International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

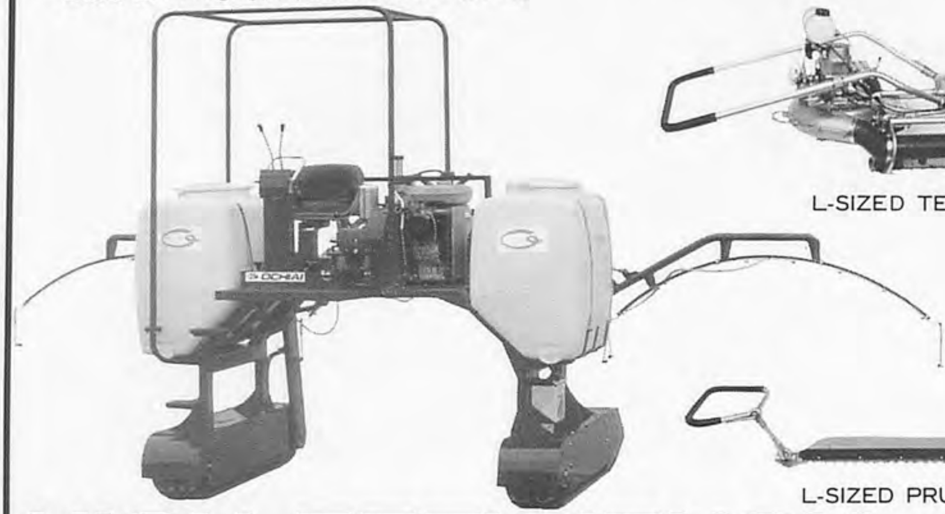
AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

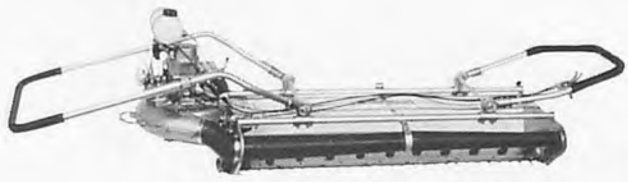
VOL.30, NO.4, AUTUMN 1999

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

OCHIAIi is the top-ranking tea-leaf piker manufacturer in Japan. OCHIAI's products are used in tea-producing areas worldwide.

OMS-2 Riding type pest control machine



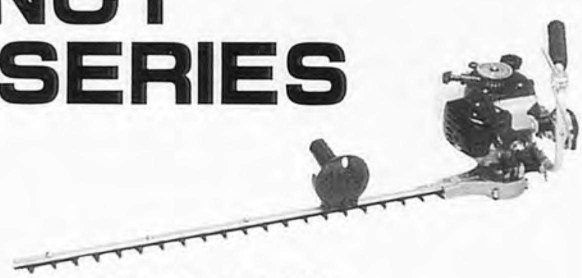


L-SIZED TEA PLUCKER *V-8*

L-SIZED PRUNER *R-8*

HIGH-EFFICIENCY RIDING TYPE SERIES

OM-25 Full-width tea picker



ENGINE PRUNER *E-6*

GUIDE TO OCHIAI

- Succeeded in devising Japan's first automatic tea-leaf picker in 1959.
- Received the Director of the Board of Scientific Technology Award in 1967.
- During the intervening period (1959-1967) obtained a number of patents, as well as receiving a variety of awards and prizes in the domain of science and technology.
- The top-ranking tea-leaf picker and tea-tree trimmer producer, holding 60% of the shares in the same line of business in Japan, surpassing the other manufacturers in sales and product, and leading the related business worlds in its expansion and development.

OCHIAI HAMONO KOGYO CO LTD

OCHIAI-SHOJI CO., LTD.

Head Office: 58, Nishikata, Kikugawa-cho, Ogasa-gun, Shizuoka-ken, Japan
Tel. Kikugawa (05373) 6-2161~5 Telex 03965824 STPA J ATTN OCHIAI

CONTRIBUTORS WANTED

This publication, published quarterly, has an objective to promote agricultural mechanization in developing countries. Its readers consist of so many people in various fields such as farmers, dealers, manufacturers, researchers, government officials, students, etc. not only in Asia but also in the whole world. To enrich contents and to reflect many opinions, we want contributors for **Agricultural Mechanization in Asia" Africa and Latin America**. Articles, comments, investigations, reports and so on will be received with open arms. If you hope to contribute, contact us without delay.

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

7-2 Kanda Nishikicho, Chiyoda-ku, Tokyo, Japan (Tel. 03/291-5717-8, 3671-4)

International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.30, NO.4, AUTUMN 1999

Edited by

YOSHISUKE KISHIDA

Published quarterly by

Farm Machinery Industrial Research Corp.

in cooperation with

The Shin-Norinsha Co., Ltd.

and

The International Farm Mechanization Research Service

TOKYO

Editorial, Advertising and Circulation Headquarters
7, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan

SHIN-NORIN Building
7, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan
Printed in Japan

This is the 105th isssue since its maiden isser inthe Spring of 1971

EDITORIAL

Disputes of Many Kinds

Regional disputes take place in many parts of the world from time to time. Currently, the world is watching how things shape up and how peace is restored after the arrival of the UN peace-keeping forces in East Timor.

Sometime ago, the author predicted that regional and ethnical disputes would increase in some parts of the world during the post-cold war period as oppressed people's insistence and dissatisfaction would sooner or later explode. And his prediction seems prophetic as regional disputes of many kinds erupt then and now.

On the earth's surface these days, economic and technical gaps are producing some kind of disputes as the gaps expand from day to day. These gaps are disseminated worldwide through such media as the TV, newspapers, internet and so on. One of these relevant disputes pertains to farming which is regarded as a lowly occupation considering some kind of exodus of the youth from the farm to urban areas - a demographic feature that contributes to economic poverty, particularly in developing countries. Agriculture seems to be looked down as it brings little profit for hard work. Even in the United States, similar scenarious are happening, i.e., not a few youngsters leave the farm where they have been raised in favor of large cities.

Why is agriculture looked down upon when it is the sector of the economy that produces food for mankind? In this regard, another dispute in technical terminology is evident, i.e., in the field of agricultural engineering, the term "agriculture" is now being replaced by such words as "bio" or "ecology". It is another way of adding glamour to agriculture, or, is it an attempt to further downgrade the dignity of farming as an occupation?

If we hope to live in a peaceful world from the 1st century on, it is of paramount importance to give farmers a break in terms of making them a little bit prosperous. After all, they comprise about half of the world's population. Consumers or non-farmers in cities should have more respect to agriculture and the eco-system, including their willingness to spend more on food as an indirect way of helping the farmers.

As always, The AMA readers and contributors are asked to join hands in a common endeavor to find solutions to the problems that beset the agriculture industry.

Yoshisuki Kishida
Chief Editor

Tokyo, Japan
October, 1999

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol.30, No.4, Autumn 1999

★ ★ ★

Seed Placement Behaviour of Sunflower Planter

by

A.M.Chauhan
Professor
Deptt. of Farm Power and Machinery
P.A.U. Ludhiana,
India


B.S. Bhatia
Professor
Deptt. of Farm Power and Machinery
P.A.U. Ludhiana
India


H.S.Dhingra
Senior Research Engineer cum Head
Sr.Ext .Specialist and
Asstt. Professor
Deptt. of Farm Power and Machinery
P.A.U. Ludhiana, India

Abstract

This paper refers to the study of sunflower planter, developed after suitable modification in multi-crop planter. Its metering performance in terms of seed placement, speed of operation, cell filling percentage, etc. was studied, both in laboratory and in field conditions. The percent cell filling and multiples in the planter was found to a have reverse trend. Whereas the percentage of missing cells varied directly with the speed of operation. The appropriate speed was in the range of 2.0 to 3.5 km/h.

Introduction

The sunflower crop was introduced in Punjab in order to diversify the existing cropping pattern and thereby rejuvenate the fragile agro-economic system. Growing of conventional crops, particularly paddy-wheat rotation for the last many years, has posed some serious problems like stagnation of farm productivity, depletion of water and soil resources and multiplication of pests, diseases and weeds. This has started creating an imbalance in the agro-ecological system at a fast pace.

The sunflower is an important oil seed crop. Being a short duration crop of about 16 weeks, it can be conveniently fitted into various crop rotations. It can be successfully grown after potato, cotton and rapeseed.

Areas planted to sunflower crop in Punjab is gradually increasing. In 1988, the crop was grown over an area of 20,000 ha resulting in 25,000 tons of seed production. At present the area planted to sunflower is about one lakh ha with a seed-production of 80,000 tons.

A few problems of technological inaptitudes, particularly in mechanization of sunflower cultivation, are being experienced in respect of some labour intensive operations like sowing and threshing. Some concerted efforts have been made by experts in developing appropriate farm machines for these operations. Success to a considerable extent, has also been achieved, especially in the case of threshing of the crop. However, some more work needs to be done for mechanizing the sowing operation of the sunflower crop.

Presently, sunflower is, by and large, sown either by hand dibbling or behind the plough (Kera). Dibbling, though, is a precise method but most cumbersome and thus not economical due to much higher time and labour requirements. On the other hand, sowing behind the plough gives the most erratic seed distribution in the rows which increases the undesirable seed rate involving higher cost and affects the yield adversely. Keeping these facts in view, a project for the development and evaluation of proper seed metering mechanism for mechanical sowing of sunflower was started at the Punjab Agricultural University in 1989-90.

During the last four years, the existing metering mechanisms, namely; vertical grooved disc (Bhadson type seed drill), fluted rollers and inclined plates (multicrop seed drill-cum-planter) were tried for sunflower planting. Consequently, an inclined seed plate with appropriate cell size and shape was developed and thereby desired changes in the transmission system of the multi-crop seed drill-cum-planter were also incorporated to make it suitable for the planting of sunflower, mechanically. Results of the trials so far achieved are quite encouraging. However, a detailed investigation in respect of proper seed rate and germination pattern of seeds delivered by the machine, has not been studied. Therefore, a study for bridging this empirical gap was planned with the following specific objectives:

i) To ascertain cell fill of different seed plates of planter;

ii) To study the distribution pattern of seeds delivered by the planting unit in different rows; and

iii)To compare the seed rate accuracy of the planter with the conventional methods of sowing sunflower.

Review of Literature

Robinson (2) studied the effect of seed spacing on the yield of sunflower. The results showed that a uniform spacing of seeds lead to higher yields. However, it was also suggested that there was no need for embarking on a hair-spliting exercise in seed spacing because of giving a reasonable distribution of seeds, sunflower crop has the ability to compensate to some variation in seed spacing.

Singh (3) designed and developed a two-row tractor drawn ridge planter for winter maize. The inclined plate metering mechanism was mounted on a commonly used three bottom ridger. The planter was tested in laboratory as well as in the field. The observations taken in the laboratory tests show that 50 seeds can be deliverd in a strip of 10 m maintaining the recommended seed-to-seed spacing of 20 cm. The results from field tests varied from those obtained in the laboratory.

Heyns 1) evaluated different types of seed planters at four speeds (6,8,10 and 12 km/h) on maize and beans. The five different planters used were: horizontal seed plate type, inclined-seed plate type, finger wheel pick-up type, pneumatic type and perforated rubberbelt type.

The pneumatic metering system did an excellent metering of seeds at all speeds ranging from 4-12 km/h with few missings and doubles primarily due to a small seed drop height.

The mechanical metering system such as the horizontal seed plate, finger wheel pick up, inclined seed plate and perforated rubber-belt types showed comparable performance at lower speeds (4-6 km/h) but with an increase in speed both metering accuracy and uniformity of spacing deteriorated considerably.

It was concluded that pneumatic type of metering mechanism had an edge over the other types of mechanisms as far as metering accuracy and uniformity of seed distribution were concerned.

Materials and Methods

A sunflower planter is essentially an attachment which can be fitted to any existing 9-row seed-cum fertilizer drill. This employs an inclined plate metering mechanism for larger seeds such as maize, groundnut, cotton soybean, sunflower etc. It consists of six seed plate housings for planting, which were equally spaced in a common box fixed rigidly at the back of the drill. The box has been at a height of 45 cm from the ground level to keep the drop height of seeds to the minimum possible to minimize the non-uniformity of seed spacing.

In order to determine the cell fill, the planter was mounted over the testing rig and was driven through a 3-phase electric motor. The intended speeds for the seed plates were selected as 13,23 and 32 rpm corresponding to the planter forward linear speeds of 2, 3.5 and 5 km/h, respectively. Seeds dropped in one minute through the tubes for all three speeds, were collected and thus the cell fill and the seed rate were derermined.

The seed distribution pattern of the planter was checked in the field in actual conditions. A field measuring 45 mx30 m was selected and divided into nine equal parts to get three replications for each of three speeds. Latin Square Design (LSD) was followed for the study.

The furrow openers of the machine were removed except at the ends. This was done in order to have vibrational effect and simulation of actual planting. Three plastic sheets of 3.5 m x 2m each were spread in the sub-plots and white paste, made by heating flour and water was evenly pasted over the sheets. The tractor was operated at the intended speeds and seed dropped at a particular hill were recorded and spacing between and within the row were recorded for all the three rows. Seed rate accuracy was determined in terms of variation over the intended seed rate in different planting systems of sunflower.

Results and Discussion

The results have been presented in line with the objectives of the study.

Cell Fill of Seed Plates

The cell fill as obtained for three plates of the planter at three speeds is shown in **Table1.**

It can be inferred from the above table that as speed increased , the average cell fill percentage decreased. It is, therefore, clear that the cell fill has a linear but inverse relationship with the formal travel/seed plate speed. Thus it can be derived that a decrease in cell fill may be due to the higher vibrations at higher speeds.

Table1. Average Cell-fill for Different Speeds

Forward speed (Km/h)	Average seed dropped through 3 seed plates (seeds/min)	Average Cell fill of 3 plates (%)
2.0	189	182
3.5	314	172
5.0	417	163

Table2. Observed Seed Spacing at Different Speeds

Row	Speeds (km/hr)		
	2	3.5	5
I	28.72	29.48	28.81
II	28.86	29.71	29.76
III	28.27	29.97	30.15
Pooled average	28.61(1.860)*	29.73(1.745)	29.57(2.584)

*Figure in brackets are the standard deviations.

Table3. Seed Placement Behaviour of Three Rows Planted at Different Planter Speeds

S.No. Particular	Speed (km/h)					
	2.0		3.5		5.0	
	No.	Percent	No.	Percent	No.	Percent
1. Missing	2	2.21	6	6.6	28	31.1
2. Singles	27	30.00	32	35.6	29	32.2
3. Doubles	33	36.60	34	37.8	32	35.6
4. Multiples	28	31.20	18	20.0	1	1.1

Table4. Seed Rate Accuracy in Three Selected Planting Systems

Treatment	Actual Seed rate per ha (kg)	Variation overintended rate (5 kg/ha)
Multicrop seed cum planter	6.375	+1.375
Conventional	5.340	+0.340

Placement Behaviour of Seeds

Placement behaviour of seeds was observed in terms of number of seeds dropped at a particular hill (missings, singles, doubles and multiples) and average spacing between the seeds within a row.

a) Average spacing of the seeds-The average seed spacing for all the three rows planted was observed tobe almost similar at rows of the selected forward travel speeds **(Table 2)**. However, there was a marginal difference in the average spacing of rows I and III at a high speed of 5 km/hr. This may be due to the higher vibrational effect on rows I and III at higher speed. It was also found that variation in seed spacing was lowest at the medium speed (3.5 km/h) and increased at either side.

b) Missings, singles, doubles and multiples-The average missing was at least 2%) at the speed of 2 km/h, 7% at 3.5 km/h and it increased heavily, (31%) at 5 km/h . Singles were found to be 30%, 3~% and 32% at the forward speeds in ascending order. A greater number of single seeds were delivered at the medium speed of 3.5 km/h, **Table 3**.

The trend of doubles was the same as in the case of singles. The highest doubles (38%) were recorded at a speed of 3.5 km/h and least (3%) at the speed of 5 km/h.

Multiples (three or more seeds in the same hill) showed an inverse relation with speed. As the forward speed increased the multiple dropping of seeds decreased. The trend was observed to be 31%, 20% and 1% at the speeds of 2 km/h, 3.5 km/h and 5 km/h, respectively.

The missings resulted in gaps in the field which affected the yield. On the other hand multiples resulted in wastage of costly seeds and inputs. These missings and multiples were recorded at the lowest (2 km/h) and highest (5 km/h) whereas the percentage of singles and doubles were maximum at a speed of 3.5 km/hr.

c) Seed rate accuracy-Regarding seed rate accuracy, the variation over the intended seed rate was less in the case of muticrop drill-cum-planter than the conventional method (kera) of planting sunflower **(Table 4)**. This implies that seed rate accuracy in the machine system is substantially higher than the conventional system .

As the minimum variation over the intended seed rate was observed in multicrop drill-cum-planter, the seedrate accuracy was highest in this machine than the other two systems. It can also be inferred that there was substantial savings in the costly seeds using the planter.

Conclusions

The following conclusions can be drawn from the present study:

1. The cell fill of the multi-crop planter tended to increase with an increase in speed.
2. The percentage of missings varied directly with the planter-speed while the percentage of multiples varied inversely with the speed.
3. The seed rate accuracy was better in the case of the multi-crop planter as compared to other prevalent systems of planting sunflower.
4. The performance of multicrop drill planter was satisfactory at a speed between 2 km/hr and 3.5 km/hr with regard to optimum efficiency, seed placement behaviour and seed rate accuracy.

REFERENCES

Heyns, R.A. 1978. Principles of Farm Machinery, AVI Publishing Co., West port, Connecticut.

Robinson R.G. 1982. Response of sunflower to uniformity of plant spacing. Agronomy Journal, 72 (2) : 363.

Singh, Setal 1984. Design, Development and Evaluation of Tractor Drawn Ridger Planter for Winter Maize. Biennial Report, Deptt.of Farm Power & Machinery, P.A.U., Ludhiana ■■

Managing Technology Change: Zero Tillage in Pakistan

by
Abbas S. G.
ph.D. candidate
Department of Agricultural Engineering
Massey University Palmerston North
New Zealand
Email: S.G.Abbas@massey.ac.nz

M. A. Choudhary
Department of Agricultural Engineering
Massey University Palmerston North
New Zealand
Email: M.A.Choudhary@massey.ac.nz

G. L. Wall
Department of Agricultural Engineering
Massey University Palmerston North
New Zealand
Email: G.L.Wall@massey.ac.nz

Abstract

Information technology is being increasingly applied in agriculture and its development appears to offer unlimited opportunities. The use of Expert System (ES) is considered the best way to derive the researcher's knowledge and aid the process of choosing an appropriate tillage technique.

During the last two decades the general situation in agriculture in Pakistan has advanced rapidly, maintaining an average annual growth rate of 3.3%. But because of high growth (3.2%) rate of population, Pakistan is still importing commodities like wheat, edible oils, tea and coffee and milk products. Therefore, the government is encouraging the introduction of new technologies to increase the rate of growth of agricultural production. Introducing zero-till technology is one such step and the researchers' knowledge on this subject is being pooled into an ES for easy access to extension workers.

This paper elaborates on various aspects of a new tillage technique called "zero-tillage" explains the social and technical problems related to introducing it in the country. The paper also suggests strategies for managing technology change in developing countries where the available farm power is much less than those in developed countries.

Introduction

Agriculture has always been the most important sector of Pakistan's economy. At the time of independence in 1947, the agricultural sector accounted for 52% of GDP. In 1987, this sector accounted for 26% of the GDP and 67% of the export earnings. The sector has maintained an annual growth rate of 4.4%. Approximately 50% of the total national labour force (66% at the time of independence) was directly engaged in agriculture, and many more are engaged indirectly (Chatha and Cheema, 1983).

Pakistan has a total land area of 79.1 million ha. Of this total, 19.8 million ha are classified as cropped area. The estimated net area sown to crops is 15.4 million ha, and 4.4 million ha are cropped more than once annually. Another 4 million ha of land is rainfed agriculture production. Of roughly 4 million farms in the country, 90% are less than 10 ha in size, 74% are less than 5 ha, and 34% are smaller than 2 ha. Despite the number of small landholders, 36% of the cultivated area is located on farms larger than 10 ha, which comprise only 9% of the total number of Pakistan's farms (Anonymous, 1992).

Pakistan is facing serious pressure on it's foreign exchange resources because of the need to import essential agricultural items to meet the increasing demands of the country. The government of Pakistan is concerned with the slow progress in agricultural development and various studies are being conducted to introduce new agricultural technologies. It has been illustrated that changes in tillage technology alone can improve the efficiency at both water and nutrient use (Abbas, et al. 1995).

Tillage itself has been undergoing a process of re-evaluation during the past two decades. In the past, extensive tillage has resulted in runoff and soil erosion problems. Alternatively, conservation tillage was the result of research aimed at reducing tillage operations, avoiding surface runoff, conserving energy and soil, and to improve surface water quality (Anonymous, 1996). Lately, these tillage systems have become common in many parts of the USA and other countries (Hobb, et al. 1988). It is anticipated that there is a need to introduce this technology into developing countries also.

The selection of a tillage system is a complicated management decision with long term complications. The use of ES is considered the best way to derive the researcher's knowledge and aid the process of choosing an appropriate tillage technique. An ES in the tillage area is under development at the Department of Agricultural Engineering, Massey University Palmerston North, New Zealand. When fully designed, it will enable extension agents to establish if zero-tillage technology is appropriate under given conditions.

Performance of Wheat in Pakistan's Economy

Pakistan is one of the 10 major producers of wheat in the world, accounting for approximately 2% of the global wheat supply (Aslam et al. 1989). Wheat is produced throughout Pakistan on 7.4 million ha during the winter season. Wheat is by far the most important crop in the country claiming three times the area and twice the value added share of the next two crops, cotton and rice, which are Pakistan's two main export earners. The wheat crop is generally rotated after rice or cotton and, to lesser extent, with conventional oilseeds, chickpeas, lentil, and clovers as fodder crop.

Land preparation for wheat is generally poor, especially in areas of heavy soils. Farmers plough/cultivate land often without achieving conditions suitable for planting wheat and its establishment is often poor. Wheat seed is generally broadcast as drilling cannot be done due to soil clods and rice stubble left due to poor land preparation. Significant time is lost in soil preparation and in most of the cases wheat is sown late. It has been established that a delay in planting wheat after 15 November there is a loss in yield of about 1% per day (Choudhary, 1983).

Zero-tillage is being encouraged to overcome the delay in the planting of wheat after rice. This method of wheat production requires adequate weed control and placement of fertilizer with a special drill. Despite its limitations, the zero tillage method of planting has given significantly higher yield compared to the conventional method of wheat sowing in Pakistan.

Agro-climatic Environment of the Cropping System

The rice-wheat area is well irrigated through a network of irrigation canals. Rains during the winter months supplement the available irrigation water for wheat production. The soil types in the rice-wheat zone vary from well drained loams to silty clay loams and sandy loams. Substantial areas of saline soil are also found which are unsuitable both for rice and wheat production. Clay loams and silty clay loams are most suitable for rice but less fit for wheat (Aslam, et al. 1989).

Choudhary, (1983) broadly categorised Pakistani agricultural area according to the priority for their potential use for crop production by zero-tillage. He suggested the following:

1. The major rainfed areas that include D.I.Khan and D.G.Khan divisions have the highest potential for introducing zero-tillage;
2. The lower North Frontier Province and the Rawalpindi division with high intensity, high rainfall (upto 1400mm) have also been classified as having potential for zero-tillage, and
3. The irrigated areas in all four provinces of Pakistan come under a separate category. In most of these areas double cropping is practised. High cropping pressures, over cultivation and lack of organic matter have adversely affected the soil structure in these areas. Thus, zero-till practice should also be encouraged in these areas.

Constraints in Adoption of Zero Tillage

Stem borer is a destructive pest of rice. It hibernates in the rice stubbles left over in the field after harvest. Farmers are required by law to uproot and destroy the stubbles by the end of February and delay the planting of rice untill 20th May in order to destroy the larvae surviving in the stubble before rice planting begins. The law is loosely followed by the farmers and the rice fields planted to clover in rotation, are seen with standing stubble. An integrated approach combining agricultural and chemical methods for stem borer control will help in adopting the zero tillage method of wheat production.

Similarly, in relaying cropping technique for sowing wheat after cotton also seemed cumbersome. The cotton sticks harvested by hand as at present no other mechanical means are available for the purpose.

General Observations

A survey of a zero-tillage wheat pilot production program reported by Aslam et al. 1991, with the following highlights:

1. Farmers were initially reluctant to spare the area for zero tillage wheat cultivation. However, extension staff convinced them by offering compensation in the case of crop failure;
2. A few farmers ploughed the zero till wheat cultivated fields before germination due to the fear of failure of this method;
3. Almost all the zero-till farmers (91%) and fallow farmers (90%)

seemed convinced of the viability of this technology after observing the successful germination of wheat on zero-till fields;

4. On average, wheat yields at zero till fields (2570 kg/ha) were 230 kg (9.82%) higher than conventional wheat planting (2340 kg/ha);
5. Land preparation costs for conventional wheat planting was Rs 1000/ha (NZ$43/ha) and zero till drill rent was assumed to be Rs 400/ha (NZ$18/ha) in comparison;
6. Net benefits for zero tillage were greater than conventional wheat planting technology (about Rs. 1250/ha (NZ$43/ha);
7. For the subsequent wheat season, both recipient and non-recipient farmers were ready to allocate about 50% of their farm area for zero tillage wheat cultivation.
8. Weed presence score was almost similar on zero till and conventional wheat fields. Ninety percent of zero-till fields and 46% of conventional fields were sprayed with weedicide. A detailed weed management study is needed at the farmers' fields to check the weed problem in zero till and conventional wheat fields.
9. The incentive for free weedicides provision for the first year, 84% of the farmers were inclined to adopt zero till wheat cultivation without demanding free weedicide facility for subsequent year;
10. Although B-385, an early maturing rice variety, partially solved the problem of late wheat planting, factors such as labour scarcity, harvesting and threshing method for the rice crop still contributed to delaying wheat planting;
11. Non-compatibility of the present drill with low power tractor could be a big constraint to a wider adoption of the zero-tillage technology.
12. Some 39% of the farmers asked for a light drill; 18% reported some technical problems in chain fixation and 13% suggested fertilizer and seed pipes adjustment to avoid bridging in the pipes;
13. Operators of large farmers were willing to buy a drill if it was available for a price of Rs. 25,000 (about NZ$1000.00) equivalent; and
14. Farmers complained that chain displacement (59%) and fertilizer seed pipes (36%) created problems during drill operation.

Proposed Strategies

The proposed strategies are asfollows:

1. The drill should be operated by medium -sized (40-50 kW) tractors;
2. The drill price should be within the price range of the average farmer (Rs 35,000 to Rs 40,000 NZ$1500 to NZ$2000);
3. The manufacturing technology may be transferable to local manufacturers in various phases. This will ease the availability of spare parts;
4. The potential local manufacturers must be identified with the collaboration of Farm Machinery Institute (FMI) for setting up certain standards for local manufacture;
5. The manufacturers must also contribute towards the establishment of demonstration plots for farmers and should help in organising field days;
6. The extension agents and manufacturers should be encouraged to use the Decision Support System (DSS) under development at Massey University, Department of Agricultural Engineering, Palmerston North, New Zealand for convincing farmers to adopt the zero-till technology in the rice-wheat areas.

Validation of the Expert System

The proposed ES which is being designed at Massey University is intended for agricultural extension workers for determining if zero-till techniques are useful under given conditions. Each ES consists of a knowledge base to forecast the effects of different management strategies and circumstances. Because of the pooling of the knowledge from different experts on the subject, the ES can help research organisations too. A well-constructed ES should usually provide: consistent recommendations, verifiable rules and relevant information within a sImilar system;

Methodology for Technology Change

The International Service for National Agricultural Research (ISNAR) study on organization and management of on-farm client-oriented research indicates that effective links with extension or other technology transfer agencies are essential for broad impact (Ortiz et al. 1991). Forging such links had been a weak point in many on-farm research efforts in developing countries. Sometimes, it was assumed that on-farm research efforts could substitute for technology transfer efforts. A study in Guatemala by ISNAR concluded that on-farm research could provide a focal point for developing strong links, but such direct links with farmers alone were not sufficient for wide dissemination of technologies (Ortiz et al. 1991). Based on this study and numerous meetings with extension staff in

Pakistan, the following model of technology change was established for introducing zero-tillage technology:

Model for introducing zero-till technology

INFORMAL SURVEY

↓

GENERAL CENSUS

↓

RAPID RURAL APPRAISAL

↓

PARTICIPATION OF PUBLIC AND PRIVATE COMPANIES

↓

TRANSFER OF ZERO-TILL TECHNOLOGY AND SUPPLY OF INPUTS

↓

MONITORING AND EVALUATION

Mechanics of the Model

In each pilot area a reasonable sample (40) farmers should be selected for an ***informal survey*** to ascertain public reaction to zero-till. If the ***general census*** is in favour then these farmers will be considered as the Impact Area Farmers (IAF). They will serve as nucleus sites for obtaining relevant information during the introductory process. They will also then serve as roving extensionists to disseminate the zero-till technology into adjoining areas. A ***rapid rural appraisal*** by a multi-disciplinary team comprising crops, natural resources, and the social scientists will also be conducted within the IAF. At this stage the ***participation of public and private sectors*** will also be sought. Based on the success and knowing that the introduction of zero-till is consistent with farmer's requirement, a full-fledged programme of ***transfer of zero-till technology and supply of inputs*** will be initiated. Of course, like all other models, the ***monitoring and evaluation*** will be an important component of the model.

Conclusion

The selection of a tillage system is a management decision with long term implications. To aid farmers and extension workers in this decision process, an expert system has potential to be an excellent method of delivering expertise from researchers. An ES has been designed for choosing or rejecting the zero-till technique which has built-in updating facilities for future development. This ES can explain how a decision has been arrived at and then justify its recommendation. It can also produce a report of its findings. It is hoped that the ES will prove beneficial for introducing zero-till technology at a wider range.

REFERENCES

Abbas, S. G., Wall, G.L., and Choudhary, M.A., (1995). Development of an Expert System for Conservation Tillage. Proceedings of the 2nd. New Zealand Postgraduate Conference for Engineering and Technology Students. 31st. August & 1st. September. Auckland, New Zealand. pp. 1-5.

Anonymous (1992). Annual Report Pakistan Agricultural Research Council (1991). ISBN No. 969-409-0804-9 pp. 63-83.

Anonymous (1996). Annual Report Pakistan Agricultural Research Council (1996). ISBN No. 969-115-2 pp 53.

Aslam, M,. Majid, A., Hobb, P.R., and Byerlee, D., (1989). "Wheat in the rice-wheat cropping system of Punjab: A synthesis of on-farm research results 1984-88. PARC/CIMMYT Paper No. 89-3 pp. 4

Aslam, M., Ahmed, M., Hashmi, N.I., Chatha, M.Q., and Veen V.M., (1991). Zero Tillage Wheat Pilot Production Programme for the Punjab Rice-Wheat System. ISBN No. 969-409-084-8. p. 35.

Chatha, M.Q., and Cheema, A.U., (1983). "Recent Agricultural Developments and Major Agricultural Policies in Pakistan." In: Proceedings of Workshop held in Bogor, Indonesia, April 6-8, 1993. ISBN 979-8059-55-7. pp. 53-60.

Choudhary, M.A., (1983). "Potential of Direct Drilling in Pakistan." Agricultural Mechanization in Asia, Africa and Latin America 1983. Vol. 14(4). pp. 20-24.

Hobb, P.R., Mann, C.E., and Butler, L., (1988). "A perspective on research needs for rice-wheat rotation." In: Wheat Production Constraints in Tropical Environments. Pub. Mexico, D.F., CIMMYT, pp. 197-211.

Lal, R., (1979). Soil Tillage and Crop Production. Proceedings of Conference "Role of Soil Physical Properties in Maintaining Productivity of Tropical Soils" held at IITA, Ibadan, 6-10 December, 1977. pp. 25-32.

Morgan, R.P.C., (1995). Soil Erosion and Conservation. ISBN 0-470-23514-4. 2nd. Edition. pp. 96-112.

Ortiz, R., Ruano, S., Juarez, F.O., Olivet, F., and Meneses, A., (1991). A new Model for Technology Transfer in Guatemala. Discussion paper No. 2 by ISNAR Publications. pp. 15-23.

■■

Influence of Deep Tillage on in-situ Moisture Conservation in Dry Farming

by
R. Manian
Professor
College of Agricultural Engineering,
Tamil Nadu Agricultural University,
Coimbatore-641003
India

Dr. K. Kathirvel
Asst. Professor
College of Agricultural Engineering,
Tamil Nadu Agricultural University,
Coimbatore-641003
India

G. Baby Meenakshi
Senior Res.Fellow
College of Agricultural Engineering,
Tamil Nadu Agricultural University,
Coimbatore-641003
India

Abstract

The sub-soil hard pan is formed due to the illuviation of clay to the sub-soil horizon in red soil due to the high exchangeable sodium content of clay complex in black soil and to the continuous cultivation of crops using heavy implements into certain depth constantly. All put together lower the infiltration and percolation rates, nutrients movement and free air transport within the soil profile which affects crop growth and yield. An attempt was made to overcome this problem by conducting experiments with different tillage implement combinations in different location. The results show that there was significant differences between the treatments in plant height, leaf area, root length and yield. The chisel plough plus coir pith application showed its superiority over the other treatments. The in-situ moisture conservation was greater in the chisel plough plus coir pith treatment. There was a 50-percent increase in the permeability of the soil due to the vertical storage of moisture. The moisture pattern in the case of chisel plough + disc plough + cultivator (CP+DP+C) showed drastic improvement in soil moisture storage. The root length in this treatment reached a maximum depth of 25 cm. In the CP+DP+C, 50 percent yield increase was obtained, leaf area index increased by 44 per cent and root length increased by 13 per cent. The chisel plough played an important role in root growth and hence increased yield.

Introduction

More frequently, the soil health is infested with physical constraints like hard pan, fluffiness and high permeability which in turn impair the crop growth to a great extent thereby limiting its productivity. The sub-soil hard pan in red soil is due to the illuviation of clay to the sub-soil horizon coupled with cementing action of oxides of iron, aluminium and calcium carbonate which increases the soil bulk density to more than 1.8 Mg m-3 Further, the hard pan can also develop due to continuous cultivation of crops using heavy implements up to a certain depth constantly. Besides, the higher exchangeable sodium content of clay complex in black soil areas also resulted in compactness of the sub-soil. All put together, they lower the infiltration and percolation rates, nutrients movement and free air transport within the soil profile. They prevent root proliferation and limit the volume of soil available for nutrients uptake resulting in depleted, less fertile surface soil. Consequently, the contribution of sub-soil fertility to crop growth is hampered.

In Tamil Nadu, red soils (Alfisols) occupy 8 million ha which constitutes 62 per cent of the total geographical area. The occurrence of hard pan at shallow depths is the major prevalent soil physical constraints in these soils. The crops are not able to enjoy the full benefits of the soil fertility and nutrient use due to this major problem.

The sub-soil hard pan areas are found in 1,320 sq.km. in Coimbatore, 2,450 sq.km. in Madurai and 1,448 sq.km in North Arcot Districts. Depending upon the depth of occurrence of hard pan, management practices are to be adopted. Hence, for soils with sub-soil hard pan at shallow depth, the following technologies could be adopted (Basker et al.,1995):

a. Ploughing the soil with chisel plough at 0.5 m interval criss-cross at 0.5 m depth once in to 3 years;
b. Application of organics to improve the aggregation and soil structure so as to prevent further movement of clay to the lower layers; and
c. Deep ploughing of the field during summer season to open up the sub-soil.

In consideration of these technologies, a study was undertaken with the following objectives:

i. To examine the improvement in soil structure using chisel plough;
ii. To study the effect of using disc plough and chisel plough in combination on In -situ moisture conservation of soil; and
iii. To evaluate the performance of these implements in terms of improvement in soil structure, crop growth and yield.

Review of Literature

Chen Guoliang (1983) reported that deep ploughing in summer increased water by more than 12 mm at 50 cm depth and the yield of the crop was increased from 17 to 30 per cent as compared to shallow ploughing. Brain et al. (1984) reported a large increase in crop yield due to deep loosening of soil. Zhao Fergbiu (1985) found that sub-soiling by loosening deep layers resulted in more water storage, higher moisture conservation and crop yield.

Barbosa (1989) indicated that the deep tillage practices on compacted soil resulted in more rapid plant growth and a significant increase of 21 to 24 per cent in soybean yield compared with conventional tillage practices.Rattan Lal (1989) reported that ameliorative tillage operation like deep ripping, sub-soiling and soil inversion can relieve low infiltration rates and improve crop yields.Mailwal (1992) learned that deep tillage and sub-soiling were usually effective in conserving moisture.

