the following limiting factors in production activities: cultivated area, amount of labor, available in terms of hours of man labor, the number of work days for different production activities (soil cultivation, maintenance, harvesting, etc.), size of cattle barns (in square meters), crop rotation from the aspect of soil fertility and market conditions.

Table 1. Production Patterns and Economic Results of an Average Farm under Different Conditions

Enterprises	Unit	Production Pattern	
		Current Situation	Planned Situation
Cereals	Ha	3.64	1.32
Industrial crops	Ha	1.23	1.84
Vegetable	Ha	2.48	3.72
Feed crops	Ha	0.96	1.43
Milk cows (per head)		1.32	1.78
Gross margin (Milyon TL* / Ha)		1245.8	1385.32
Increase in (6) with planning (%)		-	11.12
Required tractor (hours)		148.70	223.50
Idle power(%)		57.76	36.51
Gross margin index/per tractor hours		100.00	112.00

*1US$= 210,000 TL.

Results and Discussion

The average total area of the study farms is 8.31 hectares. The farmlands are used for the cultivation of cereals, (43.8), industrial crops (14.8%), feed crops (11.5%), and vegetables (29.9%). The level of input use by farmers has gradually increased, especially during the last 30 years. These inputs include machinery, fertilizer, herbicides and pesticides, and high quality seed. During the 1970s, the numbers of tractors and combines in the province were 18,811 and 196, respectively, increasing to 29, 896 and 271, respectively in 1995 (4).

The major crops grown in the dry-farming areas are wheat, barley, sunflower and, especially vegetables such as tomatoes, pepper, leak, cucumber, and bean.

Idle capacity in tractor-use has been relatively decreasing by farm planning. After the planning conditions idle power capacity has decreased from 57.76% to 36.51%, i.e., 21.25% decrease in the idle capacity of tractors after the planning conditions. The increase achieved in the gross margin per tractor was 12% after the planning.

On the other hand, in this study, the prices taken for various agricultural work in unit area and the mechanization costs were compared and tested whether the tractors were used rationally or not. According to the findings the farmers with larger farms than 21.7 hectares used their tractors rationally, and the small ones used occasionally.

Conclusions

The tractors in developing and their necessary equipment are rather low when compared the developed countries.

The important conclusions drawn from this study area;

More than half (63.7%) of the

farms in the province are small farms (under 10 hectares in size). In addition to the small size of these farms, their holdings are scattered and fragmented. This situation has negatively affected the economic efficiency of the small farms. Small farm size structure creates higher idle power and idle labor capacity which is the main reason of the low productivity of production.

If the production could be realized under planned condition, a considerable increase could be achieved both in gross margin per hectare and per tractor hours via efficient use of scarce resources and decreasing the idle capacity in tractor hours.

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(*Continued from page 71*)

Modification of Grain Thresher to Work with Groundnut

Conclusion

With the specifications of the designed and assembled parts for groundnut threshing, the threshing test results indicated the suitability of the modified thresher to work successfully with groundnut.

Although the modified thresher capacity is lower than the commercial thresher, its availability and distribution over all irrigated schemes, would improve the groundnut threshing.

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ABSTRACTS

The ABSTRACT pages is to introduce the abstracts of the article which cannot be published in whole contents owing to the limited publication space and so many contributions to AMA. The readers who wish to know the contents of the article more in detail are kindly requested to contact the authors.

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Energy Requirement for Processing Green Tea Leaves, India: L.S. Yadav, Dept. of Agricultural Engineering, North Eastern Regional Institute of science and Technology, PO, Nirjuli 791109, Arunachal Pradesh, INDIA, A.P. Srivasta, Agricultural Engineering Division Indian Agricultural Research Institute, New Delhi-110012, INDIA

In order to determine energy requirement for processing green tea leaves, a study was carried out in selected districts of Assam state. The data pertaining to year 1994-95 was collected. It was found that the "rolling" system was electrical-energy intensive, while the sun drying method was most least energy intensive. Sorting and packaging were found to be least energy intensive also. The requirement of human energy for withering and fermentation was greater than remaining operations. The tea leaves from large plantations use of modern equipment and oil energy for drying on large estate resulted in a reduction of total energy as compared to small and medium ones.

831

Use, Availability and Failure Patterns of Tractor-Drawn Vertical-Conveyor-Reapers under Farmers' Conditions: Er. Pawan Kr. Tuteja, Er. S.C.L. Premi, Department of Farm Power and Machinery, CCS Haryana Agricultural University Hisar-125004, INDIA. Dr. S. Arya, Hon'ble Vice Chancellor, CCS Haryana Agricultural University Hisar-125004, INDIA. Dr.K.L.Gulati, Department of Physics CCS Haryana Agricultural University Hisar-125004, INDIA.

The studies were conducted in Hisar and Sirsa districts of Haryana (India) to collect information about specifications, pattern of use, failures, down time and availability of tractor-drawn vertical-conveyor-reapers, through field interviews using a sample size of 51 machines spread over 37 villages.

It was observed that the total average annual-use of the vertical-conveyor-reaper was 58.84 hrs. The average annual-availability and down-time-ratio was observed to be 0.740 and 0.256, respectively. The age of the machine had an adverse effect on use, down-time, and availability. The constants for three parameters of Weibull failure probability density function were determined for the crop-cutting-system, rest-of-machine and machine-as-a-whole. Mean-time-between- failure for crop-cutting-system, rest-of-machine, and machine-as-a-whole were 33.05, 38.00 and 32.33 hrs, respectively. The reliability for crop-cutting-system, rest-of-machine, and machine-as-a-whole was 0.436, 0.346 and 0.405, respectively. Hourly failure rates at MTBF for crop-cutting-system, rest-of-machine, and machine-as-a-whole were 0.046, 0.026, and 0.036, respectively.

846

Study into Food Extruder Die 1: Design Considerations: Kehinde Adekola, Nigerian Doctorate Student, Dept. of Agricultural Engineering, Jilin University of Technology, 130025, Changchun City, P.R. CHINA. Ma Cheng-lin, Professor, Dept. of Agricultural Engineering, Jilin University of Technology, 130025, Changchun City, P.R. CHINA.

A brief review of food extrusion cooking process and research works in the area of food extrusion technology is given. The importance of die in the extrusion process is emphasized. It is observed that until very recently little research work is carried out on extruder die and the processes taking place within the die. In the light of this, this paper highlighted the areas needing research efforts in relation to food extruder die which will lead to improvement of the entire extrusion process. Finally, a multipurpose die system is designed.

941

Air Flow Through Packed Fresh Fruits: A. H. Raval, Associate Professor, College of Agricultural Engineering & Technology, Gujarat Agricultural University, Junagadh-362 001, INDIA. Rajvir Yadav, Associate Professor, College of Agricultural Engineering & Technology, Gujarat Agricultural University, Junagadh-362 001, INDIA. H. K. Saxena, College of Agricultural Engineering & Technology, Gujarat Agricultural University, Junagadh-362 001, INDIA.

A designer of the cooling system must have information about the pressure drop with the velocity of the air flow. This information will serve to design precooling facilities of appropriate sizes in order to achieve the desired cooling rates without wasting energy on excessive air velocity, or having shortage of air quantities. In the present investigation pressure drop a function of air flow, in a vent area was measured for different layers of apples in the direction of the air flow 10, 20, 30 and 94 percent. Equations were developed for prediction of pressure drop of packed spherical fruits in cartons as related to air flow rate and vent area, and number of layers. ■■

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BOOK REVIEW

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