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VOL.XVI, NO.4, AUTUMN 1985

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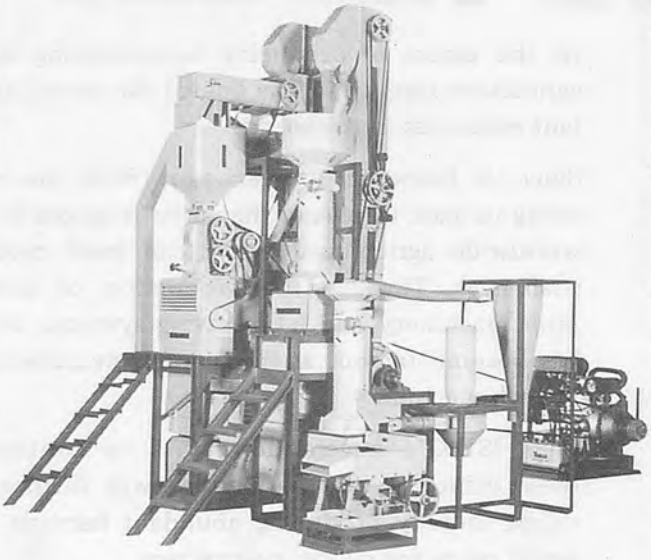

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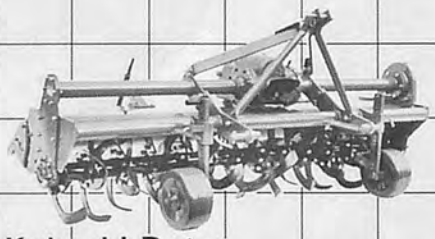

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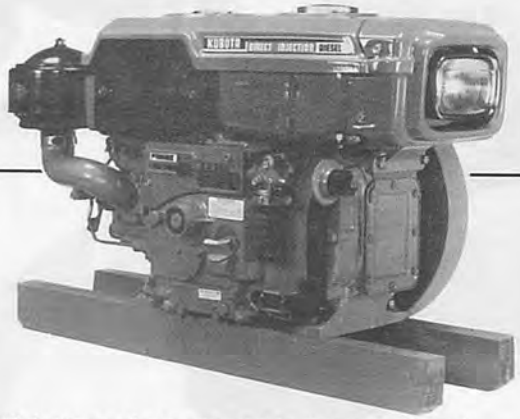

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EDITORIAL

A Need to Close Ranks

The state-of-the-art of agricultural mechanization among the developing countries of the world is one of a mosaic: quite progressive and experimenting in a few of them but backwards in many others. Even within a small region of neighboring underdeveloped or developing countries, the disparity among them is prominent in terms of farm power availability. In some of them, large-scale use of man and machines is beginning to influence agricultural productivity levels to increase and yet, in many, many others, man and animals continue to provide the bulk of farm power and where, as a consequence, agriculture equally continues to stagnate in the face of rapid development in other sectors of their economies.

Clearly then, in this cenario, there is need for all exponents of progress and greater use of farm machines to close ranks – a particularly pressing need to establish a workable communication link among countries to promote agricultural mechanization as a prerequisite to boosting farm production. In this regard, the Regional Network for Agricultural Mechanization (RNAM) that the ESCAP has initiated some years back is slowly creating that much needed network and close cooperation among national farm mechanization councils in the region. And the RNAM needs all the support that it can get in order to achieve its objectives.

Be that as it may, more than this ESCAP's initiative is the real need to establish regional centers around the globe – not only in Asia and the Pacific – where research, development and design of new farm machineries can and should be done. Such centers should be established in at least four regions: Southeast Asia, Middle East, Africa and South America. Aid givers and donor countries and organizations should provide the impetus to get these centers established. Indeed, here is another realistic need for the advanced countries to close ranks in the interest of agricultural development through farm mechanization.

The AMA, in its usual modest ways, pledges to help close the ranks by helping strengthen the communication links via its regular and special issues and by faithfully fulfilling its chosen role of exponent of progress in agricultural pursuits.