Salan et al. (1992) stated that mulching significantly enhanced vegetative growth and increased bunch yield by about 41 per cent. Doty et al.(1995) obtained positive results from disrupting sub-soil layers that were compact enough to interfere with plant root development. Nitant Pratap Singh (1995) identified that deep tillage and sub-soiling improved soil properties, suppressed weed growth, and reduced water and nutrient losses through weed uptake and enhanced profiled water storage. The increase in yield was from 89 to 127 per cent.

Materials and Methods

In-situ moisture conservation is possible through appropriate soil manipulation technology to capture and harness rainwater. Deep tillage shatters compacted sub-soil layers and aids in better infiltration and storage of rain water in the crop root zone. When the chisel ploughs are used in the field, the chisels break narrow strips of soil either up to or well beyond the root zone in the soil and leave pulverized vertical mulch. Such pulverized porous media could be left as it is, with the pulverized soil or could be added with coir pith which could act as a non-perishable moisture-holding-media under protection against evaporation. Experiments were laid out in the farmers' field and following are the details of soil, crop and treatments selected.

Observations

It is assumed that all the plots were subjected to equal precipitation levels and that the plant growths are purely influenced by the in-situ moisture levels. The leaf area index was measured since it also contributed towards productivity besides yield. Leaf area was measured by using a leaf area meter. Based on the leaf area per plant, leaf area index was determined by dividing the total area of the plant by the spacing given to the plant. The steady-state plant heights and root lengths were measured before and after harvests. Crop yield was chosen as the index of productivity. Since the mean yield levels differed due to the seasonal and other local variables, the yield of treatment T_1 (control), in which the chisel plough was excluded, is treated as the base yield, as 100 and the yields in other treatments were compared. The soil moisture contents at different depths (15, 30 cm) were measured for 30, 60 and 90 days of growth season. The moisture levels at mean root levels were compared with respect to yield level percentage for each treatment. The results were analyzed and discussed.

Results and Discussion

Leaf Area Index, Plant Height, Root Length and Yield

The mean values of the leaf area index, plant height, root length and yield obtained are shown in **Table 1** and the comparative performance is shown in **Fig.1**.

Trial I- The leaf area index, plant height and root length were significantly high in chisel + coir pith treatments. The increase in leaf area index, plant height and root length were 58 per cent,11 percent and 56 per cent, respectively. The results obtained in the chisel plough treated plot were significantly higher compared to that of the control.

The highest yield was obtained in the use chisel plough + coir pith treated plot. When compared to the control, there were 16.34 per cent and 31.80 per cent increase in yield in chisel plough and chisel plough + coir pith treated plots, respectively. Thus, the in-situ moisture conservation is effectively induced by: (a) temporary moisture retention reservoir or vertical aquifer; and (b) high canopy area in the use of chisel plough + coir pith treatment. This may be due to the shattering of compacted sub-soil layers throng deep tillage which aids in better infiltration and storage of rainwater in the crop root zone. The improved soil structure also results in better development of the root system and the yield of crops and their drought tolerance is also improved.

Soil moisture content- The chisel plough was used at a spacing of 1 m. The rain water was percolated into the loosened (chiseled) strips to a depth of 30 to 40 cm. Thus the soil moisture was saturated in these strips immediately after rainfall and the moisture front reached an equilibrium status at regular intervals. Any intermittent rain during growth season had similar effect in depth-moisture status in the field. The details of soil moisture status at different depth and days are presented in **Fig.2.** The results are summarized in Figs. 3 and 4. The moisture contents were measured below 15 cm since the mean root depth was in the range of 9 to16 cm. From **Figs.3** and 4, it can be seen that the moisture gradient in the control is identical on 30th and 90th day. dq/dx = 0.62 per cent/cm.

But the gradient on the 60th day was 0.06 per cent/cm. This implies that the soil between 15 and 30 cm is with near-equal moisture status(13.51per cent). Similarly, the moisture gradient in the treatment using chisel plough showed identical moisture gradient (0.28 per cent/cm) and near-identical moisture status 12.05 per cent during the 30th and 90th days. But in the case of treatment using the chisel plough + coir pith it can be seen that:

a. Moisture content on 60th day is in the range of 17.6 to 18.9 per cent as against 12 per cent in the other two treatments. But on 90th day the moisture gradient in the top 15cm level was so steep implying that the moisture extraction pattern drastically changed between the 30th and 90 days due to the integrated

Table 1. Mean Values of Leaf Area Index, Plant Height, Root Length and Yield

Treatment	Leaf area index	Plant height (cm)	Root length (cm)	Yield (kg/ha)
Trail-I				
T_1 Cultivator, once	1.80 (0.30)	93.31 (5.57)	8.99 (0.91)	187.50 (9.46)
T_2 Chisel plough	2.84 (0.53)	103.81 (5.41)	13.99 (1.31)	218.13 (8.40)
T_3Chisel plough+Coir pith	4.40 (0.60)	120.11 (8.17)	16.24 (2.34)	247.13
Trail-II				
T_1 Cultivator, once	2.75 (0.27)	119.0 (2.46)	12.16 (1.61)	441.67 (10.27)
T_2 Cultivator, twice	4.81 (0.45)	132.20 (4.93)	12.58 (0.84)	513.33 (8.50)
T_3Chisel plough+Disc plough + Cultivator	8.65 (0.63)	152.73 (4.86)	25.45 (0.91)	1023.33 (47.32)

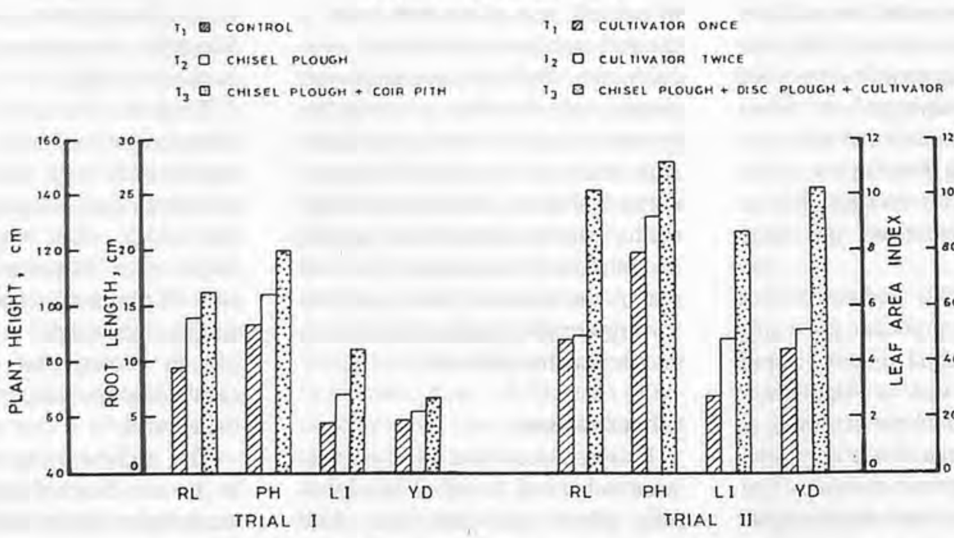


Fig.1 Root Length (RL), Plant Height (PH), Leaf Area Index (LI) and Yield (YD).

effect of the root length and plant height - canopy (leaf area index) status.

b. The moisture content at a depth of 26 cm was constant on the 30th and 90th days as can be seen at the intersecting point in this treatment. The moisture content was 15 per cent-noticed only on the 60th day at coir pith added treatment is 18.5 per cent and at control 13.7 per cent. Even though the mean root depth was 16.24 cm only, the moisture is extracted from a depth of 26 cm. At the root level of 14 cm in the use of the chisel plough plot, the moisture content was below 14 per cent whereas the addition of coir pith enriched the soil to 17.5 per cent. This phenomenon leads to the conclusion that the coir pith acts as a temporary storage reservoir or aquifer.

c. The rate of change in the moisture content in the two zones, namely; 15 cm and 30 cm in the two periods of 30-60 days and 60-90 days are given in **Table 2**. The rate of moisture change during the initial phase at 30 cm deep was similar to the control and chisel plough treatments. This may be due to the fact that the root length in these two treatments might not have reached 15 cm since the maximum root zonewas less than 14 cm.

In the case of the treatment using the chisel plough with coir pith, the root length of 16.24 cm might have extracted moisture in the depth zone of 30 cm during the initial period of 30-60 days. The rate of change in moisture in the top 15 cm during the initial growth phase was constant in all the three treatments at 0.14 per cent/day because the canopy effect would not have been felt. But during the later phase of 60-90 days, the rate of

Table 2. Rate of Change in Moisture Content

Trail-I	Between 30th and 60th day		Between 60th and 90th day	
Treatment	15 cm	30 cm	15 cm	30 cm
T_1 Cultivator, once	0.13	0.07	-0.12	-0.06
T_2 Chisel plough	0.15	0.07	-0.13	-0.06
T_3 Chisel plough+Coir pith	0.14	0.13	-0.21	-0.09

Trail-II	Between 30th and 60th day			Between 60th and 90th day		
Treatment	15 cm	30 cm	45 cm	15 cm	30 cm	45 cm
T_1 Cultivator, once	0.00	-0.05	-0.08	0.02	0.06	0.09
T_2 Cultivator, twice	0.06	0.11	-0.01	-0.10	-0.12	-0.02
T_3 Chisel plough+Disc plough + Cultivator	-0.004	-0.05	-0.05	-0.03	-0.18	0.07

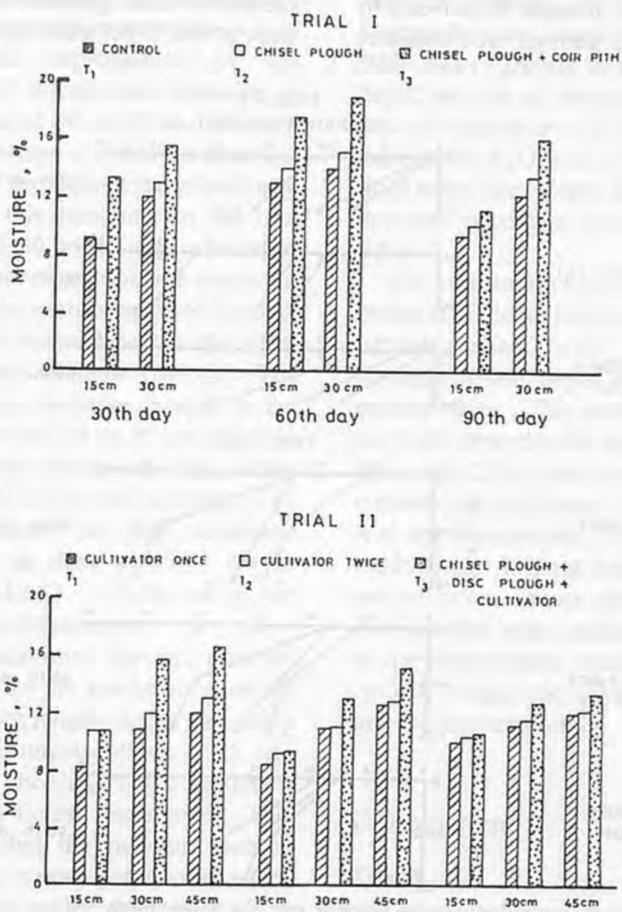


Fig.2 Soil moisture content at different depths.

change of moisture in the control and chisel plough was more or less similar at (-) 0.12 per cent/day at 15 cm depth whereas it was (-) 0.21 per cent in the treatment of chisel plough + coir pith. This shows additional moisture at the top layer by side seepage from the vertical aquifer. A Similar trend was noticed at the bottom layer of 30 cm as well even though the addition of moisture was at a lower rate of (-)0.09 per cent day -1.There was 50 per cent increase in the permeability of the soil due to the vertical storage of moisture.

Trial II- The leaf area index, plant height and root length are shown in **Table 1** and **Fig.1**. The leaf area index and plant height are significantly high in the use of CP+DP+C combination treatments (T_3) followed by cultivator twice and cultivator once. But the root length showed its superiority in T3 and the increase in T2 was less. The mean values of yield recorded in different treatments are given in **Table 1**. A similar trend is reflected in the yield obtained from different treatments. The 50-per cent yield increase obtained from the triple implement treatment suggests that the 44 per cent leaf area index increased and 13 per cent root length increased over the twice-cultivator treatment are responsible. However, among the cultivator treatments about 10 per cent increase in plant height and 42 per cent increase in LAI improves the yield by 14 per cent. These results conclude that surface mulching alone is not sufficient to improve the root prolification, and that surface mulching combined with moisture enrichment mechanism as in this case, loosens the sub-soil by tillage and through side moisture sink created by the chisel plough.

Soil moisture content- The soil moisture content at different depths for different treatments are presented in **Table 2** and summarized in **Figs. 2, 3** and **4**. The moisture contents was more or less similar at different growth seasons in the treatment with cultivator once. When the cultivator was operated twice, slight variations in soil moisture was noticed. The moisture content at a depth of 30 cm remained the same in the plot treated once with the cultivator. This shows hat the sub-soil moisture is unaffected by the cultivator with plant growth. When the cultivator was used twice, the minimum moisture content increased from 8.4 to 9.4 per cent on the 90th day.

During the initial phase of the crop growth, i.e., on the 30th day the soil moisture gradient was constant at 0.075 per cent/day for the

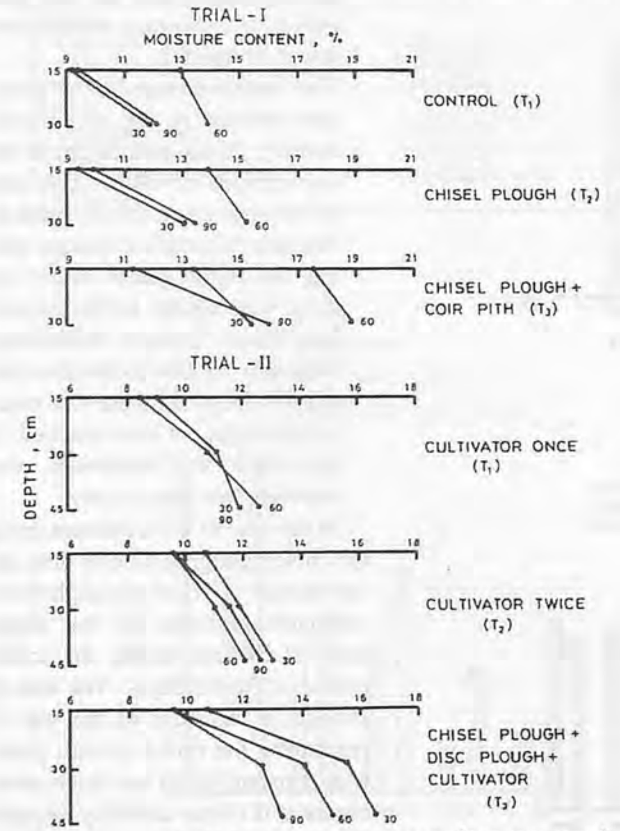


Fig.3 Moisture profile: for different tools-rate and gradient.

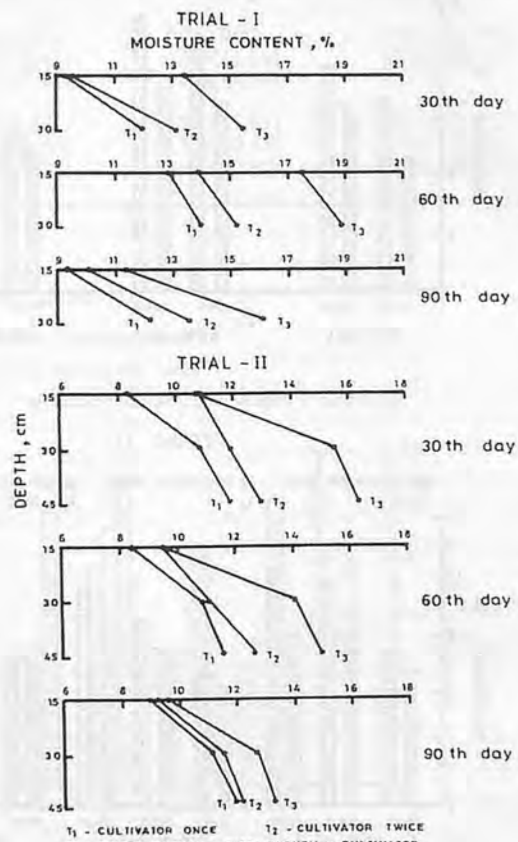


Fig.4 Moisture profile:on different days - gradient.

the soil moisture gradient was constant at 0.075 per cent/day for the treatment cultivator (twice). The initial moisture content (30th day) at 15 cm depth was 10.6 per cent which was 0.5 per cent more than that observed in single cultivator treatment. But the moisture contents at 30cm depth on the 60th day was about 11 per cent in cultivator treatments irrespective of the number of operations. But on the 90th day there was an increase of about 5 per cent at 30 cm depth in the field treated twice with cultivator. This leads to the conclusion that the mulching effect is slightly improved if the field is ploughed twice with the cultivator.

The mechanism of in-situ moisture conservation is purely by arresting the capillary flow to the atmosphere. From **Fig.4** the moisture pattern in the case of treatment with three implements shows considerable improvement in soil moisture storage and depletion in the zone of 30 to 45 cm. A minimum storage of 12.6 per cent was ensured throughout the growth season in this treatment in the root zone of 30 to 45 cm in contrast with an average moisture conservation in the narrow range of 12 to 13 per cent encountered in the treatment of cultivator (twice). The maximum moisture content in the root zone of 30 to 45 cm in triple implement treatment was in the range of 15.5 to 16.6 per cent. The root length in this treatment reached as deep as 25.45 cm as against 12.32 ± 0.16 cm in the other two treatments.

On examining the leaf area index, unlike the similarities noticed in the root lengths in the two cultivator treatments, it was 2.75 and 4.81 in once and twice cultivator operated fields, respectively. This reveals that the moisture pattern variation is mainly due to the canopy effect rather than root effect whereas the variation in triple-implement treatment is the combined effects of roots and leaves. It is interesting to note that the 15 cm depth moisture content converged to the 9.5-per cent in triple-implement and twice-cultivator treatments both at 60 and 90 days even though the 30th day moisture content was high at 10.7 per cent. This difference of additional 2.5 per cent loss at 15 cm depth may be attributed to the root and canopy effects combined since the single cultivator treatment didn't follow this trend.

The rate of change of moisture content in the sub-soil is given in **Table 2**. Between the 30th and 60th day, no change in the moisture content was detected at 15cm depth in the fields treated either with cultivator (once) or with triple implement. But in these fields at 30cm depth, an equal rate of change of (-) 0.05 per cent/day can be noticed. During the later stage of the 60th-90th days of growth stage at 30 cm depth the rate of change of moisture was maximum (- 0.18 per cent/day) which is 3.0 and 1.5 times noticed at the same depth in cultivator operated once and twice, respectively.

The moisture content was depleted at all depth levels in the field treated twice with cultivator throughout soil depth at the later growth stage. The root length in the field treated with triple implement was 25cm and hence the increased rate of change of moisture was not unexpected. These results establish the highest yield accompanied by maximum plant height. The leaf area index and root length in the fields where mulching subsurface tillage and vertical moisture storage are done.

Conclusions

Trial I

The result showed that there were significant differences between the treatments in plant height, leaf area and root length. The chisel plough plus coir pith application showed its superiority over the other treatments. The in-situ moisture conservation was greater in the chisel plough plus coir pith treatment. There was a 50-per cent increase in the permeability of the soil due to the vertical storage of moisture.

Trial II

The moisture pattern in the case of the chisel plough + disc plough +cultivator showed considerable improvement in soil moisture storage. The root length in this treatment reached a maximum depth of 25 cm. In this treatment a, 50-per cent yield increase was obtained, leaf area index increased by 44 per cent and root length increased by 13 per cent. The chisel plough played an important role in root growth and hence increased yield.

Recommendations

1. The operation of the chisel plough at 1 m interval and application of coir pith is recommended for in-situ moisture conservation and to improve soil structure; and
2. It is essential to support the chisel plough and cultivator treatments with subsurface storage system which may be through coir pith or by disc ploughing.

REFERENCES

Barbosa, L.R., O.Diaz and R.G.Barber,1989. Effects of deep tillage on soil properties, growth and yield of soya in a compacted ustochrept in Santa Cruz, Bolvia.Soil and Tillage Research,15: 5761.

(Continued on Page 29)

Development and Evaluation of Combination Tillage-Bed Furrow-Former

by
R. Manian
Professor
College of Agricultural Engineering,
Tamil Nadu Agricultural University,
Coimbatore-641003
India

V. NAGAIYAN
Asst.Executive Engineer
College of Agricultural Engineering,
Tamil Nadu Agricultural University,
Coimbatore-641003
India

Dr. K. Kathirvel
Asst. Professor
College of Agricultural Engineering,
Tamil Nadu Agricultural University,
Coimbatore-641003
India

Abstract

The concept of reduced tillage is becoming important in eliminating the effect of compaction due to repeated operations in the soil. With a view to combining the primary and secondary tillage operations, to utilise the negative draft produced by the rotory tools and to conserve moisture by forming furrows, a combination tillage-bed furrow-former (CTBFF) was developed which ensures timeliness in seed-bed preparation and also to utilise the drawbar power available in a tractor with optimum soil-energy-tool performance. The performance of the developed unit was evaluated in black clay loam and red loam soils. The performance was compared with mould board plough + cultivator, mould plough + cultivator + disc harrow, mould board plough + power tiller rototiller operations.

The percentage of fine soil particles of less than 3.5 mm were greater in the combination tillage-bed furrow-former treatment which was 43.5 per cent in black clay loam soil and 52.5 per cent in red loam soil. The bulk density was minimum in the plots tilled with combination tillage bed furrow former which was 15.4 and 20.1 per cent less in black clay loam and red loam soils, respectively, when compared with mould board plough + cultivator treatment. On analysing the total porosity occurrence in black clay loam and red loam soils, it was found that the total porosity in black clay loam varied between 49.4 and 57.3 per cent whereas in red loam soil, the variation was between 50.3 and 55.8 per cent. The maximum was in the combination-tillage bed-furrow former and the minimum was in the mould board + cultivator. The tillage with the CTBFF induced a better infiltration rate when compared to other treatments. With this combination, the cost of operation was 47.22 per cent less and the energy consumption was 39 per cent less.

Introduction

Rotary tillers are increasingly used in various operations in agriculture now-a-days. Rotary working machineries give high quality of soil cultivation and uniform mixing of the soil with plant residues, organic and mineral fertilizers. But powered tools result in negative draft (forward thrust) that may require further energy inputs to control tractor steering and three-point hitch and also may be harmful to the tractor drive train (Wismer et al., 1968). Combined machines are more complex than passive tilling implements or rotary machines, but these machines can unite the advantages of active and passive machines and they can create lower resistance than the passive machines and, at the same time, they can ensure lower specific work than the active, rotary machines. (Bernaiki et al., 1972).

Approximately 20 per cent of the energy for agricultural production is utilized in field operations with a majority being applied in tillage operations (Stout, 1984). Due to repeated use of primary and secondary tillage implements sub-soil layers are compacted. Mehuys (1984) reported that an average compaction related reductions to be 15 per cent of potential yields. Hence minimum tillage is becoming important.

The results of work carried out and reported from ICRISAT, Hyderabad in red sandy soils of Ananthapur (A.P.) are of interest. The methods adopted in preparing seedbed is called "broad based seedbed" with a low monetary input that can provide substantial benefits. The results give evidence in the control of noxious weeds, good seedbed preparation, rainfall conservation and erosion control. The cost of operation may be the deciding factor and data strongly support that the minimum tilled broad based seedbed is an ideal tillage method for dry farming in arid and semi-arid regions. The implements used in this study are bullock-drawn and hence required more time for preparing the seedbed. Based on the above, a design and development of a tractor-drawn roto tiller combined with furrow former and leveller to form broad bed was undertaken.

Review of Literature

Chamen et al. (1979) reported that a PTO-driven primary tillage tool requires 50 per cent less energy than a mould board operating at the same depth. Hendrick (1980) designed and tested a powered rotary chisel with a single rotor and compared the power requirements with that of a rigid chisel. Results show that the powered configuration required 15 per cent less power. Hendrick assumed a power transmission efficiency of 49 per cent for drawbar operations and predicted that the combination machine required 45 per cent less engine power. The powered rotary chisel also disturbed a greater volume of soil and caused greater soil breakdown than the rigid chisel.

Kumar and Manian (1986) reported that only one-third of energy input was needed to manipulate the soil for satisfactory seedbed preparation with a combination tillage tool. Hoki et al. (1988) tested a powered disk tiller and observed a reduction in total power requirements as well as reduction in draft requirement of about 10 per cent or less and they are influenced by ground speed, PTO rpm, tillage depth and soil conditions. Wilkes and Addai (1988) reported on the development and testing of a combination tillage tool known as the "Whe Double Digger". This machine was found to reduce drawbar power, wheel slip and specific energy under certain situations compared to mould board plow operating at the same depth.

Sigitov (1992) developed a combined machine for tilling, incorporation of herbicides, levelling and marking out rows for sowing at a time and reported that the soil compaction was minimised, the volume of fuel consumption was reduced by 25 per cent and labour requirement was also reduced by 30 per cent.

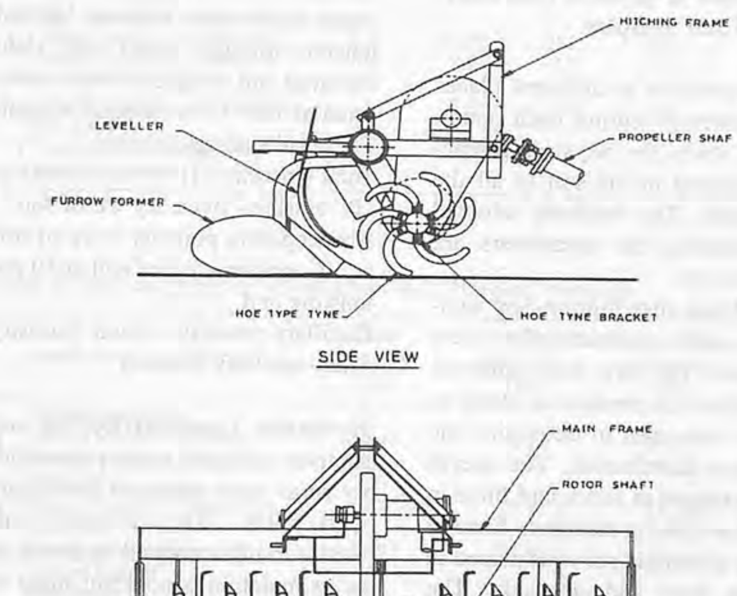


Fig.1 Combination Tillage-Bed furrow-former.

Materials and Methods

The CTBFF cited earlier was developed to combine the tillage, furrow forming and levelling operations in a single pass to ensure timeliness in seedbed preparation and also to utilize draw bar power available in a tractor by optimising soil-energy-tool performance. The CTBFF consists of: ii drive mechanism, roto tiller, furrow former and leveller attachments and main frame **(Fig.1)**.

Drive Mechanism

The drive mechanism constitutes a telescopic propeller shaft and right angle drive speed reduction gear box. The propeller shaft is provided with two universal joints so that the power could be transmitted at an inclination of 20°

The power from gear box to the roto tiller is transmitted through chain and sprockets.The speed ratio between the PTO and gear box and in between gear box and rotor shaft is 3:1 and 1:2 , respectively.

Roto tiller

This consists of two hollow shafts with a diameter each of 110 mm. A channel type mild steel brackets are welded on the circumference of the rotor drum the holds hoe type tynes. The rotor blades are mounted at equal distances along the axis and at 30 degree division on the circumference of the pipe. The blades are mounted in six rows facing each other to take the load uniformly and to offset the side thrust created by the bent portion of the blades.

Furrow Former and Levelling Board

Two tractor-drawn ridger bottoms were selected and assembled to the combined tillage bed furrow former at the two ends to open deep furrows so that in the rainy season moisture is conserved. A shovel shaped level board was fabricated and assembled behind the roto tiller to spread the soil uniformly in the seedbed. A safety guard was fabricated in sheet metal to cover the roto tiller. The complete unit can be pulled by attaching it to the three point linkage in the tractor.

Main Frame

The main frame is made of 152 mm hollow mild steel pipe with provisions for hitching mechanism at the center and two frames for furrow former assembly at the ends. The rotor drum is supported by three bearing housings attached to the main frame. The position of the levelling board can be adjusted with respect to the depth of operation of the roto tiller.

Evaluation of the Combined Tillage Bed Furrow Former

The performance of the CTBFF was compared with that of the conventional tillage practices in black clay loam and red loam soils. The sliding tillage tools were selected and grouped together according to conventional practices as detailed below:

T_1 Mould board plough + cultivator

T_2 Mould board plough + cultivator + disc harrow

T_3 Mould board plough + power tiller roto tiller

T_4 Combined tillage bed furrow former

Soil samples were taken to determine the following physical properties:

A. Clod size distribution
B. Bulk density
C. Total porosity, capillary porosity and non-capillary porosity
D. Hydraulic conductivity and
E. Infiltration rate.

Evaluation of physical Characteristics of Soil Samples

Soil samples at different places were collected during each operation to study the physical characters obtained in the soil in all the treatments. The methods adopted in estimating the parameters are given below:

Clod size distribution-Soil samples in each treatment plots were collected. The dry sieve analysis method which consists of 34mm to 3.5mm was used to determine the clod size distribution. The sieves were arranged in series and fitted in the sieve-shaking machine. Exactly one kg of sample soil was placed in the top sieve and covered. The machine was operated for 10 minutes and then the sieves were removed. The soil in each sieve was weighed and the clod size distribution was determined.

Bulk density-Tube core samples of 5 cm diameter and 10 cm long fitted with rings were driven into the soil after each implement operation for the required depth and core samples. They were collected and oven-dried separately for 24 hours at 105 ℃ weighed and the bulk density was calculated (Dakshinamurthi and Gupta, 1968).

$$\text{Bulk density} = \frac{\text{oven dry wt. of soil}}{\text{volume of the container}} = \frac{Wt}{V}\ \text{gm/cc}$$

Soil moisture - tension relationships, capillary and non-capillary porosity-The tension rings of known volume were driven in each treatment field after the implement operation at various places and the soil samples were collected. They were saturated with water overnight and weighed. A suction of 50 cm height was created in the Buchner funnel and the rings containing the saturated soil were transferred to the filter paper in the Buchner funnel. The soil was allowed to attain equilibrium with the applied tension foreight hours and then removed and weighed. Then it was dried at 105 ℃ to constant weight. The results are as follows:

Total porosity (I) = wt. of soil at '0' tension - oven dry wt. of soil;

Non-capillary porosity = wt. of soil at '0' tension - wt. of soil at 50 cm tension; and

Capillary porosity = Total porosity - non-capillary porosity

Hydraulic Conductivity-The soil samples collected in the permeability rings were saturated over night with water. The saturated soils were serially arranged in series so as to maintain a constant head of water over the soil . The water passing through the soil at a stipulated time was collected and measured until concordant values were obtained. Then the values were calculated using Darcey's equation

(Dhakshnamurthy and Gupta, 1968).

Hydraulic conductivity =

$$\frac{QL}{t \times h \times A} \text{ cm/ha}$$

where,

Q = quantity of water passed through the column, cm^3

L = length of soil + water column, cm

t = time, hr

A = area of the cylinder, cm^2

h = height of soil column, cm

Infiltration-The double ring infiltrometer procedure as recommended by Dhakshnamurthi and Gupta (1968) was adopted. Rings of 30 cm and 50 cm diameter and 20 cm height were driven in the field after each group of implements' operation, with the help of a hammer until 10 cm of each ring entered into the soil. A constant head water supply unit was arranged to maintain a head of 5 cm on the soil surface. The outer and inner rings were filled with water to a depth of 5 cm and the water supply was opened so that a constant head of 5 cm was maintained. The volume of water going into the soil were recorded at 15th, 30th, 60th and 120th minutes etc. until the value became constant. From the values obtained the infiltration rate was calculated for each sample.

Performance Evaluation of the Implement

The implement was put in trial in two types of soils, namely; black clay loam and red loam soils in the fields of the Tamil Nadu Agricultural University campus. In order to evaluate the economics of the CTBFF the time taken to cover the area and fuel consumed for the operation were observed while in op-

Table 1. Clod Size Distribution

Implement combination	Percentage of clods retained in sieves of 34 mm	28 mm	20 mm	17 mm	12 mm	10 mm	3.5 mm	under 3.5mm
Black clay loam								
T_1 Mould board + cultivator	16.4	8.9	9.6	8.0	5.5	4.4	24.2	23.0
T_2 Mould board + cultivator + disc harrow	13.8	9.2	8.7	8.2	6.1	5.1	23.8	25.1
T_3 Mould board + power tiller roto tiller	7.9	7.9	7.6	7.5	4.0	5.0	22.1	38.0
T_4 Combination tillage bed furrow former	4.6	8.1	7.2	7.6	5.1	4.6	19.3	43.5
Red loam								
T_1 Mould board + cultivator	8.4	10.1	10.2	7.8	6.6	8.2	19.8	28.9
T_2 Mould board + cultivator + disc harrow	6.3	8.9	9.7	7.4	6.5	7.4	18.4	35.4
T_3 Mould board + power tiller roto tiller	-	8.8	5.8	6.6	8.3	11.6	13.2	45.7
T_4 Combination tillage bed furrow former	-	5.0	5.1	5.4	4.8	11.3	15.9	52.5

Table 2. Physical Properties of Soil After Using Different Treatments

Implement combination	Total porosity (%)	Capillary porosity (%)	Non capillary porosity (%)	Hydraulic conductivity (%)	Bulk density (gm/cc)
Black clay loam					
T_1 Mould board + cultivator	49.40	34.15	15.25	11.60	1.49
T_2 Mould board + cultivator + disc harrow	52.30	35.95	16.35	12.32	1.38
T_3 Mould board + power tiller roto tiller	54.20	37.98	16.22	14.17	1.36
T_4 Combination tillage bed furrow former	57.53	38.89	18.64	14.84	1.26
Red loam					
T_1 Mould board + cultivator	50.30	39.60	10.70	13.24	1.54
T_2 Mould board + cultivator + disc harrow	52.80	41.20	11.60	15.56	1.39
T_3 Mould board + power tiller roto tiller	54.30	42.00	12.30	16.19	1.33
T_4 Combination tillage bed furrow former	55.80	38.20	17.60	18.12	1.23

eration at the conventional tillage practice of primary tillage with mould board plough and dual secondary ploughing with cultivator and disc harrow operations. Data for primary tillage with mould board plough and secondary tillage with power tiller were also observed. Each time more than three observations were made and the average values were tabulated.

The fixed and variable costs for each implement operation were also estimated and the results in the following aspects were calculated:

a. Time required per ha for each implement/combination operation;
b. Fuel consumed per ha for each implement/combination operation;
c. Energy required for preparing the seed bed per ha; and
d. Total cost of operation for each implement/combination.

Results and Discussion

Clod Size Distribution

The percentage of clods retained in different of sieves are shown in **Table 1** and **Fig.2**.

Black clay loam-Clod sizes greater than 34 cm each represented 16.4 per cent in the operations using the mould board plough followed by secondary tillage with cultivator. Fine particles of clod sizes of less than 3.5cm each represented the bulk(43.5 per cent) of the sieved soil samples.

Red loam i)-The clod sizes greater than 34 mm each were not available in the tillage practices except in the mould board plough + cultivator and mould board plough + cultivator + disc harrow; ii) In the tillage practice with the CTBFF the clod sizes of less than 3.5 were found in greater percentage (52.5) than in any of the other combinations; iii) The percentage of all sizes of clods were evenly distributed in all other combinations with very little difference. From **Table 1** it could be ascertained that the CTBFF is more effective in red loam than in black clay loam soils.

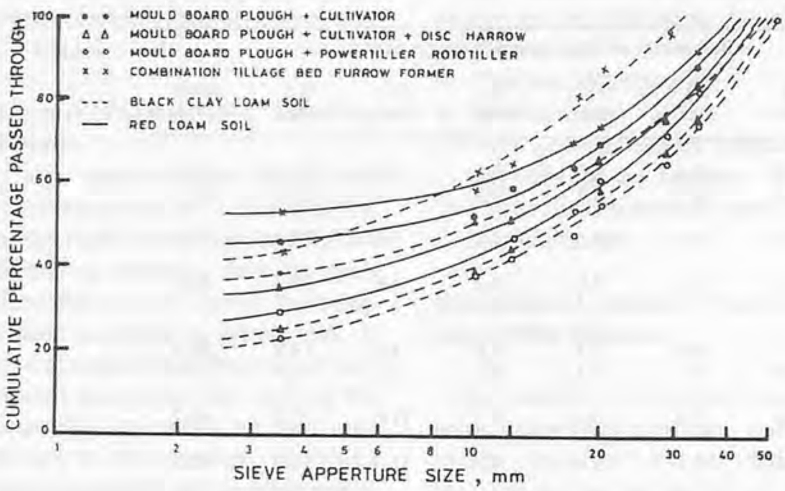


Fig.2 Pulverization effect of different implements.

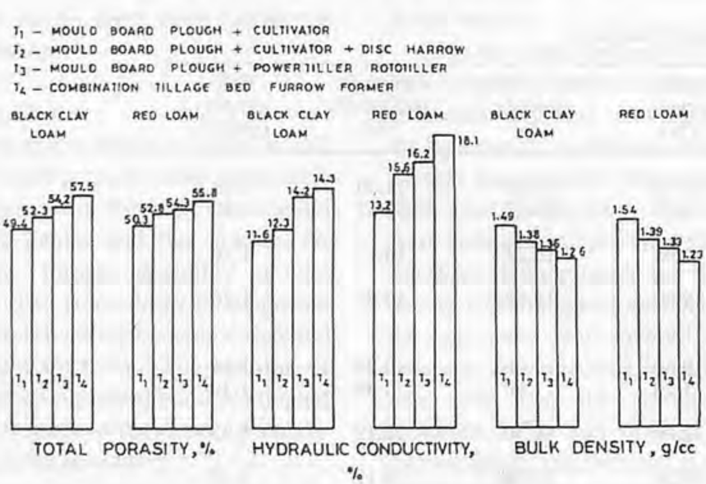


Fig.3 Soil physical properties.

Bulk Density

Table 2 and **Fig.3** shows the bulk density measured in different treatments.

Black clay loam- When the tillage was carried out using the mould board plough + cultivator, the bulk density of the block clay loam soil was as high as 1.49 gm/cm3. When the primary tillage was followed by both the secondary tillage implements the bulk density was reduced to 1.38 gm/cm3 and further declined to 1.26 gm/cm3 in the CTBFF.

Red loam- i) The bulk density in combination the CTBFF, the tilled soil was 1.23 gm/cm3 (minimum). The bulk density in the secondary tillage carried out with cultivator over the primary tillage with mould board plough was high at 1.54 gm/cm3.

ii) The bulk density was reduced to 1.39 gm/cm3 only when two secondary tillage operations were carried out over the primary tilled soil with the cultivator and disc harrow.

iii)The power tiller operation over the primarily tilled soil reduced the bulk density further to 1.33 gm/cm3 which was almost similar to that of the primary and two secondary tillage operations.

Hence, it is concluded from **Table 2** and **Fig. 3** that the tillage using the CTBFF alone produced a lower and favourable bulk density for the root penetration of many crops.

Total Porosity

Total porosity is the sum of capillary porosity and non-capillary porosity which are important physical characteristics for the movements of air, and water in the soil. **Table 2** and **Fig.3** shows the important physical properties of black clay loam and red loam soils when the mould board plough and its combination of tillage implements were used.

Black clay loam- In the mould board plough + cultivator tilled soil, the total porosity obtained was found only 49.4 per cent but when the mould board plough was followed by secondary tillage tool of cultivator and disc harrow, the percentage of total porosity increased to 52.3 per cent; and the use of the mould board plough followed by power tiller-roto tiller operation, the total porosity was in the range of 54.2 per cent. And when the CTBFF was used, the total porosity was in the range of 57.53 per cent.

Red loam soil- In the red loam soil, when the tillage was carried out using mould board plough + cultivator, the total porosity remained in the range of 50.3 per cent, but when the primary tillage was followed by a secondary tillage with the cultivator and disc harrow, the percentage of total porosity increased to 52.8 per cent; ii) When the primary tillage using the power tiller-roto tiller, the percentage of total porosity was 54.3 per cent; iii)It is interesting to note that when the combination tillage bed furrow former alone was used to till the red loam soil, the percentage of total porosity increased to 55.8 per cent.

On analysing the total porosity occurrence in black clay loam and red loam soils, it is clear that the total porosity in black clay loam varied between 49.4 and 57.3 per cent whereas in red loam soil the variation was between 50.3 and 55.8 per cent.

Capillary Porosity

Black clay loam- Reviewing the statistical data on **Table 2**, the following conclusions are drawn:

i) When tillage was done using the mould board plough followed by the cultivator in black clay loam soil the capillary porosity was only 34.15 per cent, but when the primary tillage with mould board plough was followed by cultivator and disc harrow, the capillary porosity increased to 35.95 per cent. and

ii.) when the power tiller-roto tiller was used over the primary tilled soil, the capillary porosity was as 37.98 per cent that came close to the performance a higher capillary porosity of 38.89 per cent.

Red loam soil- i) In the tillage operation using mould board plough followed by the cultivator and disc harrow, the capillary porosity was 39.6 and 41.2 per cent, respectively; and ii) using the mould board plough + power tiller-roto tiller tillage operation and individual CTBFF the capillary porosity were 42.0 and 38.2 per cent, respectively, which shows that mould board plough + power tiller-roto tiller tillage operation did better with capillary porosity. A greater difference in capillary porosity percentage was noticed in the black clay loam soil using various combination of tillage tools, but in red loam soil the difference was mignificant and almost remained the same with different combinations of implements.

Non-capillary Porosity

Black clay loam- i) The CTBFF alone created 18.64 per cent of non-capillary porosity which is greater than any other sliding tillage tool group of operations, and ii) The other tillage tool combinations created only between the range of 15.25 to 16.35 per cent.

Red loam- The CTBFF created a greater percentage of non-capillary porosity at 17.60 per cent while all other combinations made only a non-capillary porosity of between 10.7 and 12.3 per cent.

Hydraulic Conductivity

The results obtained in determining the hydraulic conductivity

Table 3. Infiltration Rate

Implement combination	Black clay loam (cm/hr) After				Red loam (cm/hr) After			
	15 min	30 min	60 min	120 min	15 min	30 min	60 min	120 min
T_1 Mould board + cultivator	92.14	8.78	6.95	10.50	86.95	9.62	6.27	9.81
T_2 Mould board + cultivator + disc harrow	97.50	8.55	5.20	11.65	94.85	6.53	5.75	8.70
T_3 Mould board + power tiller roto tiller	100.50	10.30	4.50	9.75	97.30	16.33	6.50	9.80
T_4 Combination tillage bed furrow former	116.50	9.89	5.82	12.30	104.55	14.85	8.43	12.83

in the two soil types are shown in **Table 2** and **Fig. 3** but briefly stated as follows:

Black clay loam- i) In the tillage using the mould board plough + cultivator, the percentage of hydraulic conductivity was small at 11. 6 per cent. However, when the primary tillage followed by secondary tillage with cultivator and disc harrow the hydraulic conductivity increased 12.32 per cent: On the other hand,when the power tiller-roto tiller was used over the primary tillage operation, the hydraulic conductivity further increased to 14.17 per cent -that is pretty close to the performance of the CTBFF at only 14.84 per cent.

Red loam -i)When the tillage was carried out in the red loam soil using the mould board plough + cultivator, the hydraulic conductivity was low at 13.24 per cent. But when the primary tillage was followed by the cultivator and disc harrow, the hydraulic conductivity improved to 15.56 per cent; ii) the power tiller-roto tiller was operated over the primary tilled soil, the hydraulic conductivity was still improved to 16.19 per cent. But still shy in the perfomance of the CTBFF at 18.12 per cent as shown in **Table 2** and **Fig.3** .

Table 4. Cost and Energy Requirement

Implement combination	Time required/ha (hrs)	Cost of operation/ha ($)	Energy required/ha (MJ/ha)
T_1 Mould board + cultivator	8.51	59.09	1792.32
T_2 Mould board + cultivator + disc harrow	11.22	77.92	2273.47
T_3 Mould board + power tiller roto tiller	11.89	63.54	1670.00
T_4 Combination tillage bed furrow former	2.87	27.90	652.10

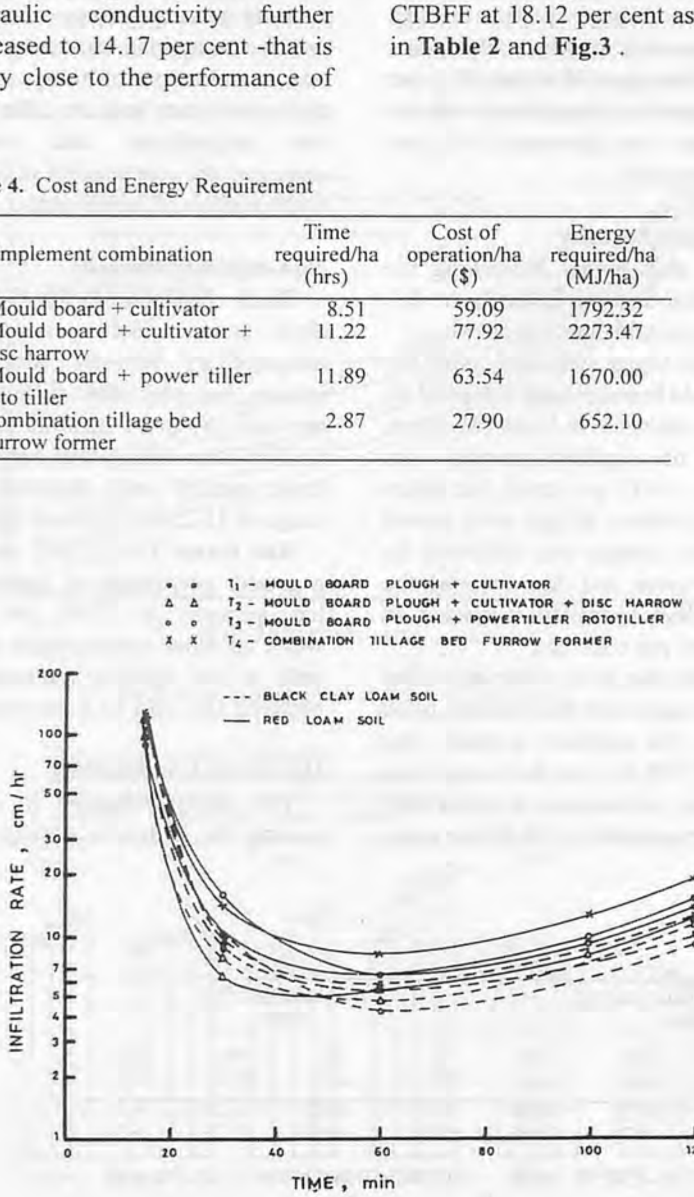


Fig.4 Infiltration rate.

Infiltration

Black clay loam- Table 3 and **Fig. 4** show the infiltration readings taken in black clay loam and red loam soils after disturbing the soil with primary and secondary tillage operations. In black clay loam soil the individual operation using the CTBFF a better infiltration rate was realized. Therefore, in black clay loam where the run off is to be avoided and good infiltration is desired, it is advisable to use the CTBFF.

Red loam- The use of CTBBF in tilling the red loam soil induced a better infiltration rate when compared with the performance of all the other tests of their combinations.

Economic Evaluation

In **Table 4** it is shown that the cost of tillage operation using the CTBFF furrow former was minimum ($27.90) when compared to other tillage implement groups (more than $ 59.09). Therefore, the cost of operation with the CTBFF is less than 47.22 per cent of the other implements group operations. The energy consumption of the CTBFF 652.10 MJ/ha, when compared to other implements combination (1670 MJ/ha), i.e., nearly 39 per cent of other conventional tillage implements. Therefore, the cost, time and energy requirements of the CTBFF is very minimum when compared to other implement groups.

Conclution

The percentage of fine soil particles of less than 3.5 mm was great using the CTBFF;more in the combination 43.5 per cent in black clay loam soil and 52.5 per cent in red loam soil. Also, the bulk density was minimum in the plots tilled with the use of CTBFF at 15.4 and 20.1 per cent less in black clay loam and red loam soils, respectively. The total porosity in black clay loam varied between 49.4 and 57.3 per cent whereas in red loam soil, the variation is between 50.3 and 55.8 per cent. The maximum porosity was also achieved with the use of the CTBFF and minimum in the use of mould board + cultivator. The tillage using the CTBFF a better infiltration rate when compared to other treatments. The cost of operation using the CTBFF was 47.22 per cent less and the energy consumption was 39 per cent less.

REFERENCES

Chamen,W.C.T., R.E.Cope, and D.E.Patterson, 1979. Development and performance of a high output rotary digger. J. Agric. Engng. Res., 24 : 301-308.

Dakshinamurthi,C.,R.P.Gupta, 1968. Practicals of soil physics. Indian Agricultural Research Institute. New Delhi.

Hendrick,J.G. 1980. A powered rotary chisel. TRANSACTIONS of the ASAE., 23(6) : 1349-1352.

Hoki, M., T.H.Burkhardt, RH. Wilkinson, and T.Tanoue, 1988. Study of PTO driven powered disk tiller. TRANSACTIONS of the ASAE., 31(5) : 1355-1360.

Kumar,V.J.F. and R.Manian, 1986. Tractor drawn combination tillage tool. Agric. Mech. in Asia, Africa and Latin America, 17(1) : 31-36.

Mehuys,G.R. 1984. Soil degradation of agricultural land in Quebec. A review and impact assessment. Science Council of Canada, Ottawa

Sigitov,A.A. 1992. Combined unit. Proizvodstve I Pererabotka, 1: 23-25.

Stout,B.A. 1984. Energy use and production in agriculture. Report No.99, Ames, IA, Iowa State University Press.

Wilkes,J.M. and S.H. Addai, 1988. The use of the 'Wye double digger' as an alternative to the plough to reduce energy requirement per hectare and soil damage. Presented at the International Conference of Agricultural Engineering, Paper No., 88-190.

Wismer,R.D., E.L. Wegsheid, H.J. Luth, and B.E. Roming, 1968. Energy applications in tillage and earth moving. SAE Paper No., 69-230. ■■

(Continued from Page 21)

Influence of Deep Tillage on in-situ Moisture Conservation in Dry Farming

Basker, A., C. Paulraj., B. rajkannan., S. Avudainayagam.,S. Poongothai., R. Natesan., K. Appavu., K.K. Mathan and Rani Perumal, 1995. Twenty five years of soil physics research in Tamil Nadu. Department of soil science and agricultural chemistry, Tamil Nadu Agricultural University, Coimbatore.

Brain, M. A., Cxhaney and D.R. Hodgson, 1984. Preliminary investigation on the response of spring barely (Horedeum sativum) to soil cultivation with the 'paraplow'. SoilTillage Research, 4: 277-293.

Chen Guoliang, 1983. The Agricultural climate resource in less plateau and its rational use. In: Shan Lun, Niu Pu (eds) selected works on Arid and Semi-Arid Farming, Vol.1 PP.92-89. Quoted by Li Sheng Xiu and Xiao Ling.

Doty, C.W., R.B.Campbell, and D.C.Reicosky, 1975. Crop responses to chiseling and irrigation in soils with a compact A_2 horizon. Trans. Am. Soc. Agr. Engg. 18: 668-672.

Maliwal, G.L. 1992. Soil and Moisture conservation for dry lands. Dry land resources and technology, Vol.5 : 210-221.

Nitant Pratap Singh, H.C. 1995. Effects of deep tillage on dryland production of redgram in central India. Soil and Tillage Research 34: 17-26.

Rattan Lal, 1989. Conservation tillage. Adv. in Agronomy. Vol.42: 147-151.

Salan, O.A., O.A.Opara and R.Swennen, 1992. Effects of mulching on soil properties, growth and yield of plantain on a topical utisoil in southern Nigeria. Soil and Tillage Research. 32: 73-91.

Zhao Fengbin, 1987. Studies on soil tillage methods southeast Shanxi drylands. Shanxi Agricultural Science 5: 30. Quoted bv Li Shengxiu and Xiao Ling, 1992. ■■

Design and Development of A Multi-crop Multi-row Seed Drill

by
Md. Abdul Wohab
Senior Scientific Officer
Bangladesh Agricultural Research Institute
Joydebpur, Gazipur 1701
Bangladesh

Md. Abdus Satter
Chief Scientific Officer
Bangladesh Agricultural Research Institute
Joydebpur, Gazipur 1701
Bangladesh

Md. Abdul Mazed
Director General
Bangladesh Agricultural Research Institute,
Joydebpur, Gazipur 1701
Bangladesh

Md. Fazlur Rahman Khan
Senior Scientific Officer
Bangladesh Agricultural Research Institute,
Joydebpur, Gazipur 1701
Bangladesh

Abstract

A manually-operated multi-crop, multi-row seed drill to be used for sowing jute, wheat, pulses and oilseeds has been designed, fabricated and tested in the Farm Machinery and Post Harvest Process Engineering(FMPED), Bangladesh Agricultural Reseach Institute(BARI). The seeder was extensively tested both in laboratory and field conditions. One person is required to operate the seeder with an average sowing capacity of 0.13 ha./hr. The weight of the seeder is 13 kg. and per unit cost is Tk. 1700 (US$ 40). The field performance of the seeder was quite satisfactory.

Introduction

It is an established fact that line sowing of jute, wheat, paddy, pulses and oilseeds contribute to high yield and involves less costs. The farmers of Bangladesh are still practicing traditional methods of broadcasting for these crops. The line sowing by mechanical means provides uniform placement of seeds with proper spacing at correct depth. It also ensures better germination, more emergence of seedlings and helps to achieve more harvestable plant population. On the other hand, over or under plant population, non-uniform growth have been observed in the fields with traditionally broadcast seed. Alam (1990) cited that a seeder of good performance can reduce jute seed requirement by about 50% and increase fiber yield by about 10-15% in line sown field.

The International Jute Organization (IJO) sponsored a project to develop a suitable jute seeder (also suitable for other crops). The FMPED of BARI implemented the project. BARI at first developed an animal-drawn six-row multi-crop seed-drill, where a roller type seed metering device was built in. To simplify the fabrication of seed metering device, the roller type metering was converted to gravity seed metering system fitted with an agitator and adjustable orifice plate suitable for different crops. Since it was not possible to make straight line sowing without a pair of trained bullock, the six-row seeder was converted to two-person operated seeder- one person pulling and another person pushing. Afterwards, to increase the ease of operation, the structure of the seeder was changed to single-person operated, push type, 3-row seeder-looks like a tricycle, called " IJO-BARI SEEDER" **(Fig.1)**. Through vigorous testing both in laboratory and field conditions, the seeder was simply modified to make it more widely useable by the farmers.

Acknowledgment
The full financial help from International Jute Organization is gratefully acknowledged.

Materials and Methods

Description of the Machine

The design of the machine is so

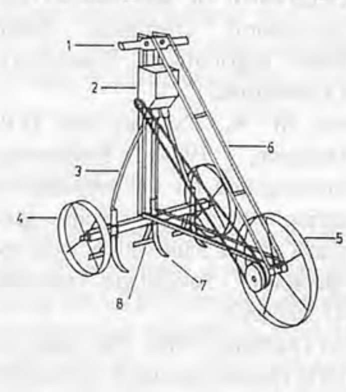


Fig.1 Multi-crop Seed-drill.

simple that it can be fabricated with locally available materials like mild steel (M.S.) anglebar, M. S.

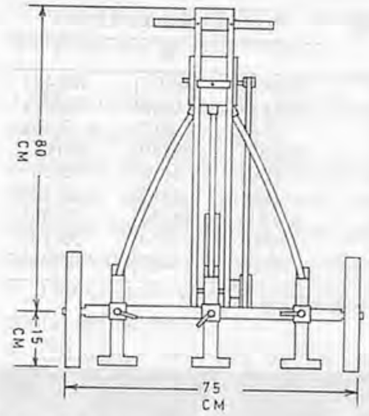


Fig.2 Back View.

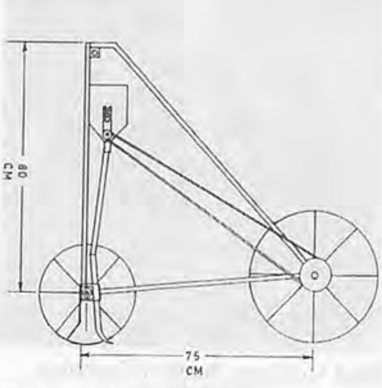


Fig.3 Side View of Seed-drill.

rod, M. S. flatbar, M. S. sheet, M. S. nutbolts and V-belt. The different functional parts made with these materials are 1) handle, 2) seed hopper, 3) seed tube, 4) back wheel, 5) front wheel, 6) frame, 7) furrower, 8) furrow closer and 9) V-belt pulley arrangement which revolves the agitator shaft **(Fig.1)**. As the seeder moves forward the agitator moves which drops the seeds through the orifices of the seed metering plate. There are different seed metering plates for different crops. Different seed metering plate have different orifice size. The metering plate is selected according to seed rate required by the crop. The plate is fitted at the bottom edge of the of the seed hopper by two nutbolts. A minimum clearance has to maintain between agitator and seed metering plate. A clearance of 2 mm fits for small-size of seeds (jute) and 5 mm for large seeds (wheat). Clearance is adjusted by placing two small pieces of metal flatbar between the agitator and metering plate.

Laboratory Test

During the laboratory test, two sizes of seeds were used, wheat (kanchan) seed as large seed and jute (capsularies) seed as small seed. Seed rate was calibrated at different speed of sowing, orifice size and orifice agitator clearance **(Table 1)**. Seed distribution in rows was also studied with both types of seeds at different orifice sizes and clearances **(Table 2, Table 3)**.

Table 1. Effect of orifice size and agitator clearance on seed rate (kg/ha) of jute and wheat at an average speed of 2.5 km/h

Jute (cap.)				Wheat (kanchan)			
Orifice dia.(mm)	Agitator clearance (mm)			Orifice dia.(mm)	Agitator clearance (mm)		
	2	3	4		5	6	7
3.0	2.50	-	-	9.0	113	76	59
3.5	6.16	4.5	3.90	9.5	129	100	75
4.0	12.00	10.00	5.50	10.0	137	106	77

Table 2. Percentage variation of jute and wheat seed drop among rows (number of seed per meter)

Jute (cap.)				Wheat (kanchan)			
Orifice dia.(mm)	Agitator clearance (mm)			Orifice dia.(mm)	Agitator clearance (mm)		
	2	3	4		5	6	7
3.5	30(17)*	34(17.1)	42(23.4)	9.0	12(4.8)	15(7.4)	22(13.5)
4.0	2(1.7)	10 (6)	11(6.8)	9.5	5.3(4)	7.6(5.7)	12(6.7)
				10.0	13(3)	11(7)	11(7.2)

The figure outside and inside the parenthesis indicate maximum variation and average variation, respectively.

Field Performance Test

The seeder has been tested in different locations with jute and wheat seeds. The locations were BARI experimental fields, Upazila demonstration firms and farmers field. Before testing the seeder in Upa-zila demonstration farm and farmers' field, it was tested at the BARI experimental field to check its performance **(Fig.4)**.

The furrow openers are adjustable both in horizontal and vertical positions. Sowing depth and row spacing can be fixed with frame according to crop requirement. As the seed is delivered from the seed hopper, it is placed in the furrow through the seed tube and furrow opener. After placing the seed in the furrow, it is covered and compacted by the furrow closer. The furrow closers are also adjustable and adjust according to the required compaction.

During the field performance tests, parameters like seed rate, orifice size of seed metering plate, orifice-agitator clearance and speed of operation were considered of the laboratory test results. Seed rate for jute and wheat were 6 kg/ha. and 120 kg/ha. respectively. Orifice sizes for jute and wheat were selected as 3.5 mm and 10 mm, respectively. The orifice-agitator clearance were selected as 2 mm and 5 mm, respectively. The speed of operations was selected as 2.5 km/hr for obtaining the required seed rate and better spacing of seeds in furrows. The work rest cycle for operator during field test was considered as 30:10. When the plants developed 2-3 leaves, the

Table 3. Effect of orifice size, agitator clearance on seed (jute and wheat) population(%) and distance covered (%) at an average speed of 2.5km/hr

Jute (cap.)					Wheat (kanchan)				
Orifice dia.(mm)	Seed spacing (cm)	Agitator clearance (mm)			Orifice dia.(mm)	Seed spacing (cm)	Agitator clearance (mm)		
		2	3	4			5	6	7
3.5	1-5	97(90)	87(80)	78(50)	9.0	1-5	94(81)	88(95)	80(48)
	6-10	8(20)	15(39)	19(36)		6-10	5(15)	10(28)	13(27)
	>10	0(0)	1(3)	3(14)		>10	1(14)	2(7)	7(26)
4.0	1-5	92(88)	84(80)	67(59)	9.5	1-5	94(81)	89(70)	85(62)
	6-10	3(12)	3(10)	10(28)		6-10	6(19)	6(18)	12(26)
	>10	0(0)	0(0)	3(13)		>10	0(0)	3(12)	3(12)
					10.0	1-5	97(91)	96(86)	93(65)
						6-10	3(90)	4(14)	59(14)
						>10	0(0)	0(0)	2(21)

The figure outside and inside the parenthesis indicate maximum variation and average variation, respectively.

Table 4. Field performance test results of the seeder for sowing jute and wheat

Particulars	Jute	Wheat
Seed germination (%)	72	87.0
Area of land under sowing (ha)	1.2	2.5
Seed rate (kg/ha)	4-6	120-140
Row spacing (cm)	25	20
Depth of sowing (cm)	2-3	3-4
Operating speed (km/hr.)	2.5-3.0	2.0-2.5
Eff. Sowing cap. (ha/hr.)	0.14	0.11
Time required (man-hr./ha)	14.2	-
Plant stand		
After emergence (plant/sq.m)	140	300
After thinning (plant/sq.m)	63	-
Draft force (kg)	9	14

plant population were counted (**Table 4**). During the laboratory as well as field tests, all necessary data were collected according to the Regional Network for Agricultural Machinery (RNAM) test code.

Results and Discussion

The multi-crop multi-row seeder has been tested extensively both in laboratory and field conditions and the results are shown in the Tables. During the laboratory test, it was observed that the different parameters of seed metering unit such as orifice diameter, orifice-agitator clearance as well as speed of operation had significant effect on seed rate. The effect of orifice size and orifice-agitator clearance on seed rate of jute and wheat are shown in **Table 1** which shows that the seed rate increased with an increase of orifice diameter and decreased with an increase of orifice-agitator clearance.

It is shown **Table 2** that there was a little planting (seed to seed distance) variation between rows. The variation increased with the increase of agitator clearance and decreased with an increase of orifice size. The average row-to-row variations were between 1.7 % to 23.4 % for jute and 3 % to 13.5 % for wheat. These planting variations occurred due to loss of precision in manufacturing the metering unit of the seeder.

The effect of orifice size and agitator clearance on seed population distribution for jute and wheat have been studied during the laboratory tests and the results are presented in **Table 3**. Considering the optimum seed rate of jute about 6 kg/ha orifice size 3.5 mm and agitator clearance 2 mm has better seed distribution (97 %) and distance covered (90 %) than the other orifice size and agitator clearance. However, wheat, orifice size was 10 mm with agitator clearance of 5 mm has better seed distribution (97 %) and distance covered (91 %) than other orifice size and clearance.

Fig.4 Multi-crop Seeder in Operation.

Table 4 represents the field performance test results of the seeder. Jute field has the maximum effective sowing capacity due to its fine land, shallow depth of sowing, less draft and faster speed of operation. The required force to operate the seeder for different crop is within the capacity of a single person. For, about 40 % plants needed thinning due to continuous sowing of seed.

During the laboratory test of the seeder, the hopper to hopper seed rate of similar seed varies significantly and varies row to row. To minimize the variance of seed rate, critical observations were followed during the laboratory tests. It was found that seed rate varied due to manufacturing defect of the seed metering unit as followeds:

1. Non-uniform round and eccentric shaft of agitator plate.
2. Centre to centre distance of orifice and agitator plate were not identical and the agitator plate was not placed centrally on the orifice.
3. The orifices were not uniformly round and smooth.
4. Clearance between orifice and agitator was not adjusted.

The manufacturing defects of the seeder were corrected with the following measures:
1. The agitator plates were cut and drilled on a lathe machine instead of free hand cutting.
2. Centre to centre distance of orifice and agitator plates were controlled by a standard template.
1. Orifices were uniformly rounded through careful drilling with a template and smoothened by grinding.
2. Clearance between orifice and agitator plate were well adjusted by placing two small pieces of metal flat bars.

Conclusion and Recommendation

Based on the laboratory and field test, the following recommendations are suggested:
1. The seeder should be operated at an average speed of about 2.5 km/h.
2. The optimum orifice diameter and agitator clearance of different seeds should be selected during laboratory test. An example, orifice diameter and agitator clearance of jute and wheat seeds are 3.5 mm, 10 mm and 2 mm, 5 mm, respectively.
3. The seed metering unit should be fabricated very carefully. Precise machining of the unit is very essential for better functioning.
4. Extensive extension and motivation work is recommended for mass scale use of the seeder in the field.

REFERENCES

Alam, A. (1990). Time and cost of sowing by line sowing using improved implements.

Paper presented at IJO sponsored National seminar on use of jute seeder in India.

BARI.(1990).Development of multi-row animal drawn seed drill.BARI annual internal review. ■■

New Co-operating Editor

Abdulsamad Abdulmalik Hazza'a

Nationality: Republic of Yemen
Birth Date: November 30, 1957
Qualifications:
Ph.D Technical Science(Agricultural Engineering),with minors in Agricultural Machines, Don-Technical University, Rostov On-Don,Russia,1992.
M.Sc. Don Technical University,Rostov On-Don, Russia, 1980.
Experience:
1998-Present:Teaching Agricultural Machines and Equipment,Mathematics and Machine Drawing.
1996-Present:Associate Professor and Head, Agricultural Engineering Department, Faculty of Agriculture, Sana'a University.
1992-1996:Assistant Professor and Head, Agricultural Engineering Department, Faculty of Agriculture, Sana'a University.
1991-1996:Assistant Professor, Agricultural Engineering Department, Faculty of Agriculture, Sana'a University.
1987-1990:Graduate Assistance, Department of Theory Mechanisms and Machines, Don-Technical University, Russia.
1985-1986:Technical Manager & Co-General Manager, Surdud Production Farm, Tihama Development Authority,Ministry of Agriculture,Republic of Yemen.
1983-1985:Head,Engineering Department Tihama Development Authority, Surdud Production Farm, American Openhiemen Industrial Farming Company, Republic of Yemen.
1981-1982:Workshop Supervisor,Surdud Production Farm, Tihama Development Authority, Ministry of Agriculture, Republic of Yemen.
Current Position:

Associate Professor and Head of Agricultural Engineering Department, Faculty of Agriculture, Sana'a University, P.O.Box 12355, Sana'a Republic of Yemen.Tel:967-1-250501, Fax:967-1-251585 ■■

Development of a Promising Manual Pump

by
Md. Abdul Wohab
Senior Scientific Officer
Bangladesh Agricultural Research Institute
Joydebpur, Gazipur 1701
Bangladesh

Md. Abdus Satter
Chief Scientific Officer
Bangladesh Agricultural Research Institute
Joydebpur, Gazipur 1701
Bangladesh

Md. Abdul Mazed
Director General
Bangladesh Agricultural Research Institute,
Joydebpur, Gazipur 1701
Bangladesh

Md. Fazlur Rahman Khan
Senior Scientific Officer
Bangladesh Agricultural Research Institute,
Joydebpur, Gazipur 1701
Bangladesh

Abstract

A 4-cylinder-manually operated pump for use in lifting ground water as well as surface water was designed, fabricated and tested at the Farm Machinery and Post Harvest Process Engineering Division (FMPHPED) of the Bangladesh Agricultural Research Institute (BARI). There were two models of the pump. Model-1 was suitable for lifting ground water as well as surface water and model-2 for lifting surface water only. One person was required to operate the pump when suction lift was less than 3m, beyond which two persons were required. The average discharge of the pump at 4m suction lift was 149 lit./min. for lifting ground water and 135 lit./min. for surface water. The cost of the pump was Taka 1000 (US$ 22).

Introduction

Water is probably the single most important factor that can "make or break" a crop. If water is not available in time and adequately, optimum crop production may not be possible. Most of the Bangladesh farmers of are poor and their socio-economic conditions do not permit them to introduce imported capital-intensive machinery. The introduction of small scale agricultural machinery can play an important role in increasing food production in Bangladesh. High initial and maintenance costs, advanced technical know-how, non-availability of spare parts, requirements of large irrigable area and other restrictions make the poor illiterate farmers reluctant to the use of deep tube-wells, shallow tube-wells or low-lift pumps. Only manual pumps are suitable for the poor farmers for small-scale irrigation.

Presently about 18% of the countrys' arable land is irrigated by traditional devices of which 32% is irrigated by manual pumps (BBS, 1991). Available human energy is now being called upon to drive manual pumps. International organizations are actively participating in implementing the installation of manual pumps in the country (Islam, 1983). There are some "Char" areas in Bangladesh where manual pumps are the only means for ground water irrigation.

Manually-operated pumps are shallow tube wells which can usually lift water for a suction lift of less than 7.4m (Islam, 1983). In order to overcome the difficulties associated with the use of modern pumps, several organizations like Rangpur-Dinajpur Rehabilitation Service (RDRS) and BRRI developed manually operated diaphragm pumps. The BRRI developed two-man operated pump requiring high power, 0.32-0.54 hp (Baqui, 1980) at suction lifts 0.91 to 6.09 m, which is beyond the capacity of even 2 person, as an average healthy person in Bangladesh can develop only 0.10 horse power (Khan, 1983). Structural design of RDRS developed pumps was too tedious and ineffective (Ali, 1987).

Considering the limitations of high-tech devices and the existing manual pumps, an attempt was taken to develop low cost, high head, high discharge and low-power requiring manual pumps for the poor farmers in Bangladesh for better small scale irrigation.

Material and Methods

Pump Description

The pump was designed and fabricated at the shop of FMPHPED of BARI. Locally available materials were used to keep the technology as simple as possible.

The pump consisted of the fol-

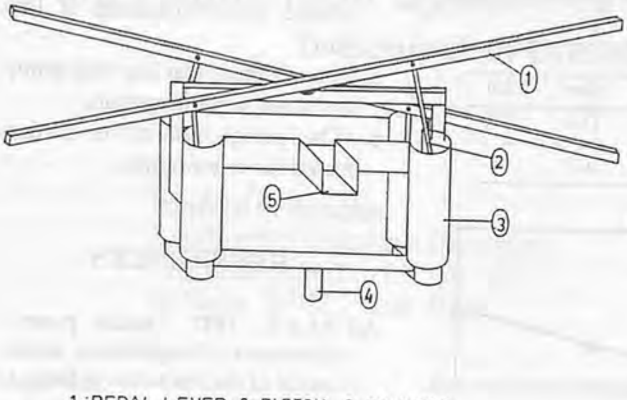


Fig.1 Manual Pump.

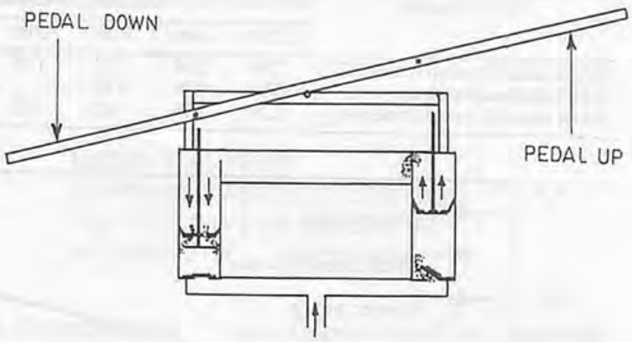


Fig.2 Schematic of Manual Pump.

Table 1. Comparative Performance of BARI Manual Pump, Tin Treadle Pump and Rower Pump for Lifting Ground Water at diffErent Suction Lift

Type of pump	Discharge (lit./min.)					
	2m	3m	4m	5m	6m	7m
BARI manual pump (model-1)	162	156	149	142	120	98
Twin treadle pump	75	57	51	47	38	33
Rower pump	57	51	45	41	38	35

lowing components (**Fig.1**):1. cylinder 2. piston 3. pedal 4. shaft 5. v-pulley 6. suction pipe 7. discharge chute.

Materials used in fabricating the pump were :a) mild steel (m.s.) angle bar b) m.s. sheet c) m.s. rod d) rubber piston e) wood f) nut, bolts etc.

There were two models of the pump. The model-1 was made with 9cm dia. cylinders suitable for lifting ground water as well as surface water. The model-2 was made with 12cm dia. cylinders suitable for lifting only surface water. Each pump unit had two pairs of cylinders arranged side by side. The pairs of cylinders were connected to a common suction pipe and discharge chute. The pump was called as "BARI MANUAL PUMP".