Yoshisuke Kishida
Chief Editor

October, 1985
Tokyo

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol. XVI, No.4, Autumn, 1985

Yoshisuke Kishida	9	Editorial
Harry D. Henderson Wolfgang Guericke	11	Economics of Tractor Operation in Swaziland
V.M. Mayande R. Sarin G.E. Thierstein	17	Animal-Drawn Wheeled Tool Carrier in India under On-Farm Conditions
M.S.U. Choudhury	25	Evaluation of Manual Planters for Selected Crops in West African Savanna
Shane M. Ward	30	Spray Characteristics of a Rotary Atomizer
Zong Sheng-Yu	33	A Kinetic Analysis of Large Rounding Jet-Irrigation Apparatus
Edwin J. Calilung Godofredo C. Salazar Celerina L. Maranan Robert E. Stickney	35	Comparison of Axial-Flow and Centrifugal Pumps for Low-Lift Irrigation
H.M.G. Herath	39	Efficiency of Resource Use in a Tube Well Irrigation Scheme in Sri Lanka
Md. Motiur Rahman Khan	43	Effect of Irrigation on Cotton Yield in Southern USSR (Tashkent)
Md. Syedul Islam Khondaker Azharul Haq	47	Performance of Indigenous Hand Weeders in Bangladesh
Mahmoud Hassan Ahmed	51	Mechanical Harvesting of Cotton in the Sudan
M.H. Pahoja C.N. Gangde	54	Study of a Segmented Paraboloid Type Solar Heat Collector
M.A. Choudhary	59	Impact of Farm Technology and Energy on Developing Agriculture
Megh R. Goyal Felix R. Rivera-Negron Eliodoro J. Ravalo Rene Otero-Davila William F. Allison	65	Status of Mechanization on Hilly Farmlands of Puerto Rico
S. Swain T.P. Ojha	69	Machinery Selection Concerning Farm Sizes
F.F.R. Koenigs	73	Two New Principles of Weighing: Bicycle Wheel as Balance and Dynamometer
A.C. Datta N.G. Bhole	76	Qualities of Retted Flax and Degummed Fibers for Commercial Use
News	81	
Book Review	83	

* * *

Index to Advertisers 75
Co-operating Editors 86
Back Issues 88

Economics of Tractor Operation in Swaziland

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Abstract

A survey was conducted in 1982 to determine the costs of tractor operation in Swaziland. Four types of ownership groups were examined. It was found that the average operator is 33 to 35 years of age, has 4 to 6 years of experience and between 2 and 4 years of elementary education.

The hydraulic system of the tractor was the most important source of troubles for the operator. Repairs cost varied from E100 to more than E1400 per year. Life expectancy of the tractors varied from 6 years in the case of the estates to 10 years for the small farmer.

The used tractor business is just getting started. Locally manufactured tractors have a low initial cost, but their low power rating and slow speed have kept them from being widely accepted.

Introduction

Machinery and power units make up as much as 40% of the total investment in modern farming. In Swaziland, it is believed that more than 3 000 tractors are in use, but prior to this study no statistics had been available since 1976.

The situation in Swaziland regarding tractor utilization is unique for a developing country in two respects: tractors are manufactured locally; and down time is comparatively short because of proximity to South African centers.

With the above factors in mind it was obvious that there was need for accurate statistics on which cost calculations can be based. The present study was undertaken through a research grant from the University of Swaziland to determine the costs of tractor operation, to isolate factors which make up these costs, and to compare the costs experienced under four types of ownership. These types of ownership are i) institutions, ii) large estates, iii) government and iv) small holders or farmers (**Table 1**).

Note: This paper is a contribution of the Department of Land Use and Mechanization and the Research Commitee, University of Swaziland, Luyengo.

Table 1 Distribution of Sample Tractors Studied

Ownership group	Number	Total no. of tractors owned	Total no. of tractors surveyed
Estates	3	87	12
R.D.A.*	1	41	10
Institutions	6	43	24
Small holders	54	60	54

*Rural Development Admistration (Government hire pools).