Pump Operation

The pump can be operated by one person within the limited suction lift (up to 3m). Beyond this lift, two-persons are required to operate the pump comfortably. For one-person operation, v-pulley arrangement in essential but not for two person operation. When the operator pushes one pedal downward one piston moves downward and the other on the opposite moves upward. The upward piston lifts water through a suction pipe and the downward piston allows water to store above it (**Fig.2**). Simultaneously, when the other operator pushes another pedal- one piston goes-down and the other on the opposite goes-up and this piston discharges water through the chute (**Fig.3**). During the pump operation 4 cm dia. pipe was used in the suction line.

Test Procedure

The pump was tested for lifting ground water (model-1) and surface water (model-2) at different suction lifts, ranging from 1.25 to 7 m. The suction lifts were increased by 1 m interval and replicated 4 times at each suction lift. The

Fig.3 Bari Pump in Operation.

pump was set by the side of a reservoir for lifting surface water. Pumped water was collected in a measured tank of 650 lit capacity. While testing for lifting ground water, pump was connected with suction pipe and strainer of same length installed side by side. A stop watch was used to measure the time of discharge. To measure the power requirement by different pumps, a spring balance of 50 kg was used.

Result and Discussion

The performance of the devel-

Table2. Comparative Performance of BARI Manual Pumps and BRRI Diaphragm Pump at Different Suction Lifts for Surface Water

Type of pump	Discharge (lit./min.)					
	1.25m	2.0m	3.0m	4.0m	5.0m	5.5m
BARI manual pump (model-2)	239	204	173	135	118	110
BARI disphragm pump	260	199	133	-	-	-
BARI manual pump (model-1)	125	126	95	112	107	97

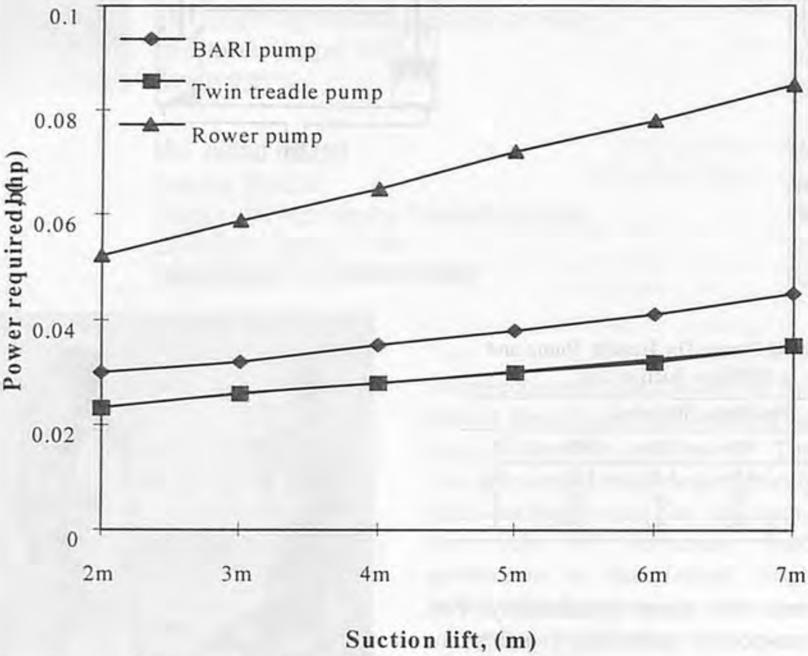


Fig.4 Comperative Power Required by Different Pump.

oped pump (model-1) and other pumps for lifting ground water is presented in Table1. The BARI pump had the highest discharge at different suction lifts. The maximum and minimum discharge of the pump were 162 lit./min and 98 lit./min. at 2m and 7m suction lift, respectively. Table 2 shows the performance of model-2 pump for lifting surface water as 204 lit./min. and 110 lit./min. at 2m and 5.5m suction lift, respectively. The discharge decreased with increasing suction lift for both models. The maximum suction lifts of model-1 and model-2 were 7m and 5.5m, respectively. Beyond these suction lifts, pumps could not be operated successfully. The BRRI diaphragm pump could not be operate beyond 3m suction lift.

Figure 4 shows the power requirement by different manual pumps. Twin treadle pump required the lowest power and the rower pump required the highest power at different suction lifts. Power required by BARI pump was greater than the Twin treadle pump but within a capacity that a healthy person could develop.

Conclusion and Recommendation

1. The pump model-1 can be useed for lifting ground water as well as surface water.
2. The pump model-2 can be useed for lifting surface water only .
3. Both pump models can be used for small scale irrigation for wheat, potato and vegetables production.
4. The pump can be made at the village level workshop at low cost.
5. Poor farmers can use this pump for small scale irrigation.
6. The pump should be further tested for ergonomics.

REFERENCES

Ali M.A.T., 1987. Treadle pump : Assessment of engineering aspect. Journal of the Institution of Engineers, Bangladesh. Vol. 15, No. 1

Baqui, M.A. 1980. Development of diaphragm pump for low-lift irrigation, AMA Vol. XI, No. 1, pp.43-46.

BBS (Bangladesh Bureau of Statistics), 1991.

Islam, M.S., M. A. Mazed and K. C. Roy. 1983. Comparative performance of different types of manual pumps, AMA Vol.12, No.3

Khan, C.M.A. 1983. Development of wheel pump for low-lift irrigation, AMA Vol. 14, No. 2. ■■

Data Acquisition System for Scheduling Irrigation

1. Equipment Operation and Calibration

by
Mahmoud H. Ramadan
Department of Agricultural Engineering
King Faisal University, P.O. Box 420
AL-Hassa 31982, Saudi Arabia

Mushari A. AL-Naeem
Department of Agricultural Engineering
King Faisal University, P.O. Box 420
AL-Hassa 31982, Saudi Arabia

Abstract

A sophisticated automatic weather station was installed, calibrated and operated at the College of Agricultural Sciences and Food, King Faisal University in order to collect data required for irrigation scheduling of wheat crop and to have full record of weather data for this site for future studies.

This paper provides a complete description for the various components of the weather station installation as was carried out together with programming software in order to collect the data and to save it automatically.

Intododuction

Successful irrigation management depends primarily on accurate measurement of weather parameter. Manual readings and recording of weather parameters are considered tedious and laborious. In some cases readings are inaccurate and unreliable. Good decision of when to irrigate and how much water to apply depends on time interval of taking continuous and fast recording of weather parameters. Agricultural development in Saudi Arabia depends basically on weather recording for better manipulation of available water recourses. The automatic recording of weather data becomes a must, especially in the presence of high sophisticated technology available in the market today. The advantages of automatic data collection are, therefore, as follows : The calculations of reference crop evapotranspiration (Eto) can be easily carried out through electronic data handling and computer programming. Data manipulating becomes easy, accurate and versatile. Operating automatic irrigation systems becomes more available. Short and long term prediction of weather conditions for different purposes based on stored historical data can be handy.

This paper describes the equipment needed for data acquisition system, installation, operation and calibration.

Installation Instructions

Sensor Siting and Exposure

Some general guidelines for site selection are listed below. These guidelines were condensed from EPA (1988), EPA (1989), WMO (1983) and AASC (1985).

In order to obtain accurate meteorological data an appropriate site the weather station was installed away from the influence of obstructions (sensors free way). It was fixed in a position where it can make measurements representative of the general area of interest. The station was installed on a square ground 50 mm on each side. One is was planted to short well vegetative grass (Doorenbus, 1979, FAO No. 27).

Wind Speed and Direction

Wind sensors were located over open level terrain and at standard measurement height of 2 m as was recommended by the American Association of State Climatologists (AASC), 1985.

Temperature and Relative Humidity

Sensors were located over an open level area and away from thermal radiation and adequately ventilated. The standard measurement height is 1.5 m as was described by the AASC; 1985.

Precipitation

A rain gauge was sited on level ground where the height of the opening is as low as possible but high enough to avoid splashing waters from the ground (AASC, 1985; EPA, 1989). The standard measurement height is 60 cm. The minimum value by (WMO, 1983 and EPA, 1988) is 30 cm.

Solar Radiation

The pyronometer was located in suh a way as to avoid shadows on the sensor at any time as well as artificial sources of radiation. Mounting height is not critical (WMO, 1983).

Soil Temperature

One square meter of typical soil

Acknowledgment: The authors of the work wish to thank King Abdulaziz City for Science and Technology (KACST) for supporting financially the equipment needed for this research.

surface of interest was chosen for soil temperature data. The measurement site was chosen in such a way that the ground surface is leveled with respect to the immediate area (10 m radius) as recommended by the AASC, 1985. The standard measurement depths are 10 cm and 50 cm. The normal range is 5 cm, 10 cm, 50 cm, 100 cm, (WMO, 1983).

CM10 Tripod Installation Procedure

Tripod Installation

The CM10 tripod-based weather station was used to provide a support structure for mounting the weather station components. The CM10 weather station (**Fig.1**) was equipped with instrumentation enclosure, meteorological sensors, and solar panel. A ground rod (earthling connections) and its clamp were connected to the tripod ground rod via the 4 AWG wire type (AASC, 1985). Then the 12 AWG wire was used to connect the tripod ground rod to the enclosure. The lighting rod was attached tight to the mast.

Tripod and Component Ori- entation

The tripod and component orientation is very vital. The tripod was oriented so one leg points south (**Fig. 2**). The mast was plumbed by adjusting the south and northeast facing legs. The slide-collar on the south facing leg was loose. With the level on the south side of the mast, the leg was adjusted to the level of plumb, then the bolt was tightened. The same procedure was repeated for the northeast facing leg with the level on the east side of the mast. Three rebar stakes were used for securing the tripod to the ground.

Sensor Mounting Brackets

Mounting brackets provided a means of mounting the sensors to the tripod. Bracket mounting heights are referenced from the top of the bell reducer.

019 ALU Crossarm Sensor Mount

The 019 ALU crossarm sensor mount was oriented East-West (with the 3/4" NU-Rail connector pointing east).

41002 - 3 Gill Radiation Shield.

The gill radiation shield was attached to the mast where it was positioned on the side of the mast facing the prevailing wind, with the top of the black plastic mounting base 36" down from the top of the bell reducer on the tripod.

015E Pyranometer Mounting Arm

The 015 pyranometer mounting arm was attached to the mast where it was positioned on the south side of the mast with the top of the mounting base 17" down from the top of the bell reducer on the tripod.

The Sx10 Solar Panel

The SX10 solar panel was used with this Met-station. The Sx10 panel bracket was bolted to the existing holes in the panel frame. Then the solar panel was mounted to the mast. It was located so as to have maximum insulation and facing the south pole. The tilt of the panel was adjusted to be perpendicular to the sun's rays at solar noon on the day of the Equinox (based on calculated values). Since the latitude of the weather station lies on line 25^{o} 15' 16" north, the tilt angle was adjusted to 35^{o} 15' 16" from horizontal, facing due south.

Sensor Installation

The different sensors used with this weather station were mounted to the brackets described above.

Fig.1: General view of weather station.

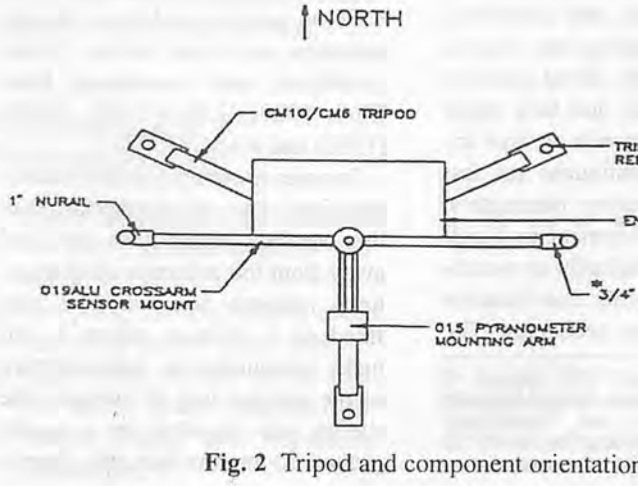


Fig. 2 Tripod and component orientation.

014A Met One Wind Speed Sensor

The 014A Met One wind speed sensor was installed to the 019 ALU cross-arm (on the far left hand side-west direction). The sensor cable was connected to the base of the sensor. A small amount of the lithium grease was applied to the threads of the connector to prevent problems due to moisture and corrosion. The sensor lead was secured to the crossarm and mast using wire ties.

024A Met One Wind Direction Sensor

The 024 A Met one wind direction sensor was mounted to the 019 ALU cross-arm (on the far right hand side-east direction). The sensor was positioned so that the counter weight points south. The sensor cable was connected to the sensor. A small amount of lithium grease was applied to the threads of the connector to prevent problems due to moisture and corrosion. The sensor lead was secured to the cross-arm and mast using wire ties.

LI200X Pyranometer

The L1200X pyranometer was mounted to the L1200X3 pyranometer base using leveling fixture. Then the L12003X was mounted to the 015E pyranometer mounting arm, ensuring that the L12003x pyranometer base was well leveled using the provided bubble level and leveling screws. The sensor lead was secured to the cross arm using wire ties.

208 Phychem Temperature and RH Probe

The 208 probe was mounted inside the 41002-3 gill radiation shield. The two mounting clamp screws on the base of the 41002-3 were loosened; the clamps were rotated away from the sensor entry hole. The 208 probe was inserted into the 41002-3. The clamps were positioned over the metal strap on the base of the 208 probe. The clamp screws were then tightened. The sensor lead was secured to the mast and the wire ties.

108 B Soil-Temperature Probe

Two soil temperature probes (series 108B) were used with this weather station: one at soil depth of 10 cm to represent soil temperature in top soil layer and the other was installed at soil depth of 50 cm to represent the sub soil temperature. An undisturbed area of ground was selected that will receive the least amount of traffic. The sensor lead was routed from the data logger, down a tripod leg, and along the ground to the selected area. A narrow trench was dug next to the sensor lead, ending the trench at least 6" short of the probe tip. The sensor lead was laid into the trench. A screwdriver was used to probe a horizontal hole into the undisturbed soil at the end of the trench, at the appropriate measurement depth. The probe tip was then inserted into the hole, then carefully, the trench was back filled. To prevent soil surface erosion and thus measurement errors, one square meter frame constructed from 2 x 4 cm^2 was buried around the probe, with the top surface flush with the soil surface.

RG2501 Sierra Tipping Bucket Rain Gauge

The RG2501 sierra tipping bucket rain gauge comes from the manufacturer as one package (sensor was already installed). All it needs was the site installation (section 1-4 above).

The 6821 Qualimetric Evapo- ration Pan

The 6844-A Qualimetric Evaporation Gauge

The standard 6821 Qualimetric Evaporation pan (Class A-Pan) was used to measure the evaporation from an open water surface. The measurements were carried out manually on daily basis using the 6844-A Qualimetric Evaporation gauge.

022RC Logger Enclosure

The 022 RC enclosure was mounted to the mast where it was positioned on the north side of the mast with the top of the upper mounting bracket down 47.5" down from the top of the bell reducer on the CM10 tripod. The enclosure was attached to the two U-bolts provided. The 14 AWG wire (WMO, 1983) was routed from the brass tripod grounding clamp to the enclosure grounding lug. The end of the wire was inserted into the grounding lug and the set screw was tightened.

Data Logger and Power Supply

21X Data Logger

The 21X data logger was mounted to the 022 RC logger enclosure. The 21XL sealed rechargeable battery was used with the logger for power up. The unregulated SX10 solar panel was connected permanently to the charging jack on the 21XL base to provide a maximum current of 300 mA for recharging the 9150 batteries.

Sensor Wiring

After the sensors were mounted, the sensor leads were routed through the entry hole in the bottom of the 022 RC logger enclosure and to the data logger. The leads were secured to the left side of the enclosure using cable ties and tabs. Any excess cable was neatly coiled and secured to the tabs. The EDLOG program available within the PC208 software was used for indicating wiring signal leads and excitation to the ana-

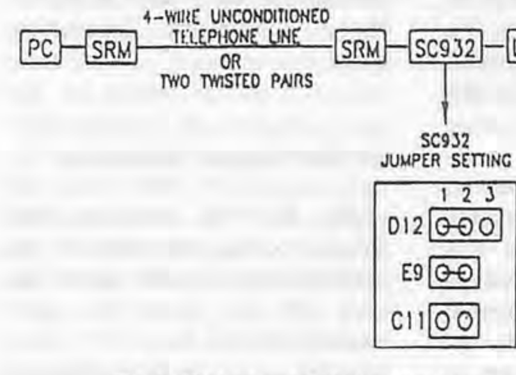


Fig. 3 SRM-6A and SC932 at Data Logger.

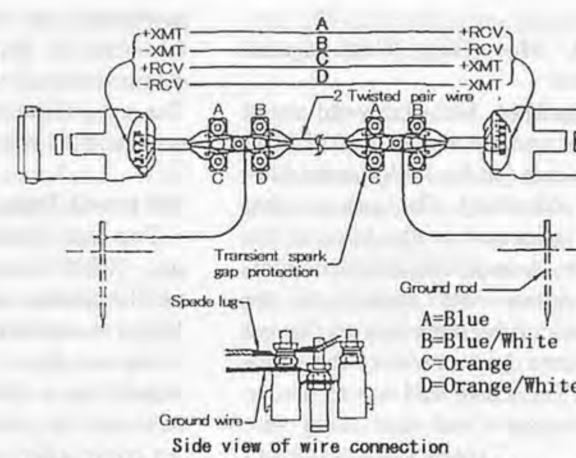


Fig.4 SRM-6A Wiring via the TwoTwisted Pairs Wires.

log inputs as well as excitation output on the data logger. Sensors were wired to the data logger. The wiring correlates with Weather Pro (PC100, which creates a data logger program and wiring program).

Communication and Data Storage Peripherals

SC932 9Pin to RS232 - DCE Interface and SRM-6A Rad Modem

Two SRM-6A RAD modems (i.e., one on the computer terminal and the other on the data logger) were used to enable communication between the 21X data logger and the computer over a cable with two twisted pairs of wires (**Fig. 3**). The SC932 interface was connected to the data logger's I/0 part with an SC12 cable. The 6361 surge protectors were mounted to the enclosure back plate. The ground wire was connected to the enclosure ground lug. Then the SRM 6A modem serial port was connected to the SC932. A12" long piece of modem cable was cut and connected to the SRM-6A. This cable was routed along with the modem cable to the 6361 surge protectors. The SRM-6A at the computer terminal, was connected to the serial port of the computer using a SC25PS cable and PN 7026 adapter cable. The SRM-6A modem was also connected to the two twisted pairs of wires routed from the data logger on the Met (**Fig. 4**). A 386 series PC equipped with the PC201 Clock-S10 Tape read card installed was used to support data retrieval functions from the 21X data logger and the SC532 9 PIN peripheral interface to a 25-PIN RS232 Asynchronous communication. A 14400 bps Fax /14400 bps data modem was also installed inside the PC.

SM192 Storage Module

The SM192 storage module (Baud Rate 300 to 76,800) was used with this meteorological station to extend the amount of memory by 192,896 bytes; viz, provides battery-backed, solid-state, RAM data storage to supplement the storage capacity in the 21X data logger. All storage module operations occur in one of the following three basic operational modes:

a) Interactive communication with data logger for data and program storage and retrieval.

b) The printer enable method for data storage with the 21X data logger .

c)The telecommunications command state for data retrieval and other miscellaneous operations.

14400 bps Fax/14400 bps Data Modem

The PC terminal was also equipped with an INTERNAL 14400 bps fax/14400 bps data modem. The device was installed to enable weather data transfer to other terminal via telephone cables. The Bitfax vers. 2.1 and Bitcom vers. 3 softwares were used for communications from inside windows 3.1 application.

Programming the 21x Data Logger

After the sensors have been wired and the communication between the PC and the data logger established, the data logger must be programmed before it will measure the sensors and store data.

The PC201 vers. 6307-00 software and the PC208 vers. 6306-06 software; by Campbell Scientific, Inc. 1993 were used in this case. The PC201 software was utilized to install the PC201 clock-S10 Tape Read card for communication. The PC208 software was implemented to programming the 21X data logger as well as manipulating weather data. The PC 208 software includes the following main editing programs:

a) Edlog is used to develop and document programs for the 21X data logger. A copy of the EDLOG is available from the authors upon request.

b) Graphterm is a terminal

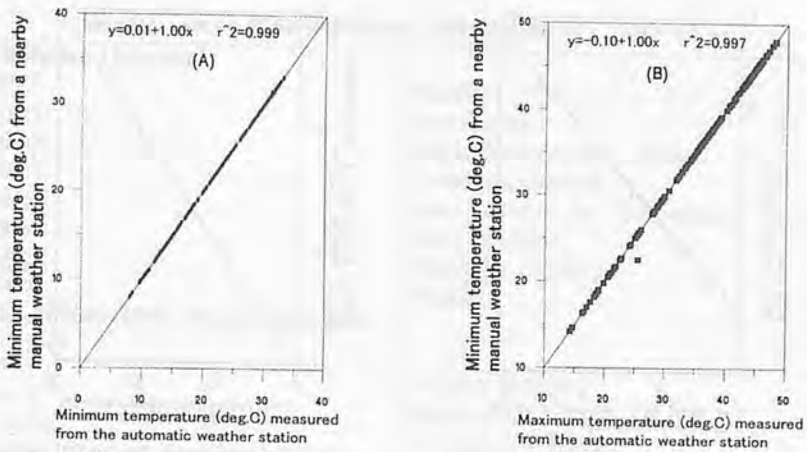


Fig.5 Calibration lines for the air temperature sensor.
(A) Min. temp (deg. C) for 189 to 365 Julian days (year 1995).
(B) Max. temp (deg. C) for 189 to 365 Julian days (year 1995).

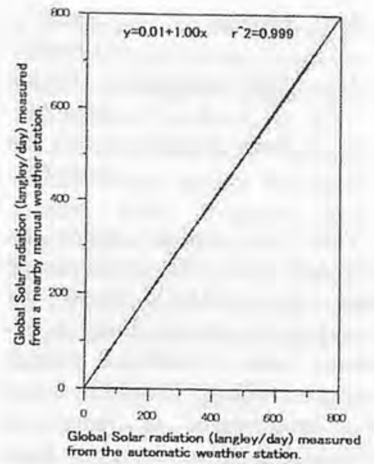


Fig.6 Calibration line for the global solar radiation sensor from 189 to 365 Julian days (langleys/day).

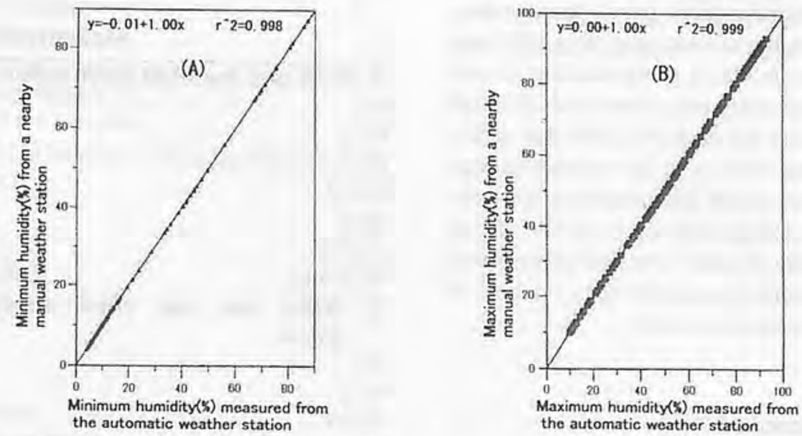


Fig.7 Calibration lines for the humidity.
(A)Min. humidity (%) for 189 to 365 Julian days (year 1995).
(B)Max. humidity (%) for 189 to 365 Julian days (year 1995).

emu-lator program with real time graphical monitoring capability that can automatically collect final storage data from the 21X datalogger.

c) Split is a general purpose data reduction program. The application includes: data processing, file reformatting, data quality checking, table generation with report and column headings, time synchronizing and merging of up to 8 files, and data selection based on time or conditions.

d)Telcom allows the PC terminal to retrieve and store data from the 21X data logger. The Telcom includes the protocol to communicate via direct wire or telephone modem and as well as RF modem. Data was collected in blocks with error checking to ensure data integrity. A station file was created for data logger station which specifies the communications link to the data logger.

The Edlog was used to develop the station program which was downloaded to the data logger through Graphterm via the modem interface.

Sensor Calibration

All sensors were calibrated in order to insure, test and validate the acquired data. Methods of calibrations indicated in the manufacturer catalogue (Campbell Sc. Inc. 1993, LI-COR, Inc. 1986 & Sierra-Misco, Inc., 1985, USA) were carefully followed.A conventional weather station nearby the site was used for this purpose. **Figures 5** to **8** show the best fittings calibration lines implemented on the PC using the Cricket graph package (ver. 1.3.1). All calibration lines exhibited linear relationships with very high coefficient of determination (i.e. r^2 = 0.99).

Station Id, Configuration and Signature

The MET station was configured on COM2 at Baud Rate of 9600. It was named KFUAGE; 4002 whic stands for King Faisal University; Agricultural Engineering Department; Number 4 as for the Fourth Hydrological Region in Kingdom of Saudi Arabia; Number 0 as for a meteorological station and Number 2 as for station Number 2. It was programmed to scan the following weather parameters every single minute:

*	Air temperature	^oC
*	Relative humidity	%
*	Wind speed	m/sec
*	Wind direction	angle/ North
*	Solar radiation	langley (Total)

* Rainfall mm (Total)
* Soil temperature (10 cm depth)°C
* Soil temperature (50 cm depth)°C

Then the station reports an KFUAGE.DAT file at 60-minute basis output (ARRAY ID=60); viz averaging the above values on 60-minute basis. Conditional rainfall output is (ARRAY ID = 101). It was also programmed to report on KFUAGE.DAT at 24-hours basis output (ARRAY ID = 24) with Max and Min. Time of Max; Time of Min; as well as battery charging condition and panel temperature. The big advantage of this MET station is that it gives readings in real time state; every hour and 24 hours a day for each JULIAN day of the year. Moreover, the weather parameters could be monitored and presented graphically in the PC at the same time as it has been measured minute by minute (i.e., on line or live measurement).

Conclusion

Water management objectives may be fulfilled through real time weather data collection via a suitable technology. The installation and operation of an automated microcomputer weather station network proved to be good reliable method for collecting data required for irrigation scheduling. Yet the use of this network may be extended for different real time agricultural production decisions. The performance of this network was tested and evaluated over almost two years without any major malfunctioning. The use of this remote weather station is a significant educational challenge.

REFERENCES

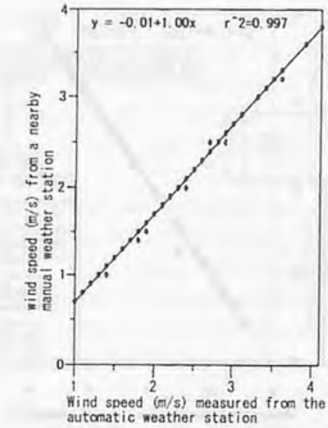


Fig.8 Calibration line for the wind speed sensor from 189 to 365 Julian days on 1995.

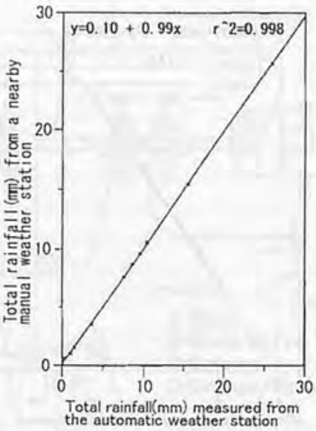


Fig.9 Calibration for the rainfall sensor on the 354 and 355 Julian. days.

Measurement Instruction

A. 014A met one wind speed sensor	
P3	Pulse
01:1	Repetitions
02:1	Pulse input channel
03:22	Switch closure configuration
04:4	Input Location
05:0.8	Multiplier (meters/sec)
06:0.447 Offset	
B. 024A met one wind direction sensor	
P4	Excite, Delay, Volt (Single-Ended)
01:1	Repetitions
02:14	250 Mv Fast Range
03:4	Single-Ended Input Channel
04:2	Excitation channel
05:2	Delay (Units=0.01 Sec)
06:500	Excitation mV
07:5	Input Location
08:0.144 Multipier	(degrees)
09:0	Offset
C. LI-200x LI-cor silicon pyranometer	
P2	Volt (Differential)
01:1	Repetitions
02:3	25 Mv Slow Range
03:3	Differential Input Channel
04:6	Input Location
05:0.2(1.4333)	Multiplier
06:0	Offset
D. 208 physchem temperature and RH probe Temperature	
P11	Temp 108 Probe
01:1	Repetitions
02:2	Single-Ended Input Channel
03:3	Excitation channel
04:2	Input Location
05:1	Multiplier (degrees ℃)
06:0	Offset (degrees ℃)

Measurement	Instruction
Relative Humidity	
P12	RH(208)
01:1	Repetitions
02:3	Single-Ended Input Channel
03:3	Excitation channel
04:2	Input Location for Temperature
05:3	Input Location
06:1	Multiplier (%RH)
06:0	Offset
E. 108 air/108b temperature probes	
P5	AC Half Bridge
01:2	Repetitions
02:14	250 mV, Fast Range
03:9	Single-Ended Input Channel
04:3	Excitation channel
05:2000	Excitation mV
06:11	Input Location
07:2000	Multiplier
08:0	Offset
P55	Polynomial
01:2	Repetitions
02:11	10 cm location
03:11	F(10) location (Temp. in degrees ℃)
04:-26.97	C0
05:69-635	C1
06:-40.66	C2
07:16.573	C3
08:-3.455	C4
09:0.301	C5
F. RG2501 sierra tipping bucket rain gauge	
P3	Pulse
01:1	Repetitions
02:2	Pulse Input Channel
03:2	Switch Closure configuration
04:7	Input Location
05:01	Multiplier (0.1 per tip)
06:0	Offset

AASC (1985) The State Climatologist. Publication of the American Association of State Climatologists: Height and Exposure Standards for Sensors on Automated Weather Stations, U. 9, No. 4 October.

EPA (1989). Quality Assurance Handbook for Air Pollution Measurement Systems, EPA Office of Research and Development, Research Triangle Park, North Carolina 27711.

EPA (1988). On-Site Meteorological Program Guidance for Regulatory Modeling Application, EPA-450/4-87-013. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina 27711.

WMO (1983). Guide to Meteorological Instruments and Methods of Observation. World Meteorological Organization No. 8, 5th edition, Geneva, Switzerland.

UCCC (1974). University of California Committee of Consultants. Guidelines for interpretation of water quality for agriculture, Univ. of California, Davis.

U.S. Department of Agriculture (1976). Diagnosis and Improvement of saline and alkali soils. Agricultural Handbook No. 6.

Ayers, R.S. and D.W. Westcot (1985). Water quality for Agriculture, FAO Irrigation and Drain Paper No. 29. Rev.

FAO/UNESCO (1973). Irrigation Drainage and Salinity: An Irrigation Source Book, Hutchinson.

U.S. Salinity Laboratory Staff (1954). Diagnosis and Improvement of Saline and Alkali soils.

Maas E.V (1984). Salt tolerance of plants. Cited in the Handbook of Plant Science in Agriculture. B.R. Christie (ed.). CRC Press. Boca Raton, Florida. ■■

Performance Evaluation of a Manually-Operated, Inclined Axis Coiled Tube Pump

by
Mohammad Ali Basunia
Assistant Professor,
Department of Farm Power and Machinery,
Bangladesh Agricultural University
Mymensingh 2202, Bangladesh

David Gee-Clough
Professor,
Division of Agriculturaland Food Engineering,
Asian Institute of Technology (AIT)
Bangkok, Thailand

Abstract

The performance of an inclined coiled tube pump, modified in AIT, was evaluated both by variable speed motor and manual operation. Maximum lift was 275 cm by using 12 turns in the coil inside a standard kerosene oil drum. Suitable rpm for manual operation was between 35 and 25 rpm. Within this speed range, a laborer can operate this pump 45-60 minutes continuously. Power requirement at 30 rpm was 15-70 watts for lift of 1.0 to 2.75 m. Optimum discharge, efficiency and angle of operation were 58 l/min, 60% and 24 degree, respectively. Keeping the average input power 30 watt (arm/shoulder) and 75 watt (pedaling) fixed cut off points at different lifts were calculated. The best cut off points for 30 watt and 75 watt occurred at speed 25 rpm and 48 rpm, lift 2.4 m and 2.5 m and efficiency 61% and 45%, respectively.

Introduction

Feeding the rapidly growing human race is an increasing vital problem. There is no readily identifiable yield-increasing technology other than the improved seed-water-fertilizer approach. Large scale, mechanized farms would not be attractive at the present days of high-priced energy. Another point is that industry is unlikely to be able to provide so many jobs so quickly as in the West since productivity per worker in industry has increased so much. Moreover, the extensive capital requirements and implication of advanced technical know-how make the large-scale farming less appropriate in the non-industrialized countries.

Intensive irrigation of small holdings is likely to become increasingly important and widely used during the next few decades, particularly in non-industrialized countries. This is because the majority of the landholdings, particularly in Asia and Africa, are quite small, under 2 ha (World Bank, 1983). Studies also have shown that small landholdings are often more productive in terms of yield per hectare than larger units. Small-scale irrigation has been shown to offer positive results in alleviating poverty. Hence , the governments are in a situation where they have to encourage the small and medium-scale farming.

The task of fulfilling these demands becomes quite difficult with the increasing prices of conventional energy sources such as fossil fuels and the absence of electrical power, especially when the region is located in remote parts of the country where most farmlands are located. Although developments in human powered devices are often mooted there is little real progress in this area. Indeed much of the alternative energy literature relates to energy sources at an "intermediate" level between the traditional human/animal power and the conventional (from a industrialized society viewpoint) usually "high tech" utilization of energy sources. Hence energy for rural developments is often associated with solar, wind, hydro, photosynthesis and biogas resources. Although developments in such renewable resources must be given due emphasis as alternatives to fossil fuels, it is nevertheless suggested that in rural areas there is often no real widespread alternative to human-and animal-powered water lifters. The problem here is that much of the "intermediate level" alternative technology is still not appropriate to many of the water lifting problems in rural areas. Although technical solutions are proposed, the socio-economic factors often mitigate against any wide-spread adoption.

The coiled tube pump is remarkable for its simplicity and cost. The design of the pump has gone through various stages. Morgan (1979), Sutucky and Wilson (1981) and Mortimer and Annable (1984) described the pump as having its axis as horizontal and incorporated as a rotating seal. This feature represented a significant drawback to design, and renders of the pump almost impossible for use in most village workshop.

Laboratory tests have been carried out by Mortimer et al, (1984) on the horizontal axis coil tube pump at Loughbough University and a theory for predicting the behavior of the pump has been developed.

A significant development in simplifying the pump and easing its manufacturer was brought about by inclining the axis of the coil, as described by Konitz (1984), Reimer (1986), Hilton (1986).

Experiments were carried out by Basunia (1989) on the internally wound, inside a standard kerosene oil drum (200 l), inclined axis coiled tube pump at the Asian Institute of Technology (AIT) to evaluate the performance of the pump. This paper presents the experimental studies of the inclined axis coiled tube pump.

Materials and Methods

Description of the Pump

Figure 1 shows the features of the pump design which was constructed with a water-tight cylindrical drum as the coil supporting structure connected to a steel water pipe. The steel water pipe was attached rigidly to the drum lid, incorporating a standard pipe socket. Inside the drum was a coil of reinforced plastic tube. One end of this tube was connected to the steel pipe and the other end was connected to a short piece of steel pipe welted to the side of the drum at the entry hole. The short piece of steel pipe used was a correct diameter to allow the flexible plastic tube to be fitted over it and was clamped with a hose clamp. At the coil outlet, a 90 degree and 45 degree elbow was used to connect a short radial pipe, which then was connected to the delivery pipe via another 90 degree elbow. Silicon rubber sealant was used on all clamped pipe joints. After assembly, the drum lid was carefully welded on to form a complete seal. A standard cylindrical kerosene oil drum size, it is submerged approximately 50% at the point where water enters the coil. It, therefore, ensures that correct entry conditions are maintained, since the drum follows the water level as it varies up and down.

The steel water pipe was used as shaft to turn the drum around and was also used to convey the water. At the upper end there was a bearing support, which is the only bearing required and is self-aligning type. Two bamboo sticks were used to control the shaft direction, while still allowing the drum to rise and fall with varying water levels (Fig. 1). On the basis of availability of construction materials, the following specifications were used for the experimental pump:

Diameter of the floating drum, 57 cm (Standard 200 l oil drum)

Diameter of the flexible coil tube, 5 cm

Diameter of the discharge steel water pipe, 5 cm

Diameter of the coil, 52 cm

Number of coils inside the drum, 12 (maximum)

How the Pump Works

When the handle of the discharge pipe was rotated by a variable speed motor/manually the floating drum on water also rotated. As the drum rotates; it collects a quantity of water and then a quantity of air repeatedly until all the coils are approximately half full of water. The pockets of air become compressed and small pressure differences are produced between each pocket of air. When all these small pressure differences are added together, enough pressure is developed to push the water in the last coil to the top of the delivery pipe. The flow is not continuous, but consists of a quantity of water being delivered for each revolution of the drum, followed by a small quantity of compressed air being released.

Measurement of Input Power

The delivery pipe was connected at the outlet end by a variable speed 0.75 kW electric motor via a 5:1 speed reduction pulleys with a V-belt drive. The speed was varied by the speed regulator of the motor.

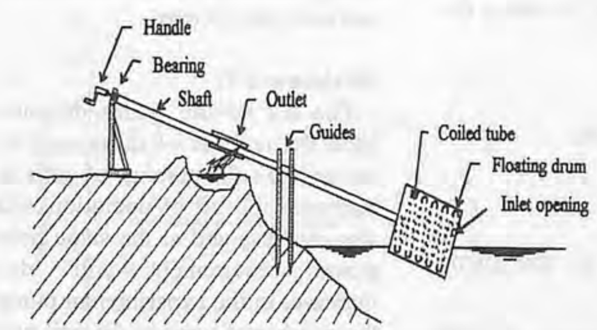


Fig.1 Diagram showing the features of the coiled tube design.

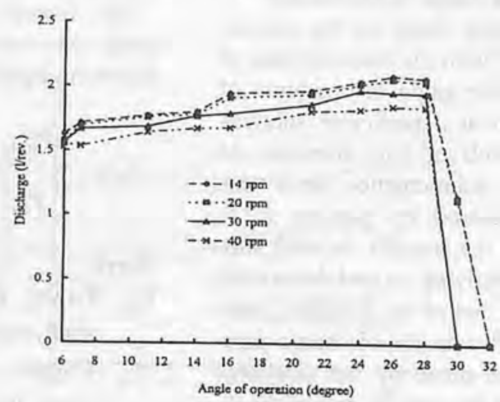


Fig.2 Maximum angle of operation at different speeds of rotation at which pump stop pumping (lift 1.0 to 1.8 m).

Input power for different operating conditions of the pump was measured. A toque meter was connected at the outlet end of the delivery pipe for direct measurement of input power. It was observed that at nearly constant rpm, input power varied continuously. So, an X-Y plotter was connected to the digital displayer of torque meter to plot the actual power requirement curve against time at different operating conditions of the pump. As it was difficult to digitize the whole plotted curve for each rpm and at each elevation head, a particular area was sleeted from the plotted curve for digitization to find the average input power requirement.

Measurement of Discharge

The volume of water being discharged per revolution at particular speeds of rotation was the volumetric discharge of the pump. The discharge was measured at different speeds of rotation, different lifts and at different angles of operation of the pump. When the speed of rotation became constant, water for three revolutions was collected in a bucket and measured by using a 1000 cc glass cylinder. The discharge per revolution was calculated from the total quantity of water discharge in three revolutions.

Optimum Angle of Operation

The angle made by the axis of the pump with the static surface of water is the angle of operation of the pump at a particular submergence levels of coil diameter. At different submergence level this was measured by placing a T-square at the straight bearing support and moving up and down until the other end of the T-square came in contact with the discharge pipe. The angle made by the discharge pipe with the contact end of the T-square was the angle of the pump which was equal to the angle made by the discharge pipe with static water surface at that particular submergence level of the coil diameter. For the determination of optimum angle of operation the pump was operated from 6.00 degree to 32.00 degree angle.

Maximum Lift

At different operating conditions the lift was measured by the vertical distance between the static surface of water and the discharge point. In order to find the maximum lift of operation, the pump was operated between 100 cm and 290 cm lift by increasing it 10 cm in each step, starting from 100 cm lift.

Power Output

The power output was determined as the product of total useful head, the discharge, the specific weight of water and acceleration due to gravity .

Power output:

$$P_{out} = \frac{Q \times \rho \times H \times g}{3{,}600}$$

where

P_{out}=Pump output power (water power), watt

Q =Volume of water discharge, m^3/h

ρ = Specific weight of water, kg/m^3

H = Useful head of the pump, m

g =Acceleration due to gravity, m/s^2

Efficiency

The overall efficiency of the pump was calculated by using the following equation:

$$\eta_e = \frac{P_{out}}{P_{in}} \times 100$$

where

P_{in} =Power input to the pump shaft, watt

η_e =Overall efficiency of the pump, %

Results and Discussions

Optimum Angle of Operation

It was found that at lower speed of rotation the discharge per revolution was greater than the higher speed of rotation **(Fig. 2)**. In all cases, the discharge per revolution increased with an increase of angle of operation of the pump as indicated in **Fig. 2**. The optimum angle of operation lies between 15 and 28 degrees. The pump lost pumping action when the angle of operation exceeded 28 degree. It is interesting to note that the discharge per revolution increased with an increase in lift because of increasing angle of operation. In reality, it is not possible to operate the pump at an angle less than 6 degrees at which the minimum lift is 100 cm.

Optimum Speed of Operation

Within the range of optimum angle of operation the pump was operated at different speeds and different lifts. The results are shown in **Fig. 3**. As the lift increased the speed of rotation of the pump became limited as shown in **Fig. 3**. At lower lift, 100 cm, the pump was operated as high as 105 rpm and at highest lift, 275 cm, pump was operated as high as 60 rpm. As the ultimate objective is to operate the pump manually, its lifts and speed of rotation depends upon the availability of manual power. The pump lost its pumping action totally when the speed of rotation was less than 12 rpm.

Maximum Lift

The lift of the pump depends upon the number of turns used in the coil. As the number of coils is increased the lift of operation will also increase and at the same time power requirement will also increase. In the experimental pump the number of turns in the coil was maximum at 12 that can be accommodated inside a standard kerosene oil drum. Hence the maximum lift that can be attained is limited to 2.75 m as shown in **Figs. 4-6**. It was also not possible to operate the pump below 100 cm because of the free floating cylindrical drum that causes almost zero submergence level at this lift condition.

Overall Performance of the Pump

The performance curves at 20, 30 and 40 rpm of the pump are shown in **Figs. 4, 5** and **6**, respectively. From **Fig. 4** it can be observed that power requirement at 20 rpm remain within 30 watt at different lifts. The maximum efficiency was 64% at a lift of 220 cm when the discharge was 35.70 l/min. **Figure 5** shows that the power required to operate the pump exceeded 30 watt when the lift was more than 210 cm. The discharge and efficiency at 210 cm lift are 52.80 l/min and 61%, respectively.

Figure 6 shows that efficiency is quite low at 20 and 30 rpm. The power requirement also exceeded more than 30 watt when the lift was more than 110 cm. This indicates that it may not be possible to rotate the pump manually for long period of time at 40 rpm when the lift exceeds more than 100 cm.

Manual Operation

The pump was also manually operated to determine the time of continuation that an operator can operate without taking a rest . It was found that an operator can operate the pump easily for 45 to 60 minutes at a speed range 25 to 35 rpm. Then the operator took 5 to 10 minutes rest and again continued for the same length of time. In this sequence, the pump was operated by the same operator for 6 hr with effective operating period of 5 hours. When the operator tried to operate it at 40 rpm he was unable to operate the pump, continuously for more than 10 to 15 minutes. This test indicates that the average speed in manual operation should not be more than 30 rpm.

Varying Lifts for Fixed Power Input at 30 Watt and 75 Watt

A reasonable power output of adults in a favorable health condition in a tropical climate sustained (6/7 hr. per day with short rests as and when required) by arms/shoulders and pedalling is 30 watt and 75 watts, respectively (Kennedy, 1985). Keeping this input power fixed , maximum discharge, maximum operating speed and maximum efficiency at different lift conditions were calculated. The results are shown in **Figs. 7** and **8**.

Form **Fig. 7** it can be observed

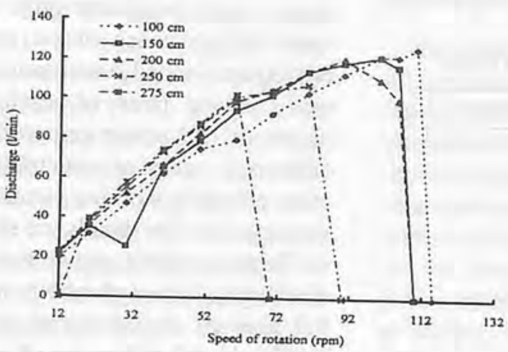


Fig3. Maximum angle of operation at different lift condition at which the pump stops pumping.

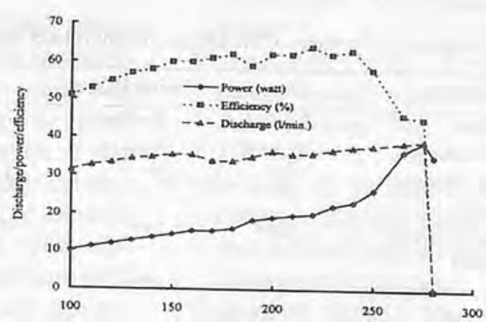


Fig.4 Pump performance curve at 20 rpm.

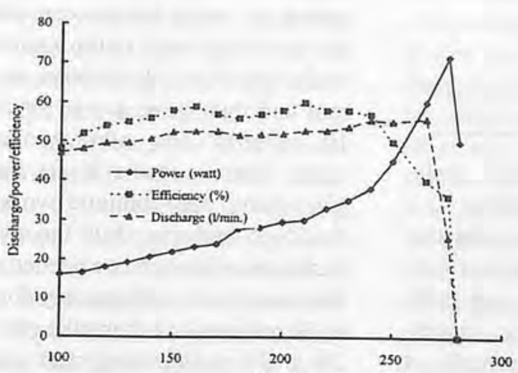


Fig.5 Pump performance curve at 30 rpm.

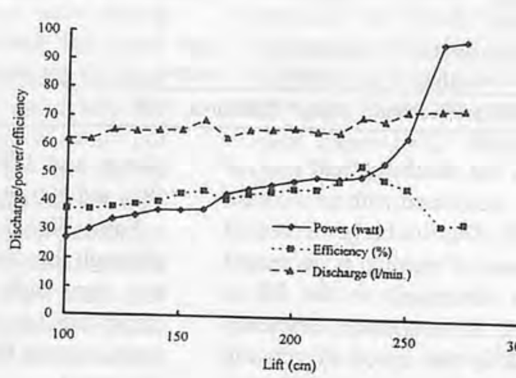


Fig.6 Pump performance curve at 40 rpm.

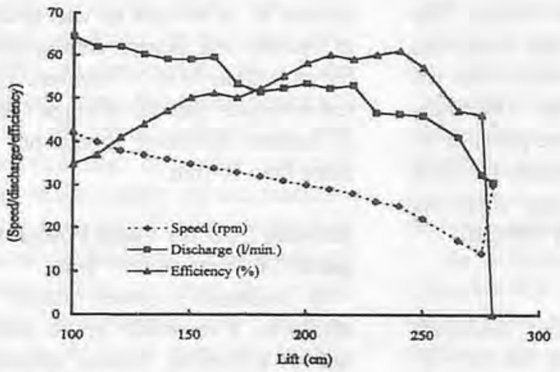


Fig.7 Cut-off rpm, discharge and lift of the pump for average input power 30 watt.

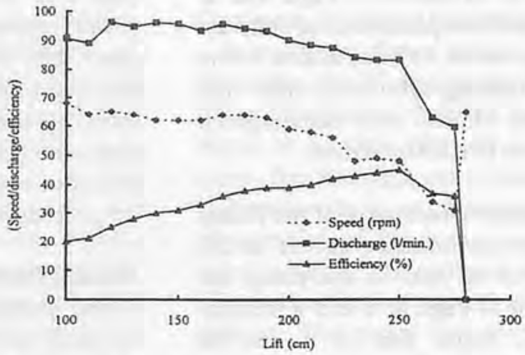


Fig.8 Cut-off rpm, discharge and lift of the pump for average input power 75 watt.

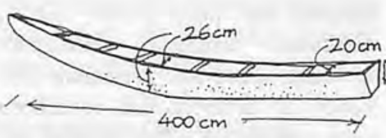


Fig.9 Typical dimensions of a dhone channel.

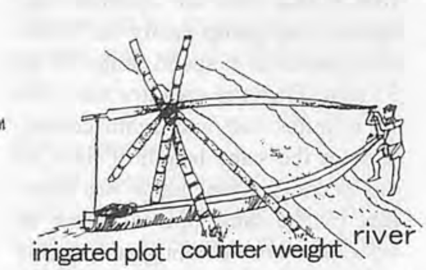


Fig.10 Dhone in operation (upper position).

Table 1. Comparative Features of the Dhone, Swing Basket and Coiled Tube Pump

Method	Dhone	Swing Basket	Coiled Tube Pump
Water source	Surface	Surface	Surface
Source of energy	Manual	Manual	Manual
Discharge, liter/sec (maximum)	7.0*	2.0*	1.2 (40 rpm)
Discharge, liter/sec (practicable)	3.4**	1.2**	0.9(30 rpm)
Effective working hour (for 6 hr/day)	3.6***	3.9**	5.0
Total discharge, m3/day	42.0	14.0	17.0
Lift, m (maximum)	1.5*	1.5*	2.75
Lift, m (practicable)	0.6**	0.6**	2.10
Capital cost (US dollar)	30.0***	2.5***	40.0***
Working life (years)	4.0*	2.0*	5.0***
Command area (ha)	0.4**	0.18**	not practiced yet

*Khan, 1979; **Kennedy, 1985; ***Basunia, 1989.

that both the discharge and rpm of the pump decreased with an increase of the lift. The discharge decreased as the speed of rotation is decreased and rpm decreased as the lift is increased. At maximum efficiency point (61%) the speed of rotation was 25 and discharge was 46.15 l/min. At 30 rpm, discharge, efficiency and lift were 53.25 l/min, 58% and 200 cm, respectively.

Form **Fig. 8** it can be seen that although the discharge per unit time was very high at high rpm, efficiency was very low. Hence, it is better to operate the pump manually at low speed .

Comparison Among Dhone, Swing Basket and Coiled Tube Pump

In rural areas most of the agricultural lands in non-industrialized countries are irrigated by traditional water lifting devices like dhone and swing basket which are not so efficient. A comparative study among two commonly used water lifting devices (dhone, swing basket) and coiled tube pump was made on the basis of discharge, height of lift, power requirement, efficiency, ease of manufacture, cost, effective working hours and working life. The details are shown in **Table 1**. which shows that the discharge of the coil tube pump is 0.9 liter/sec as compared to 1.2 liter/sec and 3.4 liter/sec of swing basket and dhone, respectively. But the effective operating time per day of the coiled tube pump is higher than that of the dhone and swing basket. A single laborer can operate the coiled tube pump continuously for 45 to 60 minutes at 30 rpm and then takes a rest for 5 to 10 minutes and start working again, whereas in the dhone a single laborer can continue working for 25-35 minutes. Only the swing basket, two laborers are needed and they can work continuously for 40 to 50 minutes and then take rest for 20 to 30 minutes and start again. Input power requirement for the coiled tube pump is only 30 watt which is less as compared to the other two. On the basis of working and resting time, working time can be determined as follows: If we take the average of the working and resting time as mentioned above, then the effective working hour for dhone, swing basket and coiled tube becomes 3.4 hr., 3.85 hr. and 5 hr,. respectively, for 6 work hours per day. Ultimately, the discharge per day of the dhone, swing basket and coiled tube pump becomes approximately 42, 14 and 17 m^3, respectively. The discharge per day of the dhone is much higher than the swing basket and coiled tube pump because of low the lift of the dhone operation. Although the discharge per sec of the coiled tube pump is less than the swing basket its high effective working hour discharge per day is higher than that of the swing basket.

When the height of lift is more than 0.75 m the swing basket method is least efficient. The dhone method needs two stages of lifting (Khan, 1979). One stage up to 0.75 m and the 2nd stage 0.75 m to 1.5 m. With this the volumetric efficiency as well as overall efficiency is reduced due to imparted ergonomic factors associated with height of lift. Also, instead of single dhone, two dhones are required to reach 1.5 m lift (Khan, 1979). But this is not limited in the case of coil tube pump. It can easily lift up to 2.75 m on single stage without further requirement of labor. Hence, two operators are needed to lift water at a height 1.5 m by the dhones and swing basket. By utilizing the same laborers the two coiled tube pump can be operated simultaneously from the same source of water without loosing efficiency and the discharge will double. i.e., 34 m^3 /day, which is near the discharge of the dhone (40 m^3 /day). This is a greater advantage of the coiled tube pump. Taking a reasonable power output for the dhone and swing basket, 20 watts and 7 watts (Kennedy, 1985), respectively, the efficiency of dhone, swing basket and coiled tube pump at 150 cm lift are 33%, 12% and 58%, respectively. This indicates that the coil tube pump is a highly efficient device.

Among the three water lifting devices the swing basket is the simplest one to manufacture. Both the dhone and coiled tube pump are not so difficult to manufacture. However, village artisans can easily manufacture both of them. The cost of the coiled tube pump is a little higher than that of the dhone but still affordable to most rural people. The higher price of coiled tube pump is associated with a minimum 5 years of working life as compared to 3 years for the dhone.

Conclusion

The performance of the manually-operated coiled tube was evaluated for different operating conditions like lift, angle of operation and speed of operation. It was observed that the discharge per revolution decreased with an increase of the rotating speed. The efficiency of the pump was found 60% at 30 rpm, when the discharge was 58 l/min. and the lift was 2.75 m. A suitable rpm for manual operation was 25 rpm when the power requirement was 30 watt at 240 cm lift. Overall, the coiled tube pump is an energy efficient water lifting device not the best one but better than the existing methods for high lift, which often is necessary for irrigation purposes. It will not replace or supersede any of the existing types of manual pumps, but it may provide an additional form of water raising device which could be useful for small scale irrigation and water supply projects, particularly in non-industrialized countries.

REFERENCES

Basunia, M. A. (1989). Testing of manually operated coiled tube pump. M. Engg. Thesis No. AE-89-6, Asian Institute of Technology, Bangkok, Thailand.

Hilton, D. J. (1986). The Inclined Coil Pump, Water lines, Vol. 5, No. 1, July.

Kennedy, W. K. and Rogers T. A. (1985). Human and Animal Powered water lifting devices, A state-of-the-art survey, Intermediate technology Publications.

Khan, H. R. (1979). Country statement, p. 227, FAO/DANIDA , Workshop on Water-lifting devices in Asia and Near East, December.

Konitz, M., (1984). Helical coil tube pump, Final Year project report, Darling Downs

Institute of Advanced Education, Toowoomba, Queensland, Australia.

Morgan, P. R. (1979). 'A new water pump: spiral tube', *Zimbabwe Science News*, Vol. 13 No. 18, 179-180.

Mortimer, G. H. and R. Annable (1984). The coil pump- theory and practice. Journal of Hydraulic Research, 22 No.1.

Reimer, M. (1985). The stream - driven coil pump, Waterlines, Vol. 4, No. 1 (July).

Stucky, A. T. and E. M. Wilson (1981). " The stream-powered manometric pump" ,Proc. of. Institute of Civil Engineers, Appropriate Technology in Civil Engineering, London.

World bank, (1983). World development report-1982, World bank/ OUP, Oxford.

Field Evaluation of Tube Well Irrigation in Bangladesh

by
S.C. Paul
Former Research Engineer
AFE, AIT, Bangkok, Thailand
College Para, Elenga
Tangail,
Bangladesh

C.P. Gupta
Former Professor of AFE, AIT
AFE Program, AIT
World Bank Consultant
Agency for Agril. Research and
Development, Situgadung, Legok
Tangerang, West Java, PO Box 2
Serong 15310,
Indonesia

Abstract

In order to evaluate the operating conditions of the tube well irrigation in Bangladesh, several field experiments were conducted during the dry season for the rice crop (January- April) of 1995. In the study area investors provided irrigation water to a group of farmers' land based on share-crop system. The study results indicate that utilized motor power was 34% to 56% of it's rated value, conveyance efficiency was 40% to 49%, pumping plant efficiency was 53% to 75% and excessive irrigation was 19% to 84% of it's required value. The average area served by individual tube well was 28% to 40% of it's potential value. The areas served by shallow tube well irrigation schemes in clay loam, silty loam, loam and sandy loam soil could be increased to 152%, 236%, 188% and 248%, respectively, by taking appropriate technical and managerial steps.

Introduction

In Bangladesh, dry season irrigation is an important input to grow high yielding variety (HYV) of rice. In 1990, 34% of net cultivated area was covered by irrigation (82% area is irrigable) of which 84% by minor (small scale) irrigation (Rashid, 1992). HYV rice in dry season needs irrigation, fertilizer and pesticide application and it can yield 2 to 3 times the production of rainy season rice.

As dry season production is less risky for agriculture, planned utilization and efficient management of water resources through irrigation is considered as the leading input for the development of agriculture (Rogers et al., 1989). Although land is extremely scarce, Bangladesh has large area of highly fertile soils, a sub-tropical climate suitable for year round cropping and abundant ground water resources for dry season irrigation. Again, heavy rainfall and the alluvial soil structure produce excellent supplies of ground water which are available up to 12 meters deep in a few regions and at less than 6 meters in large parts of the country and hence, tube well irrigation can be developed at relative low cost (Hossain, 1989). Due to siltation of rivers and rapid expansion of ground water, the surface water irrigation dropped from 84% in 1977-78 to only 42% in 1989-90. Among ground water irrigation technologies, deep tube wells, (DTWs) were popular during early years of its installation but in recent years shallow tube wells (STWs) have become popular among farmers due to its private sector operation. Owing to lifting of import ban on irrigation equipment, suspension of ground water ordinance and more emphasis on rural electrification, the rate of minor (small scale) irrigation development increased rapidly.

Bangladesh farmers can't install tube wells themselves due to their poor fragmented land and poor economic condition (per capita land is 0.08 ha and gross domestic products (GDP) is $ 185 (BBS, 1992). The Tangail district of Bangladesh bears most of the categories of agricultural soils (Khan and Hossain, 1995) and a number of electric powered tube well irrigation schemes are being operated following a share-crop payment system (Paul, 1993). Share-crop payment system is increasing day-by-day with effective privatization of minor irrigation schemes. As investors put their funds in small scale tube well irrigation to earn profit, the effective use of irrigation water is an important factor. As the benefit of investor is share of the harvested paddy from individual farmers, the optimum amount of served area by a tube well is important.

Objectives

The following were the objectives of this study:

i) To study the present operating conditions of tube well irrigation schemes and their problems in Bangladesh.

ii) To make suitable recommendations for effective utilization of land for sustainable development of irrigation schemes in agriculture.

Methodology

Selection of Study Area

As Tangail district carries most of the classes of agricultural soils in Bangladesh, five Thanas (Sub-districts) of the southern part, namely, Tangail, Kalihati, Sakhipur, Mirzapur and Basail with different types of soil texture and water table variation were chosen. The study area has available minor irrigation schemes operated by electric power following share crop payment system. Selected soils were clay loam, silty loam, loam and sandy loam. Twenty STW minor irrigation schemes (4 in each thana) were selected randomly.

Procedure for Collection of Data

The primary data were collected by direct field interview with selected scheme investors/managers/farmers/operators as respondents. The study was conducted within the period, January to April, 1995.

The secondary data such as static water table and draw down in selected areas for different months of the operating period, data about soil characteristics and type were collected from the Bangladesh Agricultural Development Corporation and Soil Resources Development Institute, Bangladesh. Other required data were collected from various related institutes (Bangladesh Agricultural University, Power Development Board and Agricultural Extension Office). Data about rainfall were collected from the Bangladesh Meteorological Department.

Field Experiments

The field experiments to measure motor input power, pump discharge, applied water to the field and conveyance loss were carried out during the survey period. From the field experiments, pumping plant efficiency, utilized motor power, conveyance efficiency, yield productivity and electricity consumption for irrigation water etc. were determined.

Input Power of Motor

The input power of the motors were determined from the average kilowatt-hour meter reading for various observed periods of consumption time during the survey.

Input power,

$$\text{kW} = (\text{Electricity consumption, kWh}) / (\text{Consumption time, h}) \quad (1)$$

Fig. 1 Measuring discharge of the pump.

Pump Output

For simplicity and ease of measurement in the field, the volumetric measurements were followed in this study, i.e., the flow from irrigation streams was collected in a cylindrical container of known volume for several measured periods of time. Then it was evaluated for unit time **(Fig. 1)**.

Pumping Plant Efficiency

The pumping plant efficiency was calculated by using the following formula (Duke, 1989).

$$E_{pp} = (QH)/(102P_e) \quad (2)$$

where,

E_{pp} = Pumping plant efficiency;
Q = The flow rate, l/s;
H = Total dynamic pumping head, m;
P_e = Motor power required to drive a pump, kW

$$H = (H_s + H_d + H_f + H_{dh} + H_v) \quad (3)$$

where,

H_s = Static depth of water, m;
H_d = Drawdown during pumping, m;
H_f = Friction head, m;
H_{dh} = Delivery head, m;
H_v = Velocity head, m.

$$H_f = (4flV^2)/(2gd) \quad (4)$$

where,

f =Frictional coefficient of pipe;
l = length of pipe, m;
V =velocity of flow through delivery pipe, m/S;
d =Diameter of the pipe, m;
g =Acceleration due to gravity, m/s^2

$$H_v = V^2 / 2g \quad (5)$$

$$V = Q/A \quad (6)$$

where,

V =velocity of delivery pipe, m/s;
Q =discharge, m^3/s;
A =cross sectional area of delivery pipe, m^2.

Measurement of Applied Water in the Field

Applied water was directly measured in the study area during the irrigation period of 1995 by using container, tape, different sizes of small pipes with different diameter to pass applied water through it and stop watch (**Figs. 2 and 3**). Conveyance efficiency was calculated by using the following formula (Dutta and Sarker, 1986). Conveyance efficiencies for various distances (distance from the delivery point to inflow into different fields) were considered and evaluated for average 100 m length of canal for individual scheme:

$$E_c = 100(W_f / W_a) \quad (7)$$

where,
W_f =water delivered to the field;
W_a =water delivered from the source;
E_c =conveyance efficiency

Percent of Utilized Motor Power

The percent of utilized motor power refers to the a percentage of rated motor power used in pumping water.

Total Water Requirement of a Crop

In order to estimate the water requirements (WR) of crops which is the basic needs for crop planning on the farm and for the planning of any irrigation project may be defined as the quantity of water, regardless of source, required by a crop or diversified pattern of crops in a given period of time for its normal growth under field conditions at a place. Water requirement includes losses due to evapo-transpiration (ET) or consumptive use (Cu) plus the losses during the application of irrigation water and quantity of water required for special operations such as land soaking and land preparation, seepage and percolation etc. It may be thus formulated as follows:

$$WR = ET + (LS + LP) + (S + P) + \text{Conveyance losses.} \quad (8)$$

where,
WR =total water requirement of a crop, mm;
ET =loss of water due to evapo-transpiration, mm;
LS =water required for Land Soaking, mm;
LP =water requirement for land preparation, mm;
S =seepage, mm;
P =percolation, mm

$$ET = (PET)\,KC \quad (9)$$

where,
PET =potential evapo-transpiration, mm;
KC =crop co-efficient.

For these requirements of water, the major source being the irrigation water (IR), effective rainfall (ER) and water in the soil profile (S).

$$WR = IR + ER + S \quad (10)$$

The field irrigation requirement of a crop, therefore refers to the water requirement exclusive of effective rainfall and contribution from soil profile which can be neglected.

$$IR = WR - ER \quad (11)$$

The values of IR in the different soils of the study area were collected from the research work of Paul, 1993 where it was determined by the following methods:

Applied Irrigation

Total applied irrigation water into the field was calculated by the following formula:

$$D = (Qt)/A \quad (12)$$

where,
Q =delivery from the pump, m^3/s;
t =total operating time of Pump of the whole irrigation season, S;
A =area covered, m^2;
D =Applied irrigation, m.

Problems of irrigation schemes at the field level were identified by asking questions to investors, farmers, operators (skilled labors) and author's own observation. Large

Fig. 2 Setting delivery pipe at the entrance of the field.

Fig. 3 Measuring applied water to the field.

scale problems were identified by asking questions to the concerned authorities.

Results and Discussion

The electric-powered tube well irrigation schemes of the study area were grouped according to four types of soils, namely; clay loam, silty loam, loam and sandy loam. Investors as the owner of the irrigation prime movers and equipment are responsible for supplying irrigation water and related technologies. They use their equipment on several farmers' land within a defined area and enjoy 25% share of the rice after harvest. On the other hand, farmers are responsible for all other works and technologies and enjoy 75% share of rice after harvest **(Fig. 4)**. This system has been started several years ago due to poor economic condition of farmers with fragmented landholdings. After the failure of the Government's cooperative system, this system became popular in the study area. Satisfaction was observed in the minds of both farmers and investors so that they both tried to apply optimum inputs to attain maximum production for their own benefit.

Experimental Results

Experimental results about required and applied irrigation, percentage of utilized motor power, pump discharge, pumping plant efficiency, conveyance efficiency, yield productivity of water and electricity consumption per unit area and unit volume of water are shown in **Table 1**. It will be shown that in every soil type, applied irrigation was higher than it's required value **(Fig. 5)**. A significant quantity of water (19% to 84%) was being lost. In sandy loam soil, both required and applied irrigation seemed highest but was the lowest in clay loam soil. The main reason for the variation in required irrigation water in different soils is the variation of seepage and percolation losses. The lack of technical knowledge of investor/operator might be the main reason for the application of more irrigation water than required. For this reason the investor's cost will increase.

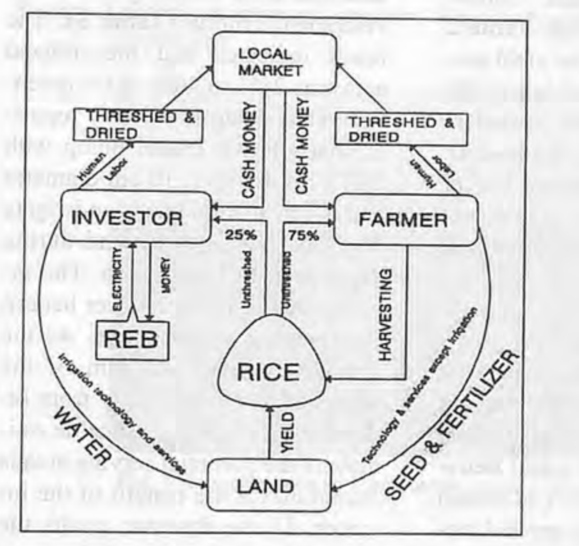


Fig. 4 Flow diagram of rice farming system in dry season.

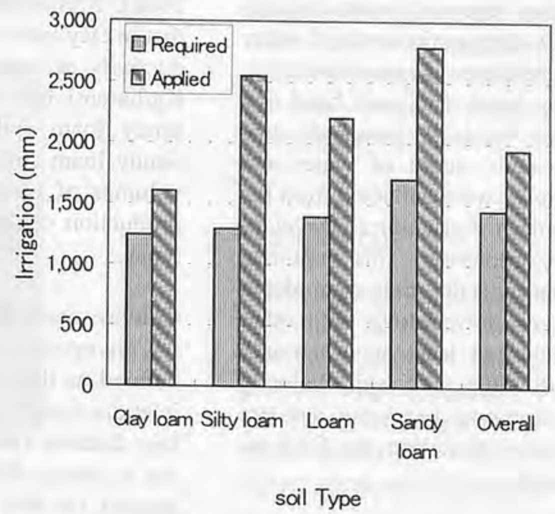


Fig. 5 Required and applied irrigation for dry season rice.

Table1. Total Dynamic Head of Selected Tube Wells

Soil Type	Pump Delivery (l/s)	Static water level (m)	Draw down (m)	Total dynamic head (m)
Clay loam	14.43	5.20	1.85	8.20
Silty loam	18.73	4.10	1.93	7.49
Loam	16.62	3.28	1.55	6.02
Sandy Laom	18.81	3.40	1.55	6.37

Note: Diameter of suction and delivery pipe was 10.16 cm (4 inch),
Frictional coefficient of old steel pipe is 0.01 (Duke, 1989)
Static water level and draw down are average values of the previous five years (source: Bangladesh Agricultural Development Corporation)

Percent of Utilized Motor Power and Pump Discharge

The utilization of motor power was 33% to 54% of it's available capacity (**Table 3**). Pump size selection might be wrong according to motor available power. All pumps in the study area delivered lower discharge (68% to 89%) than their rated capacity (21.24 lps). It can be pointed out that pumps were not tested at the field level, specially for irrigation. Investors did not follow ground water rule and installed their tubewell without maintaining the minimum distance between two tube wells. Draw down interference might be one probable cause for lower discharge rate.

Total Dynamic Pumping Head

Total dynamic pumping head for individual tube wells were calculated by adding static depth of water and draw down of pumping period, velocity head, frictional head and delivery head of pump. In this study, static depth of water and draw down were collected from the Bangladesh Agricultural Development Corporation. This organization measures the static water depth and draw down along with other parameters at least once a month for individual tube well. Velocity head, frictional head and delivery head were taken from the field experiments.

Pumping Plant Efficiency

Pumping plant efficiency may be defined as the ratio of output power of pump to the input power of motor. By direct measurement of motor input power, pump delivery and calculating total dynamic pumping head for the operating period, pumping plant efficiency of individual tube well was determined (**Table 2**). The irrigation units for clay loam and silty loam soil operated with excellent pumping plant efficiencies. But in loam and sandy loam soil the performance was not satisfactory. Some technical problems inherent inside the pump, pipe, strainer may be probable reasons.

Yield Productivity of Water

The yield productivity of water may be defined as the amount of yield per unit depth of water that has been used for crop growth i.e., evapo-transpiration, seepage and percolation (Dutta and Sarker, 1986). It is evident from **Table 2** that in clay loam soil, the yield productivity of water was highest (26 Kg/ha-cm) but was the lowest in sandy loam soil (12 Kg/ha-cm). Sandy loam soil consumed higher volumes of water but gave lower production compared to other soil types.

Conveyance Efficiency

Conveyance efficiency can be defined as the ratio of delivery to inlet discharge of the canal at a certain distance (ratio of canal delivery to pump delivery at a certain length). For this study, applied water to the field at several different distances from the pump delivery point were measured and evaluated for an average of 100 m in length. Conveyance efficiency seemed to be low (**Table 2**) for non-lined, uncompacted irregular shaped canals at the study area. A significant amount of water was being lost through seepage and percolation.

Consumption of Power

All the study tube wells were electric powered. It can be seen from **Table 2** that the sandy loam soil consumed the highest amount of electricity (954 kWh/ha) for the application of more water, but electricity consumption was lowest in clay loam soil (574 kWh/ha).

Determination of Potential Area to be Serviced by Irrigation

The potential area to be serviced by a tube well in varying soil types based on the study result were determined from various possible development criteria (**Table 3**). The result indicates that the utilized area was 28% to 40% of it's potential value. Pedrollo (1994) reported that HF6AR model pump with 18.75 lps delivery, 10 cm diameter and 6-7 m suction head can irrigate 16.19 ha (40 acre) of land during dry season in Bangladesh. The investor had to receive lower benefit for covering a lower area. As the investor receives the sum of the shares of harvested paddy from individual farmers, a reasonable estimate of the potential serving area is important for the benefit of the investor. If the investor could the cover potential value of the area, being serviced his net benefit would increase. **Table 3** shows the comparison between the present

Table2. Experimental Results of Irrigation Schemes

Soil Type	Pump Delivery (l/s)	Conveyance Efficiency(%)	Pumping plant Efficiency(%)	Yield productivity of water(kg/ha-cm)	Power consumed (kWh/ha)
Clay loam	14.43	48.3	64.4	26	574
Silty loam	18.73	42.0	75.3	24	713
Loam	16.62	49.2	53.8	20	704
Sandy Laom	18.81	42.0	52.8	13	954

Note: 16% land of scheme is covered by seepage water (Datta and Sarker, 1986).
Conveyance efficiency was computed for the average of 100 m distance from the delivery point to entrance of field.
All studied pump rated capacity is 21.24 l/s.

and potential areas. If the investor could receive his share at a low rate (<25%), then there would be an excellent opportunity to reach the potential value of the area to be serviced with less difficulty.

Problems of Irrigation Schemes

In all soil types, canals were unlined, uncompacted and had irregular shapes. A huge volume of irrigation water was being lost due to seepage and percolation. A comparison of present canal condition with compacted one is shown in **Fig. 6**. In the clay loam soil area, most of the lands are terraced (hilly area); a large volume of water pass from canal to the nearest lowland. Late transplantation of rice was observed in some lands due to delay in harvest of mustard (previous crop) and lengthening of transplantation time due to shortage of draft power. Various varieties of rice were used within the same scheme boundary. A very short distance between two tube wells (even 30 m) was observed in some areas (**Fig. 7**). Suspension of ground water ordinance by the Government of Bangladesh without other viable alternative may be one reason for covering low area under irrigation. After June 1994, the Government completely stopped the public sector minor irrigation work without creating any alternative.