General Characteristics of Tractors

Make – Massey-Ferguson was the most common tractor make among the R.D.A.s, institutions and small holders, but on the estates, International Harvester was the most popular (**Table 2**).

Age and Life Expectancy – Between 50 and 60% of all tractors studied were manufactured after 1977 (**Table 2**). The mean of the tractor age at the time of the survey ranged from 3.7 years for those owned by institutions to 6.1 years for tractors owned by small holders. The life expectancy ranged from 6.7 years for tractors in the R.D.A.s to 10.6 years for those belonging to small holders (**Table 3**).

Licenses/Conditions at Time of Purchase – The majority of the tractors under all four groups were licensed. All the tractors surveyed from estates and those from the R.D.A.s were brand-new when purchased. On the other hand, 43% of the small holders purchased used tractors.

Service, maintenance and the availability of parts were the primary reasons for the purchase of a

Table 2 Distribution and Characteristics of Tractors Studied

Item	Estates No.	Estates %	R.D.A. No.	R.D.A. %	Institutions No.	Institutions %	Small Farmers No.	Small Farmers %
Make								
Ford	0	0	0	0	0	0	4	8
Intl Harvester	6	50	0	0	0	0	6	12
John Deere	2	17	2	20	9	38	1	2
Massey Ferguson	4	33	6	60	13	54	22	42
Tinkabi	0	0	0	0	1	4	18	35
Other	0	0	2	20	1	4	1	2
Year								
Pre-1970	0	0	0	0	0	0	8	15
1970-1973	1	8	0	0	1	5	3	6
1974-1977	4	33	5	50	8	36	15	30
1978-1982	7	58	5	50	13	59	26	50
Condition at time of purchase								
New	12	100	10	100	23	96	31	57
Used	0	0	0	0	1	4	23	43
Primary reason for purchase								
Cost	0	0	2	20	0	0	19	37
Service, maintenance, parts	7	58	8	80	10	42	5	10
Suitable for type of work	1	8	0	0	2	8	9	17
Strength, long life	0	0	0	0	1	4	7	13
Brand	3	25	0	0	0	0	2	4
Other	1	8	0	0	6	25	9	17
Unknown	0	0	0	0	5	21	1	2
License for tractor								
Yes	11	92	10	100	23	96	44	85
No	0	0	0	0	1	4	7	13
Unknown	1	8	0	0	0	0	1	2

Table 3 Characteristics of Tractors and Operators

Item	Estates No.	Estates yr	R.D.A. No.	R.D.A. yr	Institutions No.	Institutions yr	Small Farmers No.	Small Farmers yr
Tractor age at time of survey	12	4.6	10	3.9	22	3.7	52	6.1
Life expectancy	11	9.1	10	6.7	21	8.4	45	10.6
Operator's age	12	34.0	10	33.5	20	35.4	50	37.6
Operator's experience	12	8.0	9	10.0	19	6.7	50	8.5

Table 4 Characteristics of Tractor Operators

Item	Estates No.	Estates %	R.D.A. No.	R.D.A. %	Institutions No.	Institutions %	Small Farmers No.	Small Farmers %
Primary operator								
Owner	0	0	0	0	0	0	27	52
One other person (than owner)	11	92	10	100	9	37	11	21
Several other people	1	8	0	0	15	63	14	27
License								
Yes	12	100	10	100	13	88	21	40
No	0	0	0	0	2	8	20	38
Car only	0	0	0	0	0	0	3	6
Unknown	0	0	0	0	1	4	8	15
Education								
More than standard 6	0	0	2	20	2	8	16	31
Std 4 - Std 6	6	51	2	20	5	21	21	40
Std 1 - Std 3	1	8	0	0	6	25	6	12
Less than Std 1	3	25	0	0	2	8	0	0
Nil	2	17	0	0	6	38	5	10
Unknown	0	0	6	60	0	0	4	8
Training								
Before present job	5	42	5	50	10	48	9	17
At present job	7	58	5	50	10	48	4	8
Unknown/not applicable	0	0	0	0	1	5	39	75

particular make among the estates, institutions and R.D.A.s while cost was the primary consideration for the small farmers (**Table 2**).