Fig.6(a) Unlined, uncompacted, irregular shaped canal.

Fig. 6(b) Proposed compacted canal.

Fig. 7 Two tube wells with interfering zones of draw down.

Table3. Area Development by Varying Criteria (STW)

Soil Type	Utilized area (ha)	Seasonal used time (h)	Utilized motor power (%)	Required irrigation (mm)	Serving area increased (ha)	Potential serving area (ha)
Clay loam	5.21	1591	54.1	1248	7.90	13.11
Silty loam	4.99	1883	33.0	1291	11.97	16.96
Loam	4.11	1506	53.8	1377	7.73	11.83
Sandy Laom	3.24	1350	50.2	1696	8.03	11.27

Assumptions:

1. Use of available motor power can be increased to 80%
2. Conveyance efficiency can be improved to 75%
3. Applied irrigation should be equal to required irrigation.
4. Motor operating time can be increased to 2000 h for dry season (18-20 h/day)
5. Electricity supply remain continuous.

Conclusions

Investors cover low areas under irrigation (28% to 40%) due to excessive irrigation (19% to 84%), low conveyance efficiency (41% to 48%), low utilization of available motor power (33% to 54%) and having some social problems. For a share crop-payment system, the optimum area under each irrigation scheme with uniform cropping pattern and share should be considered for investors' benefit. By acquiring technical knowledge about the selection of pump and motor and agronomic knowledge about crop-water requirement, the investor can achieve better result. Well designed compacted irrigation canal (lining if needed) can reduce seepage loss of water. The area under STW irrigation schemes can be increased from 152% to 236% of it's present value by taking appropriate technical and managerial measures.

REFERENCES

BBS, 1992. Statistical Yearbook of Bangladesh, Bangladesh Bureau of Statistics, Dhaka, Bangladesh.

Dutta, S.C. and Sarker, R.I. 1986. Delineation of Command Area in Four Selected Minor Irrigation Schemes, Water Market of Bangladesh, Irrigation and Water Management Department, Bangladesh Agricultural University, Mymensingh: 56-71.

Hossain, M. 1989. Green Revolution in Bangladesh - Impact on growth and Distribution of Income, University Press Limited, Dhaka, Bangladesh.

Khan, A.U. and Hossain, M. 1995. Graphoman's New Atlas, The Atlas of Bangladesh. Graphomans, Dhaka, Bangladesh.

Paul, S.C. 1993. Study on Minor Irrigation Schemes in Different Soils of Tangail District, M.Sc. Thesis, unpub. Bangladesh Agricultural University, Mymensingh, Bangladesh.

Pedrollo, 1994. Pedrollo Pump Company Ltd. A producer of Agricultural pumps, Dhaka, Bangladesh.

Rashid, R. 1992. Irrigation Development in Bangladesh, The Bangladesh Observer, March 15, 1992, Dhaka, Bangladesh.

Rogers, P., Lydon, P. and Seckler, D. 1989. Eastern Waters Study Strategies to Manage Flood and Drought in the Ganges - Brahmaputra Basin, Irrigation Support Project for Asia and the Near East, sponsored by the US Agency for International Development. ■■

Development of Animal-Drawn Weeders in India

by

H. S. Biswas
Principal Scientist (FM&P)
Central Institute of Agricultural Engineering
Nabibagh, Berasia Road, Bhopal - 462 038
India

T. P. Ojha
Ex-Deputy Director General (Engg.)
ICAR, Krishi Bhawan, New Delhi-110 001
Res: HIG-30, Gautam Nagar, Bhopal - 462023,
India

G. S. Ingle
Ex-Professor of Farm Machinery
I.I.T. Kharagpur - 721 302
India

Abstract

Traditional and improved animal- drawn weeders are widely used for mechanical control of weeds in India. Straight blade hoes and triangular blade hoes made by blacksmiths and village artisans are traditionally used. Animal-drawn cultivators with shovels, sweeps or duckfoot sweeps were introduced from several research centres. Tool carriers with pneumatic and steel wheels were also introduced for tillage, sowing, weeding and interculture operations. Use of rotary tools, e.g., discs and rotating rods is limited. Animal-drawn weeder mulcher (IISR, Lucknow) made use of four straight blades in the form of a cage. A 'V' shaped blade was recommended for conventional Bakhar (blade harrow) by CIAE. A triangular blade hoe was developed and introduced by ATRC, Bardoli for secondary tillage and weeding operations. Studies on four basic shapes of weeding tools; namely straight blade, curved blade, triangular blade and sweep were undertaken at CIAE. Efforts were made to optimize tool parameters of the four shapes for minimum draught force in black soil. There has been growing emphasis on integrated weed management in the farming system and animal drawn weeders find important place in the system. The status on animal-drawn weeders developed, used and evaluated in the country are highlighted in this paper. The major thrust for the future should be on adaptation, manufacturing promotion, training and demonstration of improved animal-drawn weeders to reduce the cost of weeding.

Introduction

Animal power plays an important role in the mechanical control of weeds in India. Traditional animal-drawn hoes made by village artisans are widely used by farmers. Traditional hoes are made from locally available materials, e.g., wood for the frame work and steel for the soil working components. The use of improved animal drawn weeders developed and introduced from various research centres have been to a limited extent, though the popularity is gradually increasing. The major constraints have been quality production of these implements and their availability at the remote villages where majority of the farmers are located.

About 85 million draft animals are available in the country. Nearly 90 % of tillage and sowing operations are still done by animal power. For weeding and interculture operations, animal power is not as extensively used as in tillage and sowing operations. For mechanical control of weeds, mostly human and animal powers are utilized. Manual weeding can give a clean weeding, but it is a slow process and due to acute shortage of manpower in the problem season, weeding can not be completed in time. Animal-drawn weeders give high output, resulting in low cost of weeding compared to the manual weeding. In some crops weeding by animal power is supplemented by manual weeding along the crop rows.

Studies at various centres in India carried out in different crops have shown that there are substantial losses caused by the crop yields by weeds. A reduction of 5 to 60 % of crop yields have been reported by many research workers. Obnoxious weeds like *Carthamus oxycantha*, *Cyperus rotundus*, *Saccharum spontaneum*, *Cynodon dactylon*, *Avena fatua*, *Phalaris minor*, *Parthenium hysterophorus* etc. have infested large areas in various states. Integrated weed management by mechanical control, chemical control, biological method, crop rotation and crop competition methods has been suggested by research workers. Use of pre-emergent herbicides to control weeds for about 4 weeks and

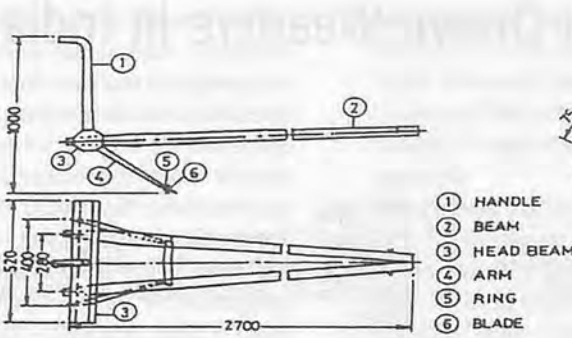


Fig.1 Blade hoe (central India).

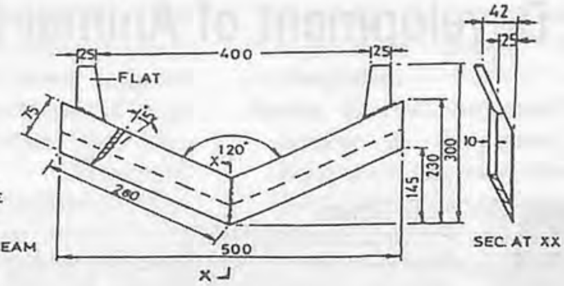


Fig.2 V-shaped blade for Bakhar(CIAE design).

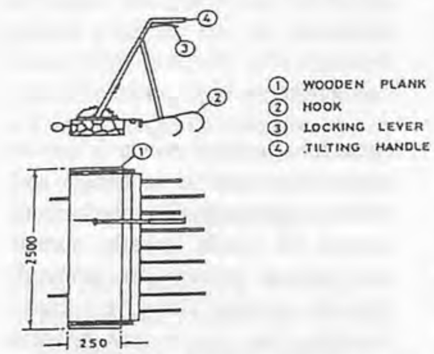


Fig.3 Patela harrow with lifting lever (CIAE design).

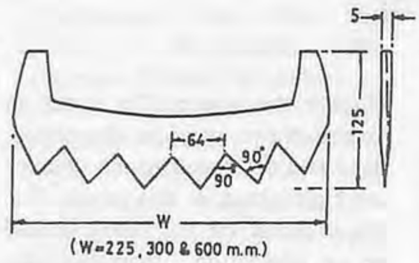


Fig.4 Serrated blade for hoe and harrow (PKV, AKOLA design).

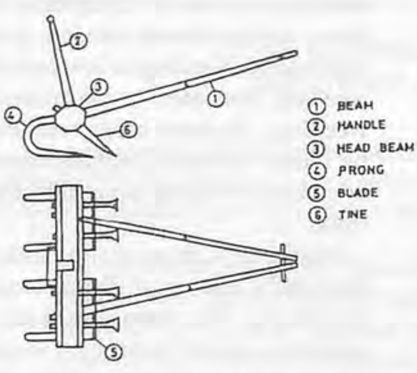


Fig.5 Bullock drawn blade cum tine hoe.

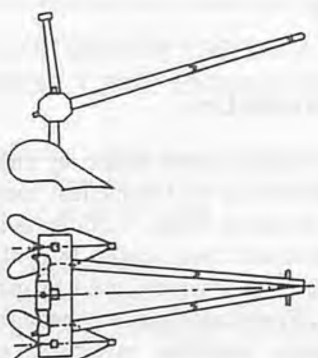


Fig.6 Bullock drawn ridger hoe.

then one mechanical weeding by manual or animal operated weeders is becoming popular for some crops during problem season.

Mechanical control of weeds shall remain by far the most widely used method of weed control in the country for the years to come. Therefore, animal power will play a key role in weed control in upland crops. Efforts should, therefore, be made to develop, evaluate, modify and introduce improved animal drawn weeders in the region.

This paper reviews the status of the development of animal-drawn weeders in the country and the research studies conducted at CIAE on animal-drawn weeders.

Review on Animal-Drawn Weeders

Research efforts to develop improved animal-drawn weeders were made at several research centres throughout the country, though popularization and adoption among the farmers had been quite limited due to several factors. Biswas (1) surveyed and reported details of 14 animal-drawn weeders used in India. Traditional hoes and improved traditional hoes are used in large numbers by the farmers.

Blade hoe **(Fig. 1)** is a traditional animal-drawn weeder that is widely used for weeding and interculture operations. Blade hoe with single blade is very popular though double blades are also used.

Bakhar (blade harrow) is a traditional implement used for primary and secondary tillage, weeding and soil mulching in black soil regions of the country. It makes use of a straight or slightly curved blade. AV -shaped blade **(Fig. 2)** that could be fitted into a traditional Bakhar was developed and introduced by CIAE (2). It was reported to have less clogging effect and draft force requirement compared to the traditional blade.

A patela harrow with lifting arrangement of hooks was developed at CIAE(2). The patela harrow **(Fig. 3)** is used after primary tillage for levelling, breaking the soil clods and collection and removal of trash and weeds from the field.

Yadav and Anderson (3) gave details of serrated blade for hoe and harrow, bullock drawn blade cum-tine hoe and bullock drawn ridger hoe for weeding and interculture operations in dryland farming. The serrated blade **(Fig. 4)** of different sizes may be fitted onto the traditional blade hoe or blade harrow (Bakhar). The serrated blades easily penetrate into the soil and help in moisture conservation. The bullock drawn blade cum-tine hoe **(Fig. 5)** is an improvement over the traditional blade hoe. There are two straight blades in the hoe and in front of each blade there are two tines to loosen the soil. The bullock-drawn ridger hoe **(Fig. 6)** makes use of two ridger bottoms on traditional wooden frame with row to row adjustments. The ridger hoe is useful for weeding and earthing operations.

Triangular blade hoes are popular in some parts of the country. A triangular blade hoe developed by the Agricultural Tools Research Centre (ATRC) Bardoli is shown in **Fig.7**. Wedges have been used for fixing the tines and blades, so adjustment of these weeders in the field is easier. The triangular blades easily penetrate the hard soil and clogging of the blade is minimum. The hoe is used for secondary tillage and weeding operations.

Animal drawn cultivators were introduced by the Indian Agricultural Research Institute (IARI), New Delhi, Allahabad Agricultural Institute (AAI), Allahabad; Punjabroa Krishi Vidyapeeth (PKV); Tamil Nadu Agricultural University (TNAU), Coimbatore **(Fig. 8)**; CIAE, Bhopal **(Fig. 9)** and other research centres. The cultivators make use of shovels, sweeps and duckfoot sweeps.

The weeder mulcher **(Fig. 10)** developed at the Indian Institute of Sugarcane Research (IISR), Lucknow makes use of four straight blades in the form of a cage. During operation only one blade works in the soil as the cage is held by a pawl mechanism. When the blade is clogged by weeds, the operator releases the pawl by means of a lever and the cage turns through 90 ° and is locked again by the pawl. This brings a new blade in working position. The weeder mulcher is useful for weeding in sugarcane and other widely spaced row crops.

The use of rotary tools, e.g., discs and rotary rods is limited. However, animal-drawn disc harrows are available for secondary tillage and weed control. A rod weeder was developed at the Andhra Pradesh Agricultural University (APAU), Hyderabad. It made use of a ground powered square rod.

Animal-drawn tool carriers with pneumatic and steel wheels were introduced from different research centres for tillage, sowing, weeding and interculture operations. Works at the International Crop Research Institute for Semi-Arid Tropics (ICRISAT), Hyderabad

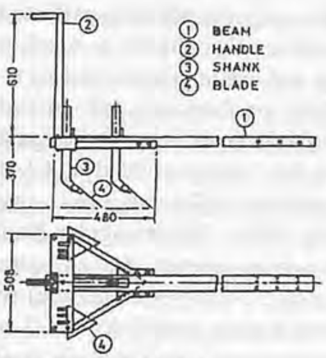


Fig.7 Trianglar blade hoe (ATRC,BARDOLI design).

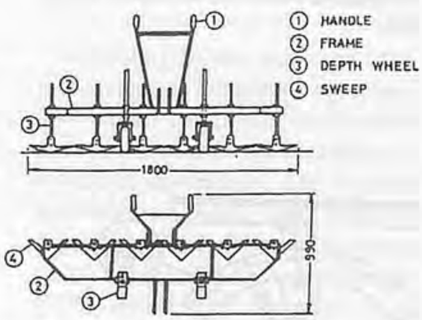


Fig.8 Animal-drawn cultivator (TNAU, COIMBATORE design).

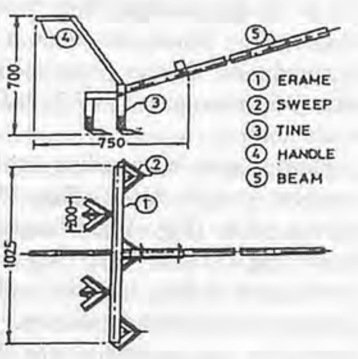


Fig.9 Animal-drawn cultivator (CIAE design).

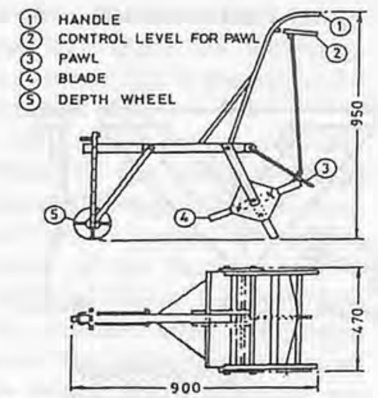


Fig.10 Weeder mulcher (IISR, LUCKNOW design).

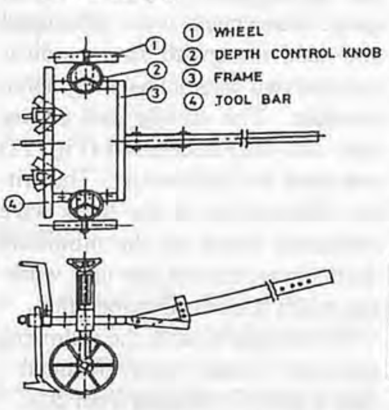


Fig.11 CIAE tool frame with steel wheels (CIAE design).

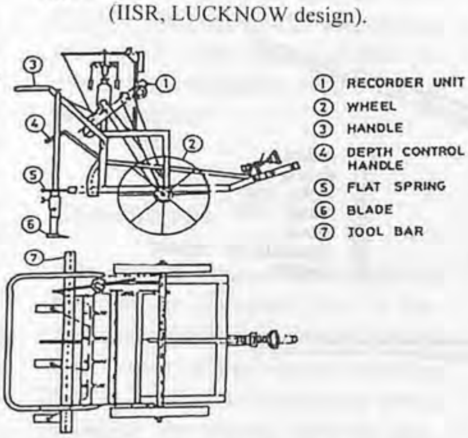


Fig.12 Mobile tool carrier unit with instrumentation (CIAE design).

and CIAE, Bhopal showed the utility of the tool carriers for varied farm operations and high field capacity compared to the traditional tools. Rajput (4), in his study on tool carriers during 1981-87 in CIAE, Bhopal , found high field capacity for the following operations - ploughing (0.065 ha/h), blade harrowing (0.106 to 0.220 ha/h) and weeding/interculture (0.287 ha/h). High cost of the tool carriers with pneumatic wheels (e.g., NIKART and TROPICULTEUR) make them prohibitive for use by common farmers. Garg and Devnani (5) introduced a tool carrier with steel wheels **(Fig. 11)**. Biswas (6) developed a mobile tool carrier with instrumentation **(Fig. 12)** for field studies of different shapes of weeding tools. A 4-channel mechanical strain gauge type recorder unit measured the draft forces acting on 3 blades at a time and the forward speed was recorded through a centrifugal system on the fourth channel.

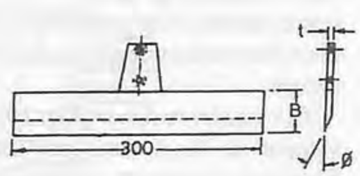


Fig.13 Straight blade.

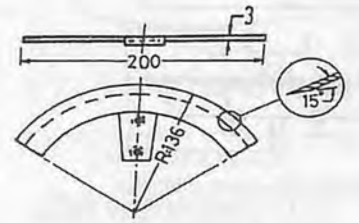


Fig.14 Curved blade.

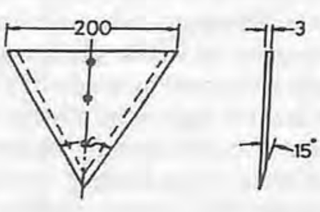


Fig.15 Triangular blade.

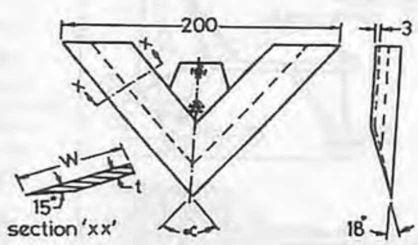


Fig.16 Sweepblade.

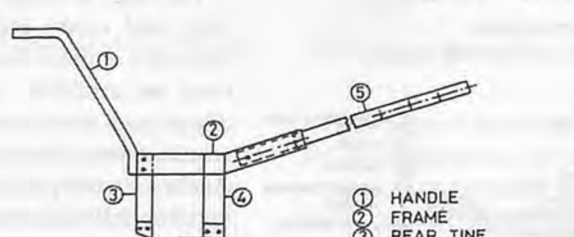


Fig.17 Animal-drawn cultivator (CIAE design).

Studies on Animal-Drawn Weeders

The animal-drawn weeders work between crop row spacings. The weeds left over along the rows may be removed manually. The straight blades in traditional hoes tend to remove weeds up to the working widths of the blades. However, due to clogging of the straight edges, the output is adversely affected. Therefore, there was a need to study and use improved blades.

Field performance of animal-drawn blade hoe and triangular blade hoe was evaluated at CIAE on soybean *(Glycine max)* crop during 1980. The triangular blade hoe worked deeper (6.3 cm compared to 5.5 cm for blade hoe) requiring higher draft force (41.5 kg compared to 33 kg for blade hoe). However, weeding efficiency was higher for triangular blade hoe (78.34 % compared to 74.65 % for blade hoe). Triangular blade hoe required more time to cover one ha area (8.23h compared to 7.73 h for blade hoe).

Four shapes of weeding tools, namely; straight blade **(Fig. 13)**, curved blade **(Fig. 14)**, triangular blade **(Fig 15)** and sweep **(Fig. 16)** were tested during 1988-90 under laboratory and field conditions. A laboratory test apparatus was developed for testing the tools in a small soil bin at a constant speed and at different depths. Strain gauge transducers were developed and used alongwith strain indicators and two channel oscillographic recorder. The mobile tool carrier unit with instrumentation **(Fig. 12)** was used for field testing. The critical dimensions of the tools were optimized based on the minimum draft force required per unit working width (Du) during operation.

For straight blades, the following optimum values were obtained : rake angle (δ) ranging from 20.6° to 22.5° blade width (B) as small as possible in the range of 15 to 50 mm, blade thickness (t) as small as possible depending upon the mechanical strength and blade sharpness angle (ϕ) of 15° and below.

For curved blades of 200 mm working width, optimum values of radius of curvature (R) was 136.4 mm and rake angle (δ) ranged from 22.0° to 22.4° .For triangular blades, optimum values of rake angle (δ) ranged from 21.6° to 21.9° and approach angle (α) ranged from 76.9° to 81.6° .

Optimum values of rake angle (δ) for straight, curved and triangular blades were close within the range of 20.6° to 22.5° . The average value of the optimum rake angle for all these blades was 21.93° .

For weeps, following optimum values were obtained : approach angle (α) in the range of 74.7° to 75.0° , wing width (W) of 50 mm and below and blade thickness (t) of less than 4 mm. Wing width and blade thickness should be minimum depending upon the mechanical strength of the sweep. High grade steel may be utilized to obtain these minimum values.

Considering the optimum values of approach angle (α) for both triangular blades and sweeps, the average optimum value of approach angle was $\alpha = 78.6°$ (n = 24, $\sigma = 1.9$) which was significant within 3 σ limits.

Field performance of weeding tools were assessed through performance index (P) suggested by Gupta (7) :

$$p = \frac{a \times q \times e}{p}$$

Where,

a = output in ha per

q = (100 - percent plants damaged)

e = weeding index in percent and

p = power input

The weeding index e was given by:

$$e = \frac{w_1 - w_2}{w_1} \times 100$$

Where

w_1 =weed count before weeding and

w_2 = weed count after weeding.

Optimized blades, one each from four shapes of the tools were tested under field conditions on the animal drawn mobile tool carrier unit with instrumentation. The highest performance index was obtained for sweep (8937) followed by triangular blade (7687), curved blade (7225) and straight blade (3777).

For straight blades, draft force and power requirement were high. Weeds clogged the cutting edge of the straight blade. Plants damage was also on higher side. Soil manipulation was high in the case of the triangular blade.

An animal-drawn cultivator **(Fig. 17)** was developed using improved sweeps and one triangular blade as jointer. The performance of the cultivator and a traditional Bakhar (blade harrow) was evaluated under field conditions. The performance index of the animal drawn cultivator was 2023.9 and that for Bakhar was 1276.7. The animal-drawn cultivator could cover about 53.03 % more area compared to the traditional Bakhar.

Conclusions

Improved animal-drawn weeders play an important role in the mechanical control of weeds. Due to high output, animal-drawn weeders help in timeliness of operation compared to the manual method and, therefore, it is economical to use. However, within the crop rows, weeds may be manually removed. Other weed control methods, e.g., chemical, crop competition, crop rotation etc., may be utilized for effective weed management.

A good number of improved animal-drawn weeders have been developed at various research centres. However, new designs of the weeders have not been adopted widely by the farmers due to many reasons, including difficulty in development of manufacturing technology by the village artisans and tiny fabricators; inadequate extension facilities for demonstration, training and popularization and non-availability of designs of improved weeders for different locations or crop specific agro-climatic conditions. Concerted efforts are, therefore, required from the research and government organizations in design and development of improved weeders, demonstration and popularization, training of extension workers and farmers on use of improved weeders and industrial liaison for quality production of improved weeders. The transfer of available technology to the farmers can reduce the loss of yields due to weeds and increase the agricultural production and productivity.

REFERENCES

Biswas HS, 1980. Weeding tools and implements of India. pp: 45 - 69. Technical Bulletin No. CIAE/78/3. Central Institute of Agricultural Engineering, Bhopal, India. 87 p.

CIAE, 1980. Bakhar blade and patela harrow. pp. 26-28. Annual Report 1976-79. Central Institute of Agricultural Engineering, Bhopal, India. 100 p.

Yadav GC and Anderson DT. 1980. Farm operations and equipment for efficient dryland management. pp. 20-22, 33-35. Technical Report. All India Co-ordinated Research Project for Dryland Agriculture, Hyderabad, India.

83p.
Rajput DS, 1987. Scope of multipurpose wheeled tool carriers in increasing work output of draft animal power. pp. 188-191. Utilization and Economics of Draught Animal Power, Proceedings of the National Seminar on Status of Animal Energy Utilization Technical Bulletin No. CIAE/87/51, Bhopal, India. 391 p.
Garg BK and Devnani RS, 1982. Performance evaluation of multipurpose tool carrier. pp. 21. Annual Report 1981-82. Central Institute of Agricultural Engineering, Bhopal, India 159 p.
Biswas HS, 1990. Soil tool interactions for mechanical control of weeds in black soils. Unpublished Ph.D. thesis, Indian Institute of Technology, Kharagpur, India. 283 p.
Gupta CP, 1981. Report on weeders. Regional Network for Agricultural Machinery, Manila, Philippines.
Garg BK and Devnani RS, 1983. Animal drawn multipurpose tool carriers. Technical Bulletin No. CIAE/83/41. Central Institute of Agricultural Engineering, Bhopal, India .
Shanmugham CR, 1982. Farm machinery and energy research in India. Technical Bulletin No. CIAE/82/32. Central Institute of Agricultural Engineering, Bhopal, India . ■■

REMINDER

The reminder might run something like this:

THE AMA EDITORIAL STAFF WILL APPRECIATE RECEIVING ARTICLES FOR PUBLICATION TYPED DOUBLE-SPACE AND NOT REDUCED IN SIZE.

FARM MACHINERY INDUSTRIAL RESEARCH CORP.
7-2Kanda Nishikicho,Chiyoda-ku,Tokyo,Japan(Tel.81-(0)3-3291-5718,3671~4)
E-mail:sinnorin@blue.ocn.ne.jp URL:http://www.shin-norin.co.jp

Performance Evaluation of a Thai-made Rice Combine Harvester

by
R. Kalsirisilp
Doctoral student
Agricultural and Food Engineering Program
School of Environment,
Resources and Development
Asian Institute of Technology
Bangkok,
Thailand

Gajendra Singh
Professor
Agricultural and Food Engineering Program
School of Environment,
Resources and Development
Asian Institute of Technology
Bangkok,
Thailand

Abstract

A study was carried out in 1993 to investigate the problems associated with the working of a locally-made rice combine harvester used by farmers and contractors in Thailand. The results infer that the farmers were satisfied with the performance of the machine. The contractors were not satisfied and wanted improvements in the machine. The design of the threshing unit and its position on the machine needed improvements. The field capacity varied from 0.10 to 0.71 ha/h with an average of 0.40 ha/h and the total grain losses varied from 0.5 to 9.6% of grain yield, with an average of 3.9%. The field efficiency varied from 28 to 92% with an average of 66%. Due to improved design the average field capacity of the machine in 1998 was estimated at 0.53 ha/h. The cost of manual harvesting was Bht 3,200/ha in 1993, the break even point was 89 ha. Due to significant increase in the price of the machine, the break even point in 1998 increased to 130 ha and the cost of manual harvesting was Bht 3,860/ha. Some suggestions have been made to improve the machine operation in order to reduce the cost of harvesting.

Introduction

Rice combine harvesters were initially introduced in Thailand during the 1957-63 period. The first prototype was fabricated by the Deberiddhi Devakul in 1957, Engineering Section, Department of Rice, but the Thai farmers at that time did not pay much attention to it. The farmers were satisfied with the use of sickle and animal power for rice harvesting and threshing, respectively. This may be due to the fact that the agricultural sector was not facing any labor shortage in those days. With the advent of industrialization, there has been a migration of labor from the agriculture sector to the industrial sector leaving limited numbers in the latter sector to do the labor-intensive farming activities like harvesting.

In 1987, local manufacturers started to fabricate rice combine harvester using the designs of combine harvester models of Western countries. In 1998, the number of locally-made rice combine harvesters in use was more than 3,000 units as estimated from the annual production of manufacturing firms.

Studies on field performance of Thai-made rice combine harvesters indicated that the repair and adjustment time due to the machine' s breakdown were around 30% of total harvesting time (Krishnaserine, et al. 1991). Therefore, more information on the problems and constraints related to the use of Thai-made rice combine harvesters was needed in order to improve its field efficiency and reduce the frequency of breakdowns.

Material and Methods

Study Sites

The manufacturing process of the Thai rice combine harvester was observed at Kasetpatana Manufacturing Company, Phitsanulok. The survey and field performance studies were carried out in four different provinces of Thailand, namely; Sukhothai, Phichit, Nakhon Sawan and Phitsanulok.

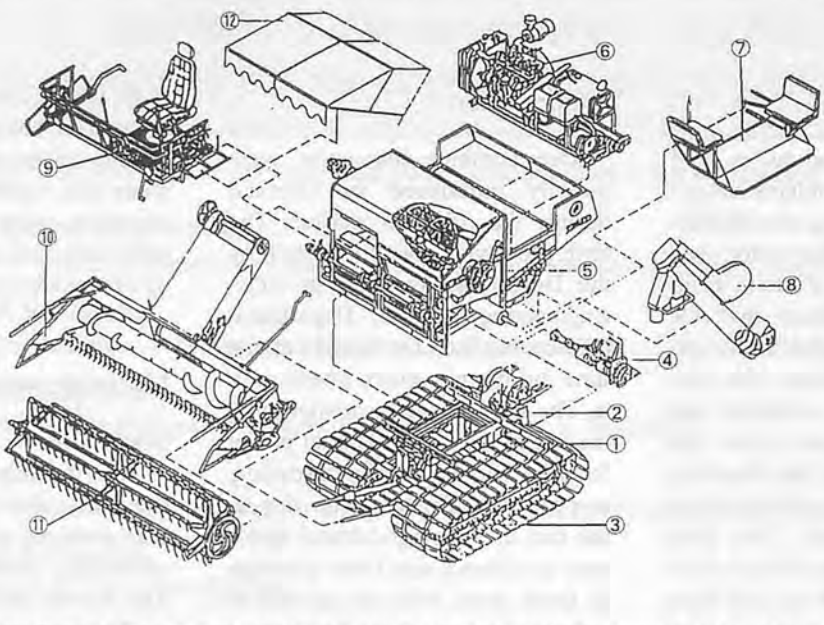
Field Survey

For collecting information, two different sets of questionnaires were prepared for farmers and contractors. Thirty farmers and 30 contractors were selected in the four provinces and were interviewed with one set each of the survey questionnaire.

The Rice Combine Harvester

The rice combine harvester is a self-propelled machine consisting of eight major units: prime mover, undercarriage, transmission and steering, reaping, feeding, threshing, cleaning and separating and bagging unit **(Fig.l)**. **Figure 2** shows the technical outline of the Thai-made rice combine harvester. **Figure 3** shows the locally made rice combine harvester in operation. The machine requires three persons to operate; one for operating the machine and the other two for sacking the threshed rice. Details of major units are given below:

1. Prime mover unit- An imported diesel engine with a rating capacity of 100-145 kW is normally used as the prime mover for the rice combine harvester. In most cases old engines are used.
2. Undercarriage unit- The chassis of the undercarriage unit is similar to heavy duty equipment but it has a sprocket and chain type power transmission system. It consists of five main components: track, track frame, idler wheel, carrier roller, and track roller units. The track unit consists of sprockets and chains. The shoe tracks are made of wood. Wide tracks of 80 x 250 cm are used to prevent the machine from sinking in wet paddy fields. The idler unit is used to guide and support the sprocket and chain unit of the combine. The carrier rollers are used to adjust the tension of the sprocket wheel and the track. The track roller unit consists of six rollers on each side and is used to support the weight of the machine.



1. Undercarriage frame 2. Sprocket and chain transmission 3. Track chain 4. Transmission gear box 5. Threshing unit 6. Prime mover 7. Packing seat 8. Grain auger elevator 9. Lever control 10 Header 11. Reel 12. Roof

Fig.1 Component parts of a rice combine harvester.

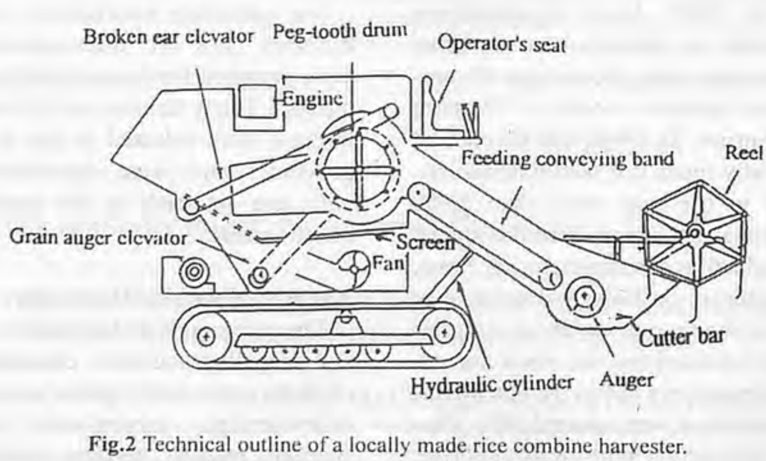


Fig.2 Technical outline of a locally made rice combine harvester.

3. Transmission and steering unit- The machine has two types of transmission systems,i.e., the direct drive and the hydrostatic drive. The direct drive system is normally used due to lower cost. The ratio between engine speed and sprocket wheel ranges from 1:28 up to 1:32 depending on the model of the machine.
4. Reaping unit- The harvesting unit consists of three main parts, i.e., a reel, front, auger, and cutter bar. The hexagonal reel with fingers feeds the paddy crop on the cutter bar for cutting. A hydraulic lever is provided at the opera-

tor' s seat to change the position of the reel by lifting it up or down. The reel has a rated speed of around 40 rpm. The 3 m wide cutter bar unit consists of a set of 39 knives and guards.

5. Feeding unit- The feeding unit conveys the cut crop to the threshing unit. It is driven by a sprocket and chain mechanism.
6. Threshing unit- An axial flow rice thresher is used as a threshing unit. The threshing mechanism consists of a peg-tooth cylinder which rotates inside a double section concave. The material is conveyed by chain conveyor and fed into the opening between the cylinder and the lower concave.
7. Cleaning and separating unit- The cleaning unit consists of two blowers and an oscillating screen. This is a built-in unit of an axial flow thresher, The machine separates and cleans the grain in three stages. In the first stage, preliminary grain and straw separation occurs at the concave. In the second stage, the unthreshed grain passes over the oscillating screen and is returned to the threshing drum for re-threshing by means of a broken ear elevator. In the third stage, threshed crop is subjected to a blast of air from the blower with adjustable air control, located beneath the threshing drum. It blows the lighter impurities from the good grains.
8. Bagging unit- The threshed paddy from the threshing unit is conveyed to the bagging unit by a grain auger elevator.

Performance Evaluation

Field performance of combine harvesters was evaluated by measuring the field capacity, field efficiency and grain losses.

Field capacity and field efficiency- The effective field capacity was determined by measuring all the time elements involved while harvesting. The total time was categorized into productive and non-productive categries. The productive time is the actual time used for harvesting the grains. The non-productive time consisted of the turning time, repair and adjustment time and other time losses. The area covered divided by the total time gave the effective field capacity. The field efficiency was determined by the ratio of productive time to the total time.

Machine operation losses- The grain losses determined were unthreshed grain loss, blower and screen loss, and shattering loss. The blower and screen losses were measured from the straw discharged by the machine.

Shattering loss refers to the ears and grains fallen unto the ground due to teel, cuoer bar Iveying operations.

Total machine loss refer to the summation of shattering loss, blower and screen losses.

Cost of Harvesting

The cost of harvesting using the rice combine harvester was calculated by considering the fixed and variable costs. The following formula was used for calculating the operational cost of the machine (Hunt, 1983):

Machine Cost

$$(Baht/h) = Fc/H + [(R\&M) + F + O + Lo + La] \quad (1)$$

where,

Fc=Total annual fixed cost (Baht)
H=Annual use (h)
R&M=Repair and maintenance cost (Baht/h)
F=Fuel cost (Baht/h)
O=Lubricant cost (Baht/h)
Lo=Operator cost (Baht/h)
La=Cost of labor for bagging (Baht/h)

The harvesting cost per ha of the machine for different annual uses was calculated and the break even point of the machine was determined.

Result and Discussion

Problems in Manufacturing of the Rice Combine Harvester- The manufacturing of the machine had four separate assembly lines. These assembly lines had a number of problems mainly due to lack of standardization of the component parts, which were manufactured outside the plant by the sub-contractors and also due to lack of the inspection of components purchased from outside. Adequate jigs and fixtures facilities were also not available in the manufacturing plant.

Farmers Opinion on Rice Combine Harvester- From the analysis of the responses in the survey, the following reasons were given by the farmers for using the machine. The figures in parenthesis show the percentage of farmers using the rice combines who cited that particular reason.

(a) Shortage of agricultural labor (93%);
(b) High wage of labor (78%);
(c) High machine capacity (93%);
(d) Lower grain losses as compared with manual harvesting (73%);
(e) It is cheaper to harvest with machine than manual labor (88%);
(f) It is an easy and convenient way of harvesting when compared with the manual method (80%).
(g) The users felt that the machine saves time (88%).

On the other hand, farmers who were using the manual harvesting method expressed the following reasons for not using the combine.

(a) Small land holding size (55%);
(b) Machine not suited to flooded field and lodged crop conditions (40%);
(c) Lack of confidence in the machine' s performance (85%);
(d) Non-availability of the machine (10%);
(e) The machine causes more grain

losses (70%);

(f) They did not have the grain drying facilities (area etc.) to handle large quantities of grain harvested by the machine in a very short period (75%).

Contractors' and Farmers' Problems about the Rice Combine Harvester

The problems needing attention by manufacturers were frequent breakdown of the machine (reported by 97% of contractors) and high cost of the spare parts at local repair shops (93% of the contractors). A major problem faced by the contractors was high transportation cost of the machine to the field (felt by 80% of contractors) as they have to use truck for transporting the machine. Harvesting of lodged crops was another major problem reported by 80% of the contractors. Other crop related problems were high moisture content of grain and straw and non-uniform maturity of the crop in the same area, thus requiring frequent adjustment, otherwise there were heavy losses. The major problem faced by the farmers (96%) was non-availability of sufficient space for grain drying due to high capacity of the machine. The farmers opined that due to this they had to sell their paddy to the mill at a comparatively lower price due to high moisture content of the grains.

Fig.3 Locally made rice combine harvester in operation.

Fig.4 Blocking of the crop in the threshing drum.

Problems During Operation of the Combine Harvester

Various problems were observed during field operation of the rice combine harvester which can be divided into three groups according to machine systems.

Feeding system- The two roller chains broke down frequently during field operation, mainly due to non-symmetry of the feeder conveyor. In the present system, the crop is conveyed to the threshing cylinder non-uniformly at both ends of the chain conveyor. This makes the chain loose on the sides. The reliability of the chain conveyor can be improved by making feeder conveyor symmetric and also properly lubricating the bearings of the feeder conveyor.

Threshing system- The blocking of crop in the threshing cylinder was very frequent during field operation, especially when the machine worked in a crop that was heavily lodged, having long straw or was harvested at high moisture content. The declogging of the threshing cylinder was a very difficult task and time consuming for the operator during field operation. This problem may be overcome by reorienting the axial flow thresher longitudinally by the manufacturer **(Fig. 4)**.

Transmission system- Sprockets and chains were used for power transmission from the engine to sprocket wheel in direct drive rice combine harvesters. The roller chains and final drive shaft frequently failed during field operation. The reliability of the transmission system can be possibly improved by providing gear transmission system instead of the sprocket and chain transmission system **(Fig. 5)**.

Field Performance of the Rice Combine Harvesters

The performance of the machines in the field was evaluated in four provinces, namely Sukhothai, Phitsanulok, Nakhon Sawan and Phichit. In these provinces, three different types of rice combine harvesters were used; a two-gear boxes, 145 hp machine, a two-gear boxes, 100 hp machine and a three gear-boxes, 100 hp machine.

Field capacity and field efficiency- The two gear boxes, 145 hp machine was used in field Nos. 1-4

Table 1. Field performance test of two-gear boxes, 145 hp rice combine harvester

Parameters	Sukhothai Province Field No.				Phitsanulok Province Field No.			
	1	2	3	4	26	27	28	29
Average speed (km/h)	4.0	4.9	4.3	3.4	2.9	2.9	3.3	3.3
Width of cutter bar (m)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Area harvested (ha)	0.17	0.30	0.30	0.18	0.43	0.44	0.40	0.48
Estimated yield (tons/ha)	4.7	4.9	3.9	4.0	4.9	4.8	4.6	4.9
Field capacity (ha/h)	0.46	0.55	0.46	0.20	0.37	0.33	0.41	0.38
Field efficiency (%)	80	86	67	55	66	67	83	67
Total grain losses (%)	4.0	3.7	3.5	4.3	3.1	3.4	3.2	3.2
Quality of grain (% purity)	92	90	93	95	87	82	83	85

in Sukhothai province and field Nos. 26-29 in Phitsanulok province as shown in **Table 1**. In Sukhothai the effective field capacity of the machine varied from 0.20-0.55 ha/h with an average of 0.42 ha/h. The average field efficiency was 70%. In Phitsanulok the effective field capacity of the machine varied from 0.33 to 0.41 ha/h with an average of 0.37 ha/h. The average field efficiency was 70% in the province.

The two-gear boxes, 100 hp machine was used in the field Nos. 5-9 in Sukhothai and field Nos. 10-17 in Nakhon Sawan as given in **Table 2**. In Sukhothai province the effective field capacity of the machine varied from 0.37-0 .71 ha/h with an average of 0.52 ha/h. The average field efficiency was found to be 82%. In Nakhon Sawan province, the effective field capacity varied from 0.10-0.40 ha/h with an average of 0.25 ha/h. The average field efficiency was 65%.

The three-gear boxes, 100 hp machine was used in field Nos. 18-25 located in Phichit province and results are shown in **Table 3**. The effective field capacity of the machine varied from 0.25-0.70 ha/h with an average of 0.42 ha/h. The average field efficiency was 52%.

Crop harvesting losses- The total machine losses in field Nos. 1-4 in Sukhothai province varied from 3.5 to 4.3 percent with an average of 3.9%, as shown in **Table 1**. The total machine losses varied from 3.1 to 3.4 percent with an average of 3.2 percent in field Nos. 26 to 29. Average losses in field Nos. 26 to 29 were not so high as compared with other fields of Sukhothai possibly due to good skill of the operator in controlling the working speed of the machine corresponding to the crop conditions.

The total machine losses in field Nos. 5-9 in Sukhothai province varied from 1.9 to 8.8 percent with an average of 4.9%, as shown in **Table 2**. Whereas, in Nakhon Sawan province, the total grain losses varied from 3.5 to 6.3% with an average of 4.4% in field Nos. 10 to 13, which were harvested by one operator. The total losses varied from 0.5 to 4.6% with an average of2.9% in field Nos. 14-17, which were harvested by another operator.

The total machine losses in field Nos. 18-21 in Phichit province, which were operated by one operator varied from 3.4 to 9.6% with an average of 6.5%, as shown in **Table 3**. The total machine losses varied from 2.4 to 3.1% with an average of 2.8% in the field Nos. 22 to 25, which were harvested by another operator. The total machine losses seemed to be more significant in field Nos. 18 to 21 than in the field Nos. 22 to 25 due to lack of louvers adjustment by operator during field operation. This loss can be reduced by adjusting the louvers at lower inclination. A significant variation in reel speed was observed in these two groups of fields, which was due to different pulley diameters used by the operators. The reel speed was observed higher in field Nos. 18 to 21 and thus leading to higher shattering losses.

The total machine losses depend on the time of harvest, crop variety, height of plant, crop inclination, grain moisture content, working

Table 2. Field performance test of two-gear boxes, 100 hp rice combine harvester

Parameters	Sukhothai Province Field No.					Phitsanulok Province Field No.							
	5	6	7	8	9	10	11	12	13	14	15	16	17
Average speed (km/h)	3.6	3.0	2.8	3.0	3.2	2.2	2.2	5.4	2.2	2.0	2.0	2.0	1.7
Width of cutter bar (m)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Area harvested (ha)	0.30	0.60	0.50	0.30	0.40	0.20	1.10	0.20	0.20	0.30	1.00	0.30	0.30
Estimated yield (tons/ha)	4.4	6.9	4.3	6.0	6.3	5.5	5.4	5.2	5.2	5.0	4.6	0.30	4.5
Field capacity (ha/h)	0.71	0.58	0.37	0.43	0.49	0.30	0.40	0.30	0.40	0.10	0.10	4.6	0.10
Field efficiency (%)	92	82	80	83	72	78	90	65	81	59	28	65	53
Total grain losses (%)	5.0	8.8	3.3	1.9	5.9	6.3	3.5	3.5	4.5	4.1	4.6	0.5	1.1
Quality of grain (% purity)	87	85	89	85	86	86	85	89	87	88	87	90	92

Table 3. Field performance test of three-gear boxes, 100 hp rice combine harvester in Phichit province

Parameters	Field No.							
	18	19	20	21	22	23	24	25
Average speed (km/h)	2.5	2.5	2.5	3.3	3.3	3.3	3.3	3.2
Width of cutter bar (m)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Area harvested (ha)	0.30	0.31	0.30	0.22	0.34	0.23	0.28	0.42
Estimated yield (tons/ha)	4.7	4.6	4.7	4.5	4.6	5.1	4.3	4.4
Field capacity (ha/h)	0.25	0.39	0.50	0.28	0.70	0.32	0.43	0.48
Field efficiency (%)	34	57	72	31	78	36	50	61
Total grain losses (%)	5.2	9.6	7.7	3.4	3.1	2.4	2.8	2.7
Quality of grain (% purity)	92	93	95	96	92	92	93	92

Fig.5 Transmission system break down in the field.

Fig.6 Kasetpatana rice combine harvester .

speed of machine, reel speed, type of machine and machine adjustment including blower speed and louvers. The machine shattering loss seemed to increase with travel speed of the machine, reel speed (reel speed to travel speed ratio), and crop condition at the time of harvest.

Labor requirement- The operation of all these rice combine harvesters requires one operator and two bagging men for collecting the grain into sacks and unloading the sacks after filling, on to the ground in the field. For sustained operation or contract work, an additional operator is generally needed. Based on the average capacity of the machine as 0.40 ha/h, the labor requirement to harvest 1 hectare will be 5.0 man-h skilled and 5.0 man-h unskilled man power.

Quality of grain- The quality of grain in terms of percent purity, as observed from the collected samples of the output of the three types of rice combine harvesters, varied from 85 to 96 percent with an average of 89 percent.

Field Performance of the 195 hp Rice Combine Harvester in 1998

The performance of the machine was evaluated in Pathumthani province as shown in **Table 4**. The effective field capacity of the machine varied from 0.50-0.58 ha/h with an average of 0.53 ha/h. The average field efficiency was 83%. The total machine losses varied from 2.3-3.2% with an average of 2.7%. **Figure 6** shows Kasetpatana rice combine harvester during field operation.

Cost of Harvesting with a Rice Combine Harvester

Based on the average field capacity of the machine as 0.40 ha/h las observed during field experimentation), the total cost of harvesting in 1993 was calculate as Baht 1,380/ha, and Baht 1,540 /ha in 1998, as shown in **Table 5**.

The total variable cost was calculated at 370 Baht/h or 925 Baht/ha, as given in **Table 5**. However, the cost of clearing the headlands should be added to the cost of harvesting. This clearing cost data was collected from the field observation as 225 Baht/ha, as given in **Table 5**. Therefore, the total variable cost of using machine was considered as 1,150 Baht/ha.

Assuming an annual use of 1,000 hours of the harvester, the total cost of harvesting was Baht 1,600/ha in 1993 which increased to Bht 1,920/ha in 1998 **(Table 5)**.

The total cost per hectare was plotted against the annual harvesting area for the machine using the

Table 4. Field performance test of two-gear boxes, 195 hp rice combine harvester in Pathumthani province

Parameters	Field No.		
	1	2	3
Average speed (km/h)	2.6	2.5	2.9
Width of cutter bar (m)	3.0	3.0	3.0
Area harvested (ha)	029	0.34	0.52
Estimated yield (tons/ha)	4.9	4.9	4.9
Field capacity (ha/h)	0.58	0.52	0.50
Field efficiency (%)	80	82	82
Total grain losses (%)	2.34	3.15	2.50
Quality of grain (% purity)	96	92	94

Table 5. Cost of operation of rice combine harvester in

Particular	Unit	Amount	
		1993	1998
Purchase price	Baht	680,000	1,500,000
Yearly use	h	1,000	1,000
Useful life	years	5	8
Salvage value (10%P)	Bht	68,000	150,000
Fixed costs per year			
a. Depreciation	Bht	122,400	68,750
b. Interest(16% in 1993 and 20% in1998)	Bht	59,840	165,000
Total fixed cost (Baht/year)	Bht	182,240	333,750
Variable costs per hour			
a. Fuel cost @6.8 l/h	Bht/h	43	75
b. Lubricant cost (@30% of fuel cost)	Bht/h	13	22
c. Labor cost			
(i) Two operators	Bht/h	100	140
(ii)Two unskilled Labor	Bht/h	30	50
d. Repair and maintenance(2.7% P/100h in 1993 and 1.3% P/100h in1998)	Bht/h	184	195
Total	Bht/h	370	482
Total machine cost	Bht/h	552	816
Average field capacity of the Machine	ha/h	0.40	0.53
Variable cost of operation (6/8)	Bht/ha	925	909
Operation cost of the machine (7/8)	Bht/ha	1,378	1,540
Average cost of labor for clearing the headlands @ 15 man-h/ha	Bht/ha	225	375
Total operation cost of the machine (10+11)	Bht/ha	1,603	1,915

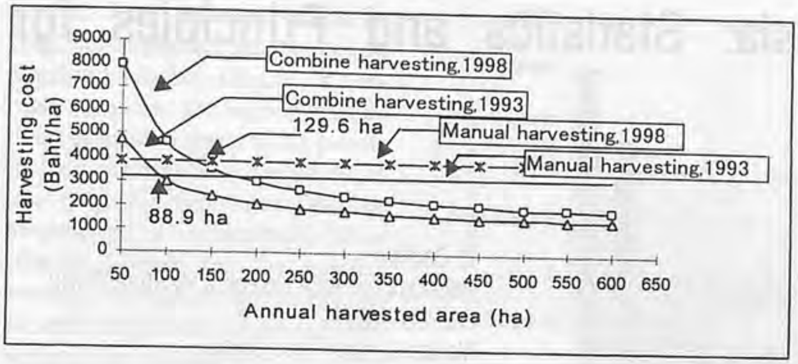


Fig.7 Relationship between cost of harvesting and annual use of the machine.

basic information regarding the cost of machine and labor rates **(Fig. 7)**. The cost of manual harvesting will increase in direct proportion to the rise in wage rates. The cost of harvesting using rice combine harvester breaks even at 89ha and 130ha/yr for a manual contract rate of Baht 3,200 and 3,860 Bht/ha, in 1993 and 1998, respectively.

Suggestions for Improvement

Based on the field observations, the following suggestions made for a more efficient harvesting operation:

1. The speed of reel should be adjusted according to crop and field conditions.
2. To reduce problem of clogging of threshing drum the speed of feeding conveyor and the rotational speed of the threshing drum have to match so that clogging at the threshing drum can be minimized. The manufacturer may consider mounting the axial flow thresher longitudinally, as this might solve the problem.
3. The suspension system of operator's seat needs to be modified to reduce fatigue due to vibrations of the machine.
4. The manufacturer should pay more attention to the safety of the operator, particularly while making adjustments. Covers for all moving parts such as belts and pulleys should be provided. Gauge and warning indicators such as for fuel and temperature should be provided.
5. The wooden tracks should be replaced by other suitable material as these do not last long.
6. A cab should be provided to reduce noise from engine and dust from the rear of machine causing fatigue and discomfort to the operator.
7. Tests should be conducted to determine the power requirement of various systems of the rice combine harvester to find the possibility of reducing the size or type of the prime mover to optimize the machine cost.

Conclusions

Based on studies conducted on locally made rice combine harvesters in Thailand the following conclusions can be drawn:

1. The Thai-made rice combine harvesters had frequent breakdowns in their chain conveyor, sprocket and chain transmission and final drive. The threshing cylinder was clogged by the rice crop frequently and there were frequent bending of the reel fingers.
2. The average effective field capacity of the machine in 1993 was 0.40, 0.35 and 0.42 ha/h for the two gear boxes (145 hp), two gear boxes (100 hp) and three gear boxes (100 hp), respectively. The average field efficiency for those combine harvester was 71, 71 and 52%, respectively. The average effective field capacity of the machine in 1998 was 0.53 ha/h and the average field efficiency was 83%.
3. The average total grain losses of the rice combine harvesters in 1993 were 4.8, 5.1 and 5.4% of the total grain yield for the two gear boxes (145 hp), two gear boxes (100 hp) and three gear boxes (100 hp) rice combine harvester, respectively. The average total grain loss of 195 hp machine in 1998 was 2.7% of the total grain yield.
4. Based on the annual use of 1,000 hours, the average cost of harvesting with a 145 hp rice combine harvester (purchase price of 680,000 Bht) in 1993 was estimated to be Bht 1,600/ha and Bht1,920/ha for a 195 hp machine (purchase price 1,500,000 Bht) in 1998. The cost of manual harvesting of rice were Bht 3,200/ha and Bht 3,860/ha in 1993 and 1998, respectively. The machines had the break-even area at 89 ha/year and 130 ha/year in 1993 and 1998, respectively.

REFERENCES

Hunt, D. (1983). Farm Power and Machinery Management, áXáVth ed., The Iowa State University Press, Ames, Iowa, USA.

Kalsirisilp, R., (1993). Performance Evaluation of a Thai-made Rice Combine Harvester Unpublished M.Eng. Thesis, AIT, Bangkok, Thailand

Krishnaserine, S., Thongsawatwong, P., Kiatiwat, T and T. Nakkua (1991). Development and Dissemination of a Rice Combine Harvester in Thailand. A paper presented at the 14th ASEAN Seminar on Grain Post Harvest Technology, Holiday Inn, Roxas Boulevard, Metro Manila, Philippines. 5-8 November 1991. ■■

Mechanization in Asia: Statistics and Principles for Success

by
M.A. Bell
International Rice research Institute (IRRI)
P.O. Box 3127,
Makati Central Post Office
(MCPO) 1271 Makati City,
Philippines

P. Cedillo
International Rice research Institute (IRRI)
P.O. Box 3127,
Makati Central Post Office
(MCPO) 1271 Makati City,
Philippines

Abstract

Successful mechanization and modernization of rice production in Asia will involve the concerted efforts of various players in both the private and public sectors. This paper provides a general framework for determining demand for mechanization in the region and identifies key points to consider in the process.

Patterns of Mechanization Shifts

With rising populations and growing economies, there is a growing demand throughout Asia for increased mechanization, especially in rice production. Such growth offers opportunities and challenges to both the public and private sectors to ensure that appropriate development paths are taken (e.g., Clarke, 1997). While the general patterns of mechanization shifts are known (**Tables 1** and **2**), the appropriate shift depends upon the socio-economic circumstances of the farmer. It is also important to note that each technology shift has implications for management of the system. For example, the adoption of combine harvesting can have significant implications for infrastructure development, field water management, field size and grain handling systems.

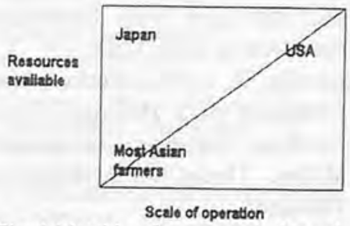


Fig. 1 Matching farmer needs depends on the levels of available resources and scale of operation.

The first challenge in identifying appropriate mechanization is to identify the true needs of the target community. For example, although the need may be for improved land preparation options, the level of socio-economic development will determine what constitutes a viable option. **Table 3** gives some additional examples on how technologies can differ for different levels of mechanization. For example, in terms of mechanizing land preparation, the solution may be an improved implement for existing animal power systems, a hand tractor or a four-wheel tractor. Thus, the level of development and farming system must be correctly identified. **Figure 1** demonstrates a conceptual framework for the different scales of production and resource availability. Typically, most Asian farmers are in the lower left hand corner (small scale, few resources), farmers of countries like the Rep. of Korea (ROK) and Japan would be in the top left hand corner (small scale, many resources) while farmers in Australia and the USA are in the top right hand corner (large scale, relatively many resources). Overlaid on this scheme is the emerging role of contractors in the region. Examples include contract threshing services within the Philippines and land preparation services for resource poor farmers of NE Thailand. These Thai farmers do not have resources to own 4-wheel tractors but regularly contract the service from private tractor operators.

Table 1. General pattern of mechanization adoption in Asia (In part from Khan, 1996)

Water management - hand pumping to machine
Land preparation - hand and animal tractor to hand tractor
Threshing - hand threshing to mechanical threshing
Milling - hand and Engleberg milling to rubber roll
Crop establishment - Hand transplanting
Harvesting - hand cutting and hauling to reaping to combine harvesting

A Statistical Overview of the Region.

Population and economic statistics for Asia can be used to help identify appropriate interventions for the different countries. For example, while the peoples' Rep. of China (PRC) has the largest total population of the different countries **(Fig.2)**, Bangladesh has the highest population density **(Fig.3)**. In contrast, Japan has the highest productivity demand in terms of the people to feed per available arable ha of land **(Fig.4)**. When we consider the abundance of agricultural labor **(Fig.5)**, Bhutan has the greatest number of workers per arable ha. In terms of present levels of mechanization as indicated by the number of tractors per arable ha, Japan is well in front **(Fig.6)**. (**Figure 6** would be better if expressed in terms of machine HP per ha, but such data could not be found for all the countries involved in the comparison.) If we also overlay the classifications of Hossain (1996) on factors such as the adoption of mechanized transplanting, direct seeding and use of chemical inputs, then we get an additional picture of the relative levels of mechanization throughout the region **(Table 4)**.

If we now take gross domestic product per capita (GDPPC) **(Fig.7)** as an indicator of economic development and compare it with the abundance of agricultural labor, then we have a general indication for each country of what may presently be an appropriate level of mechanization **(Fig.8)**; acknowledging that the GDPPC and agricultural labor are somewhat interrelated. For example, countries with few agricultural workers and well developed economies (right hand lower corner) are highly mechanized. Countries with abundant labor and low GDPPC will require a different focus for mechanization - the focus being perhaps improving existing systems rather then shifting to a higher level of mechanization. Other countries such as Cambodia with abundant land and relatively scarce labor supplies are seeing the emergence of contractors (e.g., for land preparation) to help meet demand, even though the overall GDPPC is relatively low.

It should be noted that the num-

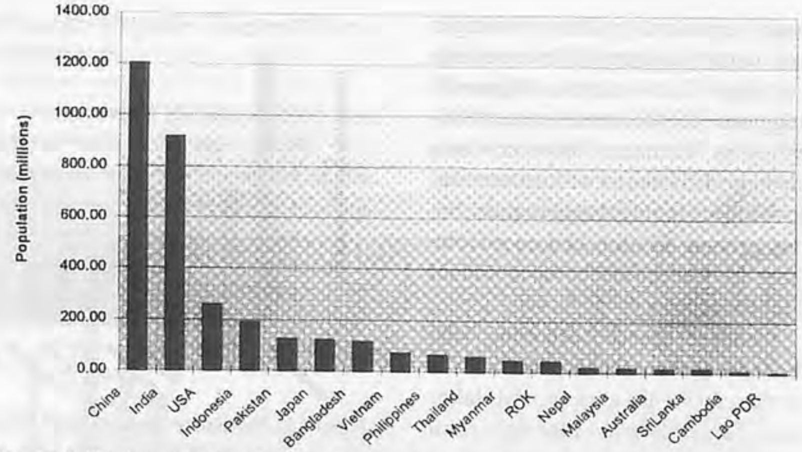


Figure 2. Total population of major rice growing countries in Asia (plus USA and Australia) .

Table 2. System and component technology changes expected in rice production systems of Asia

Factor	System changes: Subsistence to Semi-commercial to Commercial		
Production shifts			
Land preparation	Hand	Animal & 2-wheel tractor (puddling)	4-wheel tractor/reduced tillage/precision leveling
Germplasm	Current germplasm/ traditional varieties	Germplasm with improved nutrient use efficiency yield potential stress tolerance grain quality	
	Poor seed	Certified/clean seed	
Crop establishment	Manual transplanting	Direct seeding, mechanized transplanting	
Water management	Hand pump	Motor pumps	
	Flood irrigation		Reduced irrigation (precision leveling)
Pest control	Manual weed control	fixed herbicide spray regime	integrated weed management (incl. herbicides)
	Spray insects on sight	calendar spray applications	integrated pest management
Nutrient management	Manure applications	blanket nutrient management	site-specific nutrient management
Post-production shifts			
Harvesting	Manual harvesting cut & haul		combine harvesting
Threshing	Manual threshing/ animal treading	portable threshers	combine harvesting
Handling and storage	Bag handling & storage		bulk handling & storage
Drying	Sun drying		commercial drying
Milling	Hand	Small mills	commercial mills
Byproduct use	Byproduct waste		Byproduct useóadding value
System changes	Monoculture		diversified systems
	Small farms/fields		larger farms/fields
	Government extension services		contract supply & extension services
	Subsistence or local market		commercial market specialized quality rice & products markets(adding value)
	Lack of concern for the environment		public & legislative environmental concern

bers represent country averages and within country differences can be large. For example, **Figure 8** suggests little demand for mechanization in Vietnam. However, there are large differences within the country with mechanization demands being greater in the Mekong Delta than in the more labor-abundant Red River area.

Another factor affecting the demand for mechanization in rice is the shifts in agricultural labor use. For example, although rural labor in many countries is decreasing in percentage terms, it is in fact remaining fairly constant in absolute terms. Nonetheless, labor shortages are being seen even in countries such as Bangladesh because as the economies develop, there is greater demand for alternate crops such as vegetables and fruits. Such activities typically pay more and so labor, although remaining within the rural sector, is being drawn away from rice to other more lucrative rural activities.

Principles of Market Development

With the above background, the demand for mechanization can begin to be segmented, based on economic development and rural labor abundance. Once the needs are appropriately identified, the public and private sectors need to determine their appropriate response to the various needs. While the public sector is primarily about identifying technologies and developing technologies to meet needs, the private sector has a critical role to provide the hardware to their target groups which include both farmers and contractors. For the local and foreign private sector to gain market share effectively, a number of simple principles should be considered, namely:

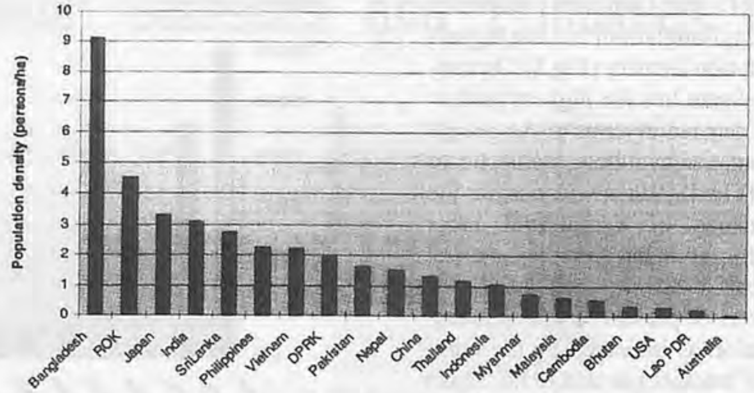


Figure 3. Population density (total population/total land area) of major rice growing countries in Asia (plus USA and Australia).

Table 3. Levels of mechanization technology for different operations

Function or operation	Level of mechanization technology[a] Hand tool	Draft animal	Mechanical power
Land clearing	Brush hook, hand saw, motor chain saw	Buffalo and elephant for skidding and loading	Track-type tractor for clearing, skidders for log transport
Land development	Spade, hoe, basket, wheelbarrow	Earth scoop, leveling scraper, bund former	Wheel tractor, track-type dozer, motor scraper
Land preparation	Hoe, spade	Wooden plow, steel plow, spike harrow, disk harrow	Single-axle tractor, power tiller, two-axle tractor with various implements
Planting or seeding	Seed distribution by hand, plant stick, jabber,row marker, hand-pushedseeder	Furrow opener, marker wheel for dibbling, seed drill, seed-cum-fertilizer drill	Tractor seed drill, seeding with aircraft
Transplanting	Hand-operated paddy transplanter		Motorized paddy transplanter
Harvesting	Finger-held knife, sickle, scythe, threshing table, pedal thresher	Peanut lifter, cutter-bar mower, reaper, reaper-binder, treading (threshing)	Power reaper, power reaper-binder, power thresher, combine harvester
Crop husbandry	Hoe, weeding hoe, hand sprayer, water can, irrigation scoop	Wooden interrow weeder, walking-type tool carrier, riding-type tool carrier, spraying machine, Persian water wheel	Interrow weeder, motor knapsack sprayer, tractor boom sprayer spraying with aircraft,diesel or electric irrigation pumps
On- farm processing	Mortar and pestle, flour-grindin stone, hand-operated paddy husker	Animal-powered sugarcane crusher, power gear for driving processing machinery	Single-pass rice mill, rubber-roll rice mill, hammer mill
Crop storage	Sun-drying, bag storage		Artificial drying, bulk storage, elevator, fork lift
Handling	Carrying, wheelbarrow, push cart		
Rural transport	Porter, push cart, rickshaw	Sled, pack harness, bullock cart	Power tiller with trailer, two-axle tractor with trailer,track

[a]Within each operation, the level of sophistication increases vertically.
Source: Rijk 1986

1. Complexity of equipment - Will local users be able to use it effectively?

For example, complex equipment suited for quality-seeking well-educated Japanese farmers may be unsuited for use by farmers in other areas. Cost, complexity and quality have to be weighed against local needs and purchasing abilities.

2. After sales service - Will back-up in terms of service, and spare parts be available?
   Inappropriate use or lack of spare parts quickly leads to equipment lying idle and thus getting a "bad" name.
3. Substitution - Can the equipment be serviced by local industry and/or can parts be substituted by locally available alternates? Decreasing down time and maximizing use are musts.
4. Cost and competition - Who else is out there at what price and with what quality?
   In the Asian arena, there are a number of key players. In particular Korea, (ROK), Japan, and China for many items are in competition with various local manufacturers.
5. Suitability for local conditions - What type of equipment will actually suit the agronomic and socio-economic conditions of the target area? A piece of equipment that works quite adequately in one country may not suite the needs of a different clientele. A typical example of this is combine harvesting - combines vary significantly in terms of their mobility in muddy conditions, their field capacities and costs.
6. Other system characteristics - What is the availability of credit, role of subsidies, role of contractors and government policy?

All these factors need to be considered, as any single factor can cause a mechanization venture to collapse. Clarke (1997) outlines in greater detail these and other useful considerations required in considering and developing a mechanization approach.

Public-Private Sector Partnerships

Appropriate mechanization will require the concerted efforts of a range of players. In particular, the agricultural engineers have a significant role to play. In a recent think-tank held at the International Rice Research Institute (Bell et al, 1998), a number of key recommendations were generated aimed at increasing the impact of engineering in agricultural and rural devel-

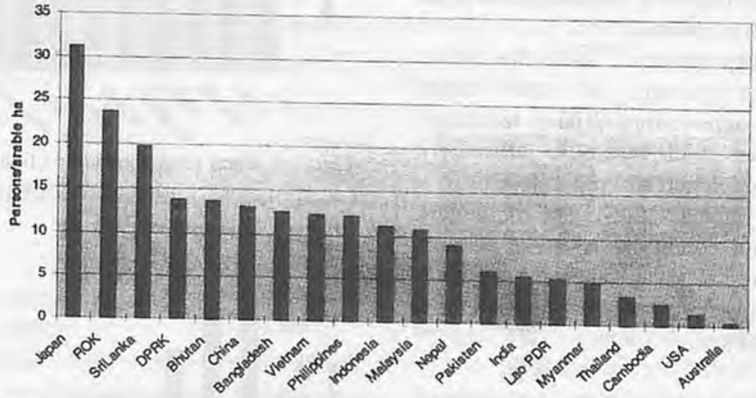


Figure 4. Productivity demand (i.e., total population/total arable land) of major rice growing countries in Asia (plus USA and Australia).

Table 4. Adoption of herbicides and direct seeding, and pesticide use ha-1 for different countries in Asia. (Countries are listed by level of tractor mechanization **(Fig. 6)** within economic grouping

Country	Herbicide use[b]	Direct seeding[b]	Pesticide use[c] (US$ha^{-1})
Group 1. High income, self-reliant			
Japan	>100% herbicide	<0.5% (mech. transpl.)	775.80
Korea, Rep.	75-100%	10% (mech. transpl.)[d]	361.90
Malaysia	?	>60%	
Taiwan	>90%	Very little (mech. transpl.)	>57.10
Group 2. Excess rice production capacity			
Thailand	80% in direct seeded 10% in transplanted	30-40%	5.50
Myanmar		>50% in dry season	3.20
Lao PDR	Very little	?	
Cambodia	Very little	?	
Group 3. Risk of food insecurity			
Sri Lanka	Common[e]	>80%[e]	
Pakistan	?	Very little	
China	30-40%	5-10%	9.50
India 4.90	Limited in northeast and south		30%[g]
	Popular in other areas	30%[g]	
Indonesia	>25%	<5%	9.50
Philippines	>50%	>30% in dry season	8.00
Nepal	Very little	<10%[f]	
Vietnam			5.90
Mekong Delta	Widely used	>94%[h]	
North	Limited	20%	
Bangladesh	Hand weeding	Transplanting	2.10
Bhutan	Hand weeding	Transplanting	

[a] Data from FAO (1996)-these figures make no allowance for differences in hp.
[b] Data from Naylor (1996)-obviously these figures can change dramatically.
[c] Herbicide, insecticide, and fungicide data from Wood Mackenzie Consultants Ltd., London.
[d] Data from Lim et al (1991) and J.K. Kim (pers. commun.).
[e] Data from Pathinayake et al (1991).
[f] Estimates from P. Hobbs (pers. commun.).
[g] Mostly in rainfed upland and some deepwater environments (R.K. Singh, pers. commun.).
[h] Mekong Delta produces >50% rice.
[i] Estimates from T. Tuong (pers. commun.)

opment. The key points were that an integrated, participatory systems approach was required as follows:

1. Integrated across research disciplines and sectors. In particular, the private and public sectors should be working to bring their comparative advantages to bear on problems.
2. Participatory - with the active involvement of the target groups, appropriate technologies will be more efficiently developed and promoted.
3. Systems - the range of players and conditions must be considered to ensure that any technology promoted fits with the entire system.

By appreciating the true needs of the target clientele and the socio-economic characteristics of the production system, mechanization can be facilitated to help improve the range of options available to improve the livelihoods of Asia's farmers.

Labor Displacement

Finally, it is important to consider the concerns that arise over labor displacement in relation to mechanization. In reality, despite these necessary concerns, mechanization rarely leads to labor displacement. Typically, mechanization is only one of many factors changing in response to shifts in economies. Thus, if left to market forces, labor prices will rise as alternate labor markets (e.g., industry, commerce) develop. Thus, the lack of labor due to the development of alternate employment opportunities typically drives the need for mechanization. Thus, any government programs on mechanization and modernization must consider the socio-economic setting. It is critical for mechanization to be viewed in a more holistic approach - i.e., as one of many system changes that can occur, but which can specifically reduce drudgery, provide farmers with options and thus enhance their livelihoods.

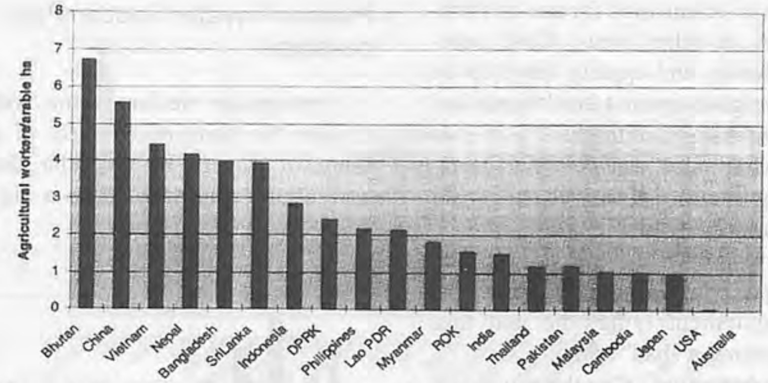


Figure 5. Rural labor abundance (Total number of Agricultural workers/total arable land area) of major rice growing countries in Asia (plus USA and Australia).

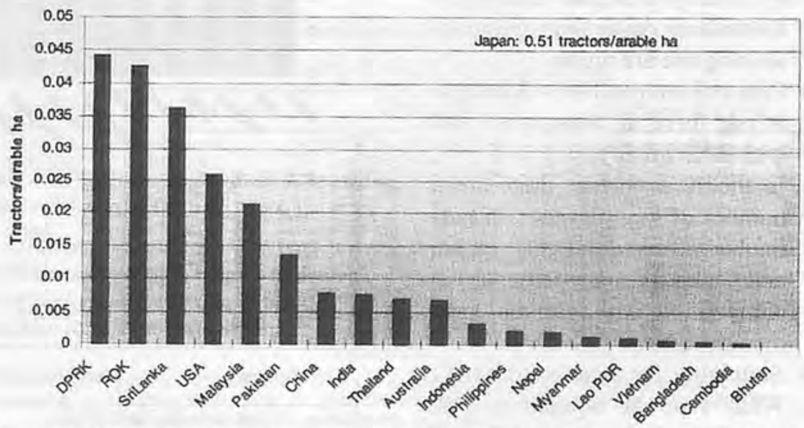


Figure 6. Tractor abundance (tractors/total arable land area) as a measure of mechanization of major rice growing countries in Asia (plus USA and Australia).

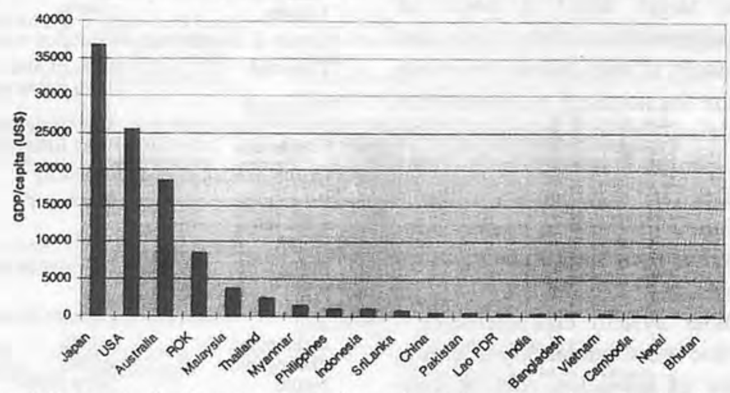


Figure 7. Economic development (gross domestic product per capita) of major rice growing countries in Asia (plus USA and Australia) .

REFERENCES

Bell, M.A., Dawe, D. and Douthwaite, M.B, editors. 1998. Increasing the impact of engineering in agricultural and rural development. Deliberations of a think tank, 26-28 February, 1998, IRRI, Los Banos, Philippines. IRRI Discussion Paper Series No. 30. Manila (Philippines): International Rice Research Institute. 108 pp.

Clarke LJ. 1997. Agricultural mechanization strategy formulation concepts and methodology and the roles of the private sector and government. Agricultural Engineering Branch, Agricultural Support Systems Division, FAO, Rome, Italy.
FAO (Food and Agriculture Organization). 1996. FAO yearbook 1995. Vol. 49. Rome: FAO.
Hossain M. 1996. Recent developments in the Asian rice economy: challenges for rice research. In: Evenson RE, Herdt RW, Hossain M, editors. Rice research in Asia: progress and priorities. CAB International in association with the International Rice Research Institute. p 17-33.
Huke RE, Huke EH. 1997. Rice area by type of culture: South, Southeast, and East Asia. A revised and updated database. Manila (Philippines): International Rice Research Institute.
IRRI (International Rice Research Institute). 1986. Small farm equipment for developing countries. Proceedings of the International Conference on Small Farm Equipment for Developing Countries: Past Experiences and Future Priorities, 2-6 Sept 1985. Sponsored by USAID and IRRI.
IRRI (International Rice Research Institute). 1989. Rice farming systems: new directions. Proceedings of an International Symposium, 31 Jan-3 Feb 1987. Rice Research and Training Center, Sakha, Egypt.
IRRI (International Rice Research Institute). 1995a. World rice statistics 1993-94. Manila (Philippines): IRRI.
IRRI (International Rice Research Institute). 1995b. Program report for 1994. Manila (Philippines): IRRI.
IRRI (International Rice Research Institute). 1997. Sustaining food security beyond the year 2000: a global partnership for rice

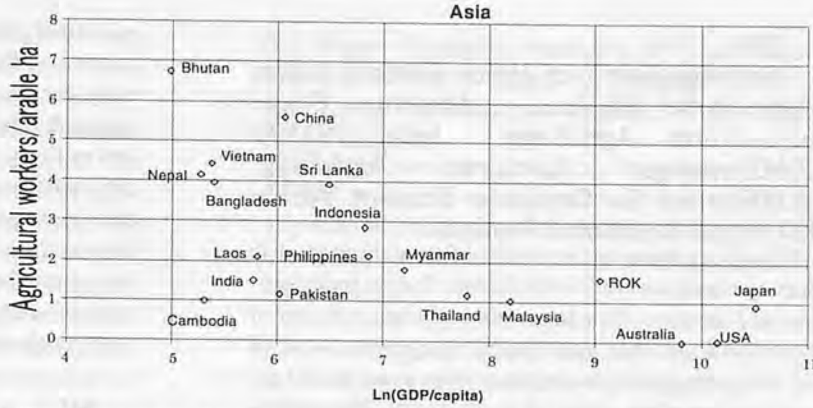


Figure 8. Present mechanization potential as determined by the relationship between rural labor abundance (total number of agricultural workers/total arable land) versus economic development (Ln[gross domestic product per capita]) of major rice growing countries in Asia (plus USA and Australia).

research. Manila (Philippines): IRRI.
Khan AU. 1996. Agricultural mechanization and machinery production in Bangladesh. Report prepared for Agrobased Industries and Technology Development Project (ATDP).
Lim MS, Yun YD, Lee CW, Kim SC, Lee SK, Chung GS. 1991. Research and prospects of direct seeded rice in Korea. In: Direct seeded flooded rice in the tropics. International Rice Research Conference, 27-31 Aug 1990, Seoul, Korea. Manila (Philippines): International Rice Research Institute.
Naylor R. 1996. Herbicide use in Asian rice production: perspectives from economics, ecology, and the agricultural sciences. In: Naylor R, editor. Herbicides in Asian rice: transitions in weed management. Palo Alto, Calif. (USA): Institute for International Studies, Stanford University, and Manila (Philippines): International Rice Research Institute.
Pathinayake BD, Nugaliyadde L, Sandanayake CA. 1991. Direct seeding practices for rice in Sri Lanka. In: Direct seeded flooded rice in the tropics. International Rice Research Conference, 27-31 Aug 1990, Seoul, Korea. Manila (Philippines): International Rice Research Institute.
Pingali PL, Hossain M, Gerpacio RV. 1997. Asian rice bowls: the returning crisis? CAB International and International Rice Research Institute.
Pinstrup-Andersen P, Pandya-Lorch R, Rosegrant M. 1997. The world food situation: recent developments, emerging issues, and long-term prospects. Presentation at the Consultative Group on International Agricultural Research, International Centers Week, Washington, D.C., 27 Oct 1997.
Rijk AG. 1986. The role of farm mechanization in developing countries: experiences in Asian countries. In: Small farm equipment for developing countries. Proceedings of the International Conference on Small Farm Equipment for Developing Countries: Past Experiences and Future Priorities, 2-6 Sept 1985. Sponsored by USAID and IRRI.
Wailes EJ, Cramer GL, Chavez EC. 1995. Arkansas global rice model: international baseline projections for 1995. Fayetteville, Ark. (USA): Arkansas Agricultural Experiment Station.

■■

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.

733

Anthropometry of North Eastern Indian Agricultural Workers : Niranhan Prasad,Lecturer Agril.Engg. India 791109 ,K.N.Dewangan Lecturer Agril.Engg. ,A.N.Pandey Ex-Graduate Student ,NERIST,Nirjuli Arunachal Pradesh.

This paper presents the results of an anthropometric survey conducted on North Eastern Indian male agricultural workers. The data were collected as a part of a project to modify agricultural equipment. A set of 35 body dimensions were taken from a sample 50 agricultural workers (aged 18 to 50 years). The anthropometric measurements are compared with those of India men from Central, Western, Northern, Eastern and Southern part of India and with those of the American, German and Japanese men. The results indicate that,in general, the North Eastern man is smaller than the Northern and Western as well as smaller than men in America, Germany and Japan.

738

Mechanized Rice Farming in Pakistan: Abdul Razzag Senior Subject Matter Specialist (Enngg:)Adaptive Research Farm,Sheikhupura,Pakistan.

Rice is one of the major summer monsoon food crops in Pakistan. Being the second largest foreign exchange earner, it is a very important commodity for the national economy. It is a crop of irrigated area and grown on about 10% of the total cultivated land. Transplanting is the dominant practice in rice culture in the country. Direct seeding is also practiced but in limited scale. The adoption of site specific technology package consisting of a suitable bio-hydra-chemical-mechanical combination is a must for proper plant growth and carrying out profitable crop production. Broadly speaking,technology is of two kinds; mechanical and non-mechanical. Non-mechanical technology brings about radical changes. Mechanical technology on the other hand assists in achieving the ultimate objectives precisely and efficiently. This paper describes mechanical aspect of rice cultivation, its pros and cons and level of adoption in Pakistan.

742

Analytical and Experimental Investigation of Tractor Seat-Operator System: Niranjan Prasad,Lecturer,Agril.Engg.Dept., Nerist, NIrjuli-791199 Arunachal Pradesh, India, V.K. Tewari, Associate Professor Agril. & Food Engg. Dept. I.I.T. , Kharagpur-721302 , W.B. , India

An analytical model for a seat suspension system is presented in this paper. The model could be employed as a tool in the selection of optimal suspension parameters for the suspension systems used in different types of vehicles. Agricultural tractors, buses, trucks and military vehicles. The response characteristics of the model using computer simulation technique has also been made. The influence of supension parameters on the vibration transmissibility performance of the seat to the operator could be easily estimated. The analytical approach has been validated and compared with results obtained in laboratory simulation studies.

745

Combined Forecasting Method of Grain Yield : Yuan Quan, Postgraduate University Hangzhou, Zhejiang 310029 P.R.China Agric. Engineering Dept.. Zhejiang Agric.University Hangzhou, Zhejiang 310029 P.R.China and He Yong Professor and Head, Agric. Engineering Dept.. Zhejiang Agric. University Hangzhou, Zhejiang 310029 P.R.China.

This paper introduced the combined forecasting method used to forecast the grain yield in the Zhejiang Province of P.R.China. The performance of this method was analyzed and the optimum -weight coefficients were obtained by the linear programming model and the results were discussed .Grain yield is usually affected by climate, environment , pests and other factors . The value changes and fluctuates every year. A study of the nature these changes is necessary to forecast the future trend in order to make planning and decisions properly. Combined forecasting is a new method using two or several different forecasting models to forecast the same object and weighting all the results to obtain the optimum average as the final results. This method is active in recent years. It contains useful message of every single method, having the adaptability to the future changes, reducing the forecasting risks and improving the forecasting precision. The main problem is to obtain the weight of each single method. Using different methods to obtain the weights, we can obtain different forecasting models. In this paper, the linear programming method was used to obtain the optimum weights and to forecast grain yield in Zhejiang Province. By this example, the advantage of this method was shown clearly.

757

A Diagram Proposed for Evaluation of Soil Dispigrsivity: H.Rahimi, Associate professor, Tehran University, Iran , M,Delfi, Graduate Student, Tehran University, Iran .

The evaluation of soil dispersal has been of interest to researchers for last the three decades. Different methods have been proposed for this purpose. These methods include three tests : physical test or crumb, double hydrometer and pin-hole tests and a chemical test one based on dissolved salts of pure water. The chemical method was proposed by Sherard et al in the mid-eighties, and dispersal is evaluated using the amounts of total dissolved salts and percent sodium of saturated extract of the soil using a special diagram. Regarding the use of the diagram, different contradictory results have been reported. In a recent geotechnical studies of a major project in South-West plains of Iran, the same problem has been observed. A detailed study was made to evaluate the Sherard's chemical method, specially for saline soils of the Khoozestan plain in South-West of Iran. Based on the results obtained, it was found that the Sherard's diagram in the present form is not valid for Khoozestan's soils. To overcome the problem, a new diagram was proposed, considering the effects of EC and pH on concentration and quality of dissolved salts in saturated extract of the soils. Also the effect of leaching in changing the dispersal potential (due to a reduction in dissolved salts concentration) has been studied. It is recommended to considered the phenomena even in other methods, such as pin-hole test. The method was applied to more than two hundred samples taken from the area, and found complete validation with no exception.

768
Approapriate Technology for Rural Women in Nigeria: **A.J.Akor, M.J. Ayotamuno, Agricultural Engineering Department , G.K. Ngeri-Nwagha, Institute of Foundation Studies , Rivers State University of Science and Technology Nkpolu, Port Harcourt Nigeria.**

This paper presents the results of research work carried out in Nigeria to obtain data on women and appropriate technology in that country with a view to identifying problems and recommending necessary improvement.

The results of the survey reveals that the production technologies available for rural women in Nigeria have remained basically unchanged from the traditional technologies over the years.

Most rural women can't afford simple labour-saving domestic and agricultural tools aside from hoe, knife and machete. Technological development in Nigeria is based on the needs of men.

The paper reveals further hat there is need to unify and integrate the extension services to serve all farmers, bringing in rural women into the mainstream. Rural women should be protected from the exploitation of the men folk who leave the tedious, back-breaking task for women and quickly jump in to take over technologically simplified task.

Deliberate efforts should be made by those concerned to provide rural women will adequate resources and controls so that they can take charge of their lives, reducing their dependency on men.

More should be done in the area of providing all-weather roads, education for girls, the design and development of appropriate machine and equipment for women. ■■

THE XIV Memorial CIGR World Congress 2000
November 28-December 1,2000
Tsukuba,Japan

The Japan Association of International Commission of Agricultural Engineering(JAICAE) will organize THE XIV MEMORIAL CIGR WORLD CONGRESS in Tsukuba on November 28-December 1, 2000 with the help of local arrangement by the University of Tsukuba.

JAICAE, associated by 11 academic societies regarding agricultural engineering in Japan, namely; Japanese Society of Irrigation, Drainage and Reclamation Engineering (JSIDRE), Japanese Society of Agricultural Machinery (JSAM), Society of Agricultural Meteorology of Japan (SAMJ), Japan Association of Agricultural Electrification (JAAE), Japanese Society of Environment Control in Biology (JSECB), Japanese Society of Farm Work Research (JSFWR), Society Of Agricultural Structures of Japan (SASJ), Association of Rural Planning (ARP), Japanese Society of Closed Environmental Life Support Systems (CELSS), Japanese Society of High Technology in Agriculture (SHITA) and Japanese Society of Agricultural Informatics (JSAI), has been the official representative of Japan within CIGR for these years. Further, Science Council of Japan (SCJ) has joined CIGR as the National Member Organization since 1995. Therefore the Congress is now sponsored by Science Council of Japan as well as CIGR, based on the scheme of the special Congress emphasized on 70th year-celebration.

Thus, JAICAE sponsored by CIGR and SCJ, would like to encourage papers in two emphasized technical areas in addition to regular topics based on Section I-VI. One area is Global Agriculture in 21st century which will include agricultural engineering mainly regarding irrigation and drainage in the rice field. Another area is New Agricultural Technology in 21st century which will include new agricultural engineering regarding environmental controlled life support systems, namely the future engineering both for Animal Production and for Plant Factory, and Informatics for computer-network using of agricultural data base and knowledge base.

Scientific Secretariat

Prof.Y.Seo(Chairman), Prof.S.Oshita(Secretary)
Department of Biological and Environmental Engineering Graduate School of Agricultural and Life Sciences,
The University of Tokyo,
Yayoi,1-1-1,Bunkyo-ku,Tokyo 113-8657,Japan
Fax:+81-3-5841-8174
E-mail:
aoshita@hongo.ecc.u-tokyo.ac.jp

Local Arrangements

For more information on local arrangements, please contact the following persons:
Secretariat:Prof. T.Maekawa(Chariman),Prof. T.Satake(Secretary)
Institurte of Tsukuba
Tennodai 1-1-1,Tsukuba 305-8572,Japan
Fax:+81-298-55-2203
E-mail:
satake@sakura.cc.tsukuba.ac.jp

General Information

Final date of Abstract submission: 31st December 1999 (average number of words should be about 500 words on A4 paper).

The annoucement of the result of the reviewed Abstract is February 2000.

Mailing of final annoucement is May 2000.

Final date of submission of Full Paper is June 2000.

Additional information on the Congress site maps, and updates on the scientific programs will be available through the World Wide Web.
URL:http://bee2.en.a.u-tokyo.ac.jp/cigr2000/

Hohenheim M.Sc. Programme Agricultural Sciences, Food Security and Natural Resource Management in the Tropics and Subtropics

Facing the challenges of international competition the University of Hohenheim has introduced an M.Sc. Programme which combines the sectors of agriculture, nutrition and natural resources in an integrative approach. The programme is taught entirely in English and has a duration of 2 years. The successful completion will lead to the Master-of-Science degree.

The course consists of a highly flexible system of interdisciplinary modules which have been designed with regard to the requirements of the international agricultural sector. Accordingly, teaching focuses on the development of skills, methodologies and principles rather than on the accumulation of information. Guest lecturers from partner institutions are actively involved. In addition, the course includes scope for an integrated stay abroad so that a high level of international input and insight forms an essential part of the programme.

Admission will be granted to 40 students a year. Applicants require a B.Sc. or equivalent degree and proof of English proficiency. For candidates accepted on the programme, tuition fees will be covered by the regional authority so that they will only have to finance their own living expenses.

For further information please contact

The Programme Manager, Cen-

tre for Agriculture in the Tropics and Subtropics, University of Hohenheim, 70593 Stuttgart, Germany
e-mail:
masterpr@uni-hohenheim.de
or visit our Web Site:
http//www.uni-hohenheim.de/~zsb/Tropical_Agriculture.htm

CIGR World Congresses

2002--Chicago, USA, joint with ASAE, July 28-August 1,for information contact Ms.Melissa Moore(moore@asae.org).
2006--Proposals are now being accepted, for information contact the CIGR General Secretariat(CIGR@uni-bonn.de).
URL:http://www.ucd.ie./cigr/

CIGR Section Symposia

2001--Campinas, SP, Brazil, September 5-7, "AgriBuilding 2001 Int'l Symposium of Agricultural Buildings", contact: e-mail: cigr@cnpsa. embrapa. br

2000--Budapest, Hungary, April 9-15, "International Conference on Rational Use of Renewable Energy Sources in Agriculture"

2001--Bogor, Indonesia, contact Dr. A. Kamaruddin, Institut Pertanian Bogor (crea-ipb@indo-net.id).

ISHS MECHANIZATION of VEGETABLE PRODUCTION 2ND ISHS-Symposium in conjunction with the VDI-MEG-Colloquium

June 14-16, 2000
University of Bonn,Germany

Conference Background of Objects

The theme of symposium is the mechanization of field production of vegetables. Precondition of any economical and ecological crop production is an optimized technology of crop installment with minimized losses on energy, seed,plants, fertilizer, and marketable products. Problems concerning the areas of seed quality,plant propagation, drilling /precision seeding will be covered.

Further Informations
Secretariat of ISHS Symposium
c/o Institut fur Landtechnik
Nussallee 5, D-53115 Bonn
Tel :0049-228-732395
Fax:0049-228-732596
E-mail:landtechnik@uni-bonn.de
URL:http://www.landtechnik.uni-bonn.de

4th International Conference on Soil Dynamics(ICSD-Ⅳ) IAMA

March 26-30, 2000
University of South Australia Adelaide, South Australia

URL:http://www.unisa.edu.au/icsd-iv/index.htm

PLAST CULTURE 2000 29th National Agricultural Plastics Congress and the International Congress for Plastics in Agriculture

September 23-27, 2000
Hershey Lodge & Convention Center
Hershey, Pennsylvania, USA

More Information
As planning continues, more details will be available on the A.S.P. website:
http://www.plasticculture.org

AGENG WARWICK 2000 PLAST CULTURE 2000 29th National Agricultural Plastics Congress and the International Congress for Plastics in Agriculture

July 2-7, 2000
University of Warwick,UK

Conference Information

For general information and inclusion on ou mailing list, contact Caroline Lissaman, Royal Agricultural Society of England, Stoneleigh Park, Warwickshire, CV8 2LZ, United Kingdom
Fax:+44-1203-696900
E-mail:caroline@rase.org.uk

For more information on the scientific programme of the conference,please contact
AgEng 2000Sientific Secretariat, Mrs. Liz Field,
Silsoe Research Institute, Wrest Park,Silsoe,Bedford,MK45 4HS,UK
Tel:+44-1525-860000
Fax::+44-1525-860156
E-mail:ag.eng@bbsrc.ac.uk
URL:http://www.rase.org.uk

AETC 2000 Agricultural Equipment Technology conference 2000

February 23-25, 2000
Kansas City,Missouri,USA

Information Contact
Chuck Brundage,Conference Chair
AGCO Corporation
12423 W 101st Terrace,Lenexa, KS 66215
Tel :816-836-6382
Fax:816-836-6344
E-mail:chuck.brundage@ind.agcocorp.com

Brenda West or Sharon McKnight
ASAE Meeting & Conferences
2950 Niles Road, St. Joseph, MI49085-9659
Tel :616-429-0300
Fax:616-429-3852
E-mail:hq@asae.org ■■

Co-operating Editors


A K Mahapatra


F M Fonteh


E A Baryeh


A A K El behery


A M El Hossary


B S Pathak


D B Ampratwum


R J Bani


I K Djokoto


D K Some


K Houmy


J C Igbeka


E U-Odigboh


K C Oni


U B Bindir


N G Kuyembeh


A H Abdoun


A B Saeed


Surya Nath


A I Khatibu


S Tembo


H A Cengolo


I de A Naas


A E Ghaly


E J Hets


A A Valenzuela


R Aguirre


O Ulloa-Torres


H O Laurel


S G C Magana


W J Chancellor


M R Goyal


A L Philips


G R Quick


S M Farouk


M A Mazed


M Gurung


Wang Wanjun


A M Michael


T P Ojha


S R Verma


Soedjatmiko


M Behroozi-Lar


J Sakai


B A Snorbar


C J Chung


C C Lee


I Haffar


M Z Bardaie


M P Parriyar

Graeme R. Quick
Leader, Power & Machinery Section, 200 Davidson Hall, Agricultural and Biosystems Engineering Dept., Iowa State University, Ames, Iowa, 50011-3080 U.S.A.

-ASIA and OCEANIA-

Shah M. Farouk
Professor and Vice-Chanceller, Bangladesh Agricultural University, Mymensingh, 2202 Bangladesh

Mohammed A. Mazed
Director General, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh

Manbahadur Gurung
Natural Resource Training Institute, (Construction) Lobesa. P.O. Wangdiphodrang. Bhutan

Wang Wanjun
Senior Engineer of Chinese Academy of Agricultural Mechanization Sciences, Honorary President of Chinese Society of Agricultural Machinery, No. 1 Beishatan, Deshengmen Wai, Beiling, China

A.M. Michael
1/64, Vattekunnam, Methanam Road,Edappally North P.O., Cochin, 682024, Kerala State, S. India

T.P. Ojha
H.I.G.-30, Gautam Nagar, Bhopal 462 023,India

S.R. Verma
Prof. of Agricultural Engineering, College of Agril. Engg., Punjab Agricultural University, Ludhiana -141004, India

Soedjatmiko
Head of Subdirectorate of Agric. Engineering, Ministry of Agriculture, Jakarta, Indonesia

Mansoor Behroozi-Lar
President, Iranian Society of Agricultural Machinery Engineers, P.O. Box 31585-574, Karaj,Iran

Jun Sakai
Professor Emeritus, Dept. of Agric. Engineering. Faculty of Agriculture, Kyushu University 46-05, Hakozaki, Higashi-ku, Fukuoka 812,Japan (Mailing address: 31-1, Chihaya 2-chome, Higashi-ku, Fukuoka 813, Japan

Bassam A. Snobar
Vice President, Professor of Agricultural Engineering, Jordan University of Science & Technology, P.O. Box 3030 Irbid 22110,Jordan

Chang Joo Chung
Emeritus Professor, College of Agriculture and Life Sciences, Seoul National University, Suweon 441-744 Korea 103

Chul Choo Lee
Reserch Professor, Seoul Woman's University, Mailing Address: Rm. 514 Hyundate Goldentel Bid. 76-3 Kwang Jang Dong Ku,Seoul, Korea

Imad Haffar
Associate Professor of Agric. Mechanization, Faculty of Agricultural Sciences, United Arab Emirates University, Al Ain, P.O. Box 17555 UAE

Muhamad Zohadie Bardaie
Professor and Deputy Vice Chancellor (Development Affairs), Universiti Pertanian Malaysia, 43400 UPM, Serdang, Selangor, Darul Ehsan, Malaysia

Madan P. Pariyar
Consultant, Rural Development through Self-help Promotion Lamjung Project, German Technical Cooperation. P.O. Box 1457, Kathmandu, Nepal

ElTag Self Eldin
Mailling Address: Dept. of Agric. Mechanization, College of Agriculture, P.O. Box 32484, Al-Khod, Sultan Qaboos University, Muscat,Sultanate of Oman

Nawaf A. Abu-Khalaf
Engineer, the Project Directorate in Palestinian Agricultural Ministry, P.O.Box 405, Hebron, Palestine, Telfax: 972-2-2227846/7, E-mail: abukhalaf @ hebronet.com

Allah Ditta Chaudhry
Professor and Dean Faculty of Agric. Engineering and Technology, University of Agriculture, Faisalabad, Pakistan

A.Q.A. Mughal
Vice Chancellor, Sindh Agriculture University,Tandojam, Pakistan

Rafiq ur Rehman
Director, Agricultural Mechanization Reserch Institute, P.O. Box No. 416 Multan, Pakistan

Reynaldo M. Lantin
Interim Head, Agric. Engineering Div., International Rice Research Institute, P.O. Box 933, 1099 Manila, Philippines

Ricardo P. Venturina
President & General Manager, Rivelisa publishing House, 215 F. Angeles St. cor Taft Ave. Ext., 1300 Pasay City, Metro Manila,Philippines

Saleh Abdulrahman Al-suhaibani
Professor, Agricultural Engineering Dept.,College of Agriculture, King Saud University,P.O. Box 2460 Riyadh 11451, Saudi Arabia

Ali Mufarreh Saleh Al-Amri
Associate Professor, Dept. of Agric. Engineering, Colleg of Agricultural and Food Sciences, King Faisal University, Al-Ahsa,Saudi Arabia

S.G. Illangantileke
Head, Dept. of Agric. Engineering, Faculty of Agriculture, University of Peradeniya, Sri Lanka (Mailing Address: Postharvest Specialist and Regional Representative South WestAsia, International Potato Center (CIP), Regional Office, IARI Campus, New Delhi 11012,India)

Sen-Fuh Chang
Professor, Agric.-Machinery Dept. National Taiwan University, Taipei, Taiwan

Tieng-song Peng
Deputy Director, Taiwan Agricultural Mechanization Research and Development Center. FL. 9-6, No. 391 Sinyi Road, Sec. 4, Taiwan

Surin Phongsupasamit
Professor of Agricultural Engineering, Dept. of Mechanical Engineering, Faculty of Engineering, Chulalongkom University, Phyathai Road, Patumwan, Bangkok 10330, Thailand

Chanchai Rojanasaroj
Research and Development Engineer, Dept. of Agriculture, Ministry of Agriculture and Cooperatives, Gang-Khen, Bangkok 10900, Thailand

Vilas M. Salokhe


E S Eldin


N A Abu-Khalaf


A D Chaudhry


A Q Mughal


R ur Rehman


R M Lantin


R P Venturina


S A Al-suhaibani


A M S Al-Amri


S Illangantileke


S F Chang


T S Peng


S Phong-supasamit


C Rojanasaroj


V M Salokhe


G Singh


Y Pinar


P V Lang


A P Kaloyanov


P Kic


H Have


G Pellizzi


A A Wanders


J Kigour


M Martinov

Professor, AFE Program, Asian Institute of Technology, P.O. Box 4, Klang Luang. Pathumthani 12120, Thailand

Gajendra Singh
Professor, AFE Program, Asian Institute of Technology, P.O. Box 4, Klongluang, Pathumthani 12120, Thailand

Yunus Pinar
Professor, and Head, Agric. Machinery Dept, Faculty of Agriculture, University of Ondokuz Mayis, Kurupelit, Samsun, Turkey

Pham Van Lang
Director, Vietnam Institute of Agriculturai Engineering, Vien Truong, Vien Gong Cu Va Co Gioi Hoa Nong Nghiep Phuong Mai, Dong Da Ha Noi, Viet Nam

--EUROPE--

Anastas Petrov Kaloyanov
Professor & Head, Research Laboratory of Farm Mechanization, Higher Institute of Economics, Sofia, Bulgaria

Pavel Kic
Associate Professor, University of Agriculture Prague, Faculty of Agric. Engineering, 165 21Praha 6-, Suchdol, Czechoslovakia

Henrik Have
Prof. of Agric. Machinery and Mechanization at Institute of Agric. Engineering, Royal Veterinan/ - and Agricultural University, Agrovej 10DK2630 Tastrup, Denmark

Giuseppe Pelliui
Director of the Institute of Agric. Engineering of the University of Milano and Professor of Agric. Machinery and Mechanization, Via G. Celoria, 2-20133 Milano, Italy

Aalbert Anne Wanders
Staff Member, Dept. of Development Cooperation, Netherlands Agricultural Engineering Research Institute (IMAG), Wageningen, Netherlands

John Kilgour
Senior Lecturer in Farm Machinery Design at Silsoe College, Silsoe Campus, Silsoe, Bedford, MK45 4DT, UK

Milan Martinov
Associate Professor of Agricultural Engineering, University of Novi Sad, Faculty of Engineering Sciences, Institute of Mechanization,Novi Sad, Yugoslavia ■■

REMINDER

The reminder might run something like this:

THE AMA EDITORIAL STAFF WILL APPRECIATE RECEIVING ARTICLES FOR PUBLICATION TYPED DOUBLE-SPACE AND NOT REDUCED IN SIZE.

FARM MACHINERY INDUSTRIAL RESEARCH CORP.
7-2Kanda Nishikicho,Chiyoda-ku,Tokyo,Japan(Tel.81-(0)3-3291-5718,3671-4)
E-mail:sinnorin@blue.ocn.ne.jp URL:http://www.shin-norin.co.jp

INQUIRY and REQUEST to AMA

Please let us know your need. We shall promptly reply them. Inquire on any catalog listed in the advertisement in this issue. We shall try our best to serve you. We welcome articles of interest to agricultural mechanization.

Fill in the reverse side of this card and send us by sealed letter.

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

7-2, Kanda Nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan

ADVERTISED PRODUCTS INQUIRY

Product	Advertiser	Vol., No., Page

EDITORIAL REQUEST TO AMA

Your Name :

Address :

Occupation :

SUBSCRIPTION/ORDER FORM

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (AMA)

Issued Quarterly

Subscription Rate (includes surface mail postage)

Annual (4 issues)--------------¥.6,000
Single copy --------------¥.1,700

Back Issues (1971−75, ¥.2,000 per copy)
(1976−77, ¥.1,200 per copy)
(1978−80, ¥.1,500 per copy)

★Spring, 1971
★Vol.2 Autumn, 1971
☐Vol.3 No.1, 1972
☐Vol.3 No.2, Summer, 1972
★Vol.4 No.1, Spring, 1973
☐Vol.4 No.2, Autumn, 1973
★Vol.5 No.1, Summer, 1974
☐Vol.6 No.1, Spring, 1975
★Vol.6 No.2, Autumn, 1975
☐Vol.7 No.1, Winter, 1976
☐Vol.7 No.2, Spring, 1976
☐Vol.7 No.3, Summer, 1976
☐Vol.7 No.4, Autumn, 1976
☐Vol.8 No.1, Winter, 1977
☐Vol.8 No.2, Spring, 1977
☐Vol.8 No.3, Summer, 1977
☐Vol.8 No.4, Autumn, 1977
☐Vol.9 No.1, Winter, 1978
☐Vol.9 No.2, Spring, 1978
★Vol.9 No.3, Summer, 1978
★Vol.9 No.4, Autumn, 1978
☐Vol.10 No.1, Winter, 1979
☐Vol.10 No.2, Spring, 1979
☐Vol.10 No.3, Summer, 1979
☐Vol.10 No.4, Autumn, 1979
★Vol.11 No.1, Winter, 1980
★Vol.11 No.2, Spring, 1980
☐Vol.11 No.3, Summer, 1980
☐Vol.11 No.4, Autumn, 1980
★: Indicates issues out of stock.
☐ **Abstract and Index, 1971-80 (Special Issue, 1983)**

(Check issues and number of copies you wish to order)

Back Issues from 1981, ¥.1,700 per copy (Vol. 12 No. 1 and No. 4 are out of stock)
Abstract and Index, Special Issue, 1983, ¥2,000 per copy.

Vol.___ No.___, ___ 19___, ___ copy/copies

(check one)
☐ Please invoice me/us

☐ I/We enclose remittance for ¥________

****

Name: ____________________

Firm: ____________________

Position: ____________________

Address: ____________________

(block letters)

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

7, 2-chome, Kanda Nishikicho, Chiyoda-ku,

Tokyo 101-0054, Japan

Tel. (03)−3291−3671~4, 5718

STAMP

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

7, 2-CHOME, KANDA NISHIKICHO, CHIYODA-KU

TOKYO 101-0054, JAPAN

1st FOLD HERE

2nd FOLD HERE

INSTRUCTIONS TO AMA CONTRIBUTORS

The Editorial Staff of the AMA requests contributors of articles for publication to observe the following editorial policy and guidelines in order to improve communication and to facilitate the editorial process :

Criteria for Article Selection

Priority in the selection of articles for publication is given to those that -

a. are written in the English language ;
b. are relevant: to the promotion of agricultural mechanization, particularly for the developing countries ;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission ;
d. deal with practical and adoptable innovations by, small farmers with a minimum of complicated formulas, theories and schematic diagrams ;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article ;
f. are printed, double-spaced, under 3,000 words (approximately equivalent to 6 pages of AMA-size paper) ; and those that
g. art: supported by authentic sources, reference or bibliography.
h. written on floppy disc.

Rejected/Accepted Articles

a. As a rule, articles that are not chosen for AMA publication are not returned unless the writer(s) asks for their return and are covered with adequate postage stamps. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
b. When an article is accepted but requires revision/modification, the details will be indicated in the return reply from the AMA Chief Editor in which case such revision/modification must be completed and returned to AMA within three months from the date of receipt from the Editorial Staff.
c. "The AMA does not pay for articles published. However, the writers are given collectively 5 free copies (one copy air-mailed and 4 copies sent by surface/sea mail) of the AMA issue wherein their articles are published. In addition, a single writer is given 25 offprints of the article and plural writers are given 35 offprints (also sent by surface/sea mail)"
d. Complimentary copies: Following the publishing, three successive issue are sent to the author(s) .

Procedure

a. Articles for publication (original and one-copy) must be sent to AMA through the Co-operating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article may be sent directly to the AMA Chief Editor in Tokyo.
b. Contributors of articles for the AMA for the first time are required to attach a passport size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
c. The article must bear the writer(s) name, title/designation, office/organization, nationality and complete mailing address.

Format/Style Guidance

a. Article must be sent on 3.5 inch floppy disk with MS DOS format (e.g. Word Perfect, Word for DOS, Word for Windows... **Absolutely necessary TEXT FORMAT**) along with two printed copy.
b. The data for graphs and the black & white photographs must be enclosed with the article.
c. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features :
   i) brief and appropriate title ;
   ii) the writer(s) name, designation/title, office/organization ; and mailing address ;
   iii) an abstract following ii) above ;
   iv) body proper (text/discussion) ;
   v) conclusion/recommendation ; and a
   vi) bibliography
d. The printed copy must be numbered (Arabic numeral) successively at the top center whereas the disc copy pages should not be number.Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e.g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Figure 1. View of the Farm Buildings".
e. **The data for the graph must also be included.(e.g. EXCEL for Windows)**
f. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare(t/ha) and smaller units in kilogram or gram(kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies in US dollars and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.

BACK ISSUES

(Vol. 29 No. 2, Spring, 1998 ~)

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

(Vol. 30, No. 2, Spring, 1999)

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

(Vol. 30, No. 3, Summer, 1999)

■■