Characteristics of Operators – In 52% of the cases studied of the small farmers, the owner operated the tractors. All of the operators employed by the estates and R.D.A.s have licenses, but only 40% of the operators working on small farms have tractor driving licenses (**Table 4**).

Educational levels of tractor operators varied greatly. Strangely enough, the majority of operators employed by institutions have received no education while those the majority of R.D.A. operators was not known (**Table 4**).

The mean age of the tractor operators ranged from 33.5 years for operators employed by the R.D.A.s to 37.6 years for those working on small farms. The average number of years of experience for operators ranged from 6.7 years for operators employed by institutions to 10 years for operators employed by the R.D.A.s (**table 3**).

Service, Maintenance, Overhauls and Accidents

Service and Maintenance – Operators are largely responsible for the daily service and maintenance of tractors owned by the estates, R.D.A.s and institutions. Owners are most often responsible for this work on small farms. Mechanics are generally responsible for the weekly, monthly and yearly servicing of tractors except in the case of the samll farmers who usually perform all servicing tasks except for the yearly ones.

Overhauls – The majority of the tractors owned by estates, institutions and small farmers do not receive overhaul service while most of those owned by the R.D.A.s do. Company workshops handled 100%

Table 5 Economics of Tractor Operation in Swaziland: Service, Maintenance, Accidents

Item	Estates No.	Estates %	R.D.A. No.	R.D.A. %	Institutions No.	Institutions %	Small Farmers No.	Small Farmers %
Daily service								
Owner	0	0	0	0	0	0	28	54
Operator	12	100	10	100	23	96	21	40
Mechanic	0	0	0	0	1	4	2	4
Other	0	0	0	0	0	0	1	2
Weekly/monthly service								
Owner	0	0	0	0	0	0	28	53
Operator	0	0	0	0	5	21	18	35
Mechanic	12	100	10	100	19	79	6	12
Other	0	0	0	0	0	0	0	0
Yearly service								
Owner	0	0	0	0	0	0	9	17
Operator	0	0	0	0	2	8	6	12
Mechanic	12	100	10	100	22	92	33	63
Other	0	0	0	0	0	0	4	8
Overhauls								
Yes	3	25	7	70	3	13	21	40
No	9	75	3	30	21	88	31	60
Overhauled by:								
Owner/operator	0	0	0	0	0	0	4	19
Dealer	0	0	0	0	3	100	14	67
Company/institution workshop	3	100	7	100	0	0	3	14
Accidents								
Yes	1	8	0	0	3	13	6	12
No	11	92	10	100	21	88	45	87
Unknown	0	0	0	0	0	0	1	2

Table 6 Annual Work of Study Tractors

Item	Estates No.	Estates %	R.D.A. No.	R.D.A. %	Institutions No.	Institutions %	Small Farmers No.	Small Farmers %
Hours								
0 - 250	2	17	0	0	4	17	8	15
250 - 500	4	33	6	60	5	21	17	33
500 - 750	2	17	3	30	7	29	7	13
750 - 1000	1	8	1	10	6	25	10	19
Over 1000	2	17	0	0	2	8	9	12
Unknown	0	0	0	0	0	0	1	2
Types of Work*								
Tillage	2	17	10	100	21	88	45	87
Harvest	0	0	0	0	12	50	14	27
Planting/ fertilizing	0	0	0	0	14	58	34	65
Transport (field)	7	58	10	100	18	75	48	92
Cultivation	1	8	10	100	15	63	35	67
Transport (highway)	3	25	10	100	6	25	29	56
Spraying	4	33	0	0	16	67	8	15
Blade work/ loader	0	0	0	0	7	29	5	10
Mowing, raking, baling	0	0	0	0	15	63	11	21
Chopping	0	0	0	0	4	17	4	8
Other	2	17	0	0	1	4	15	29

* Percent columns will not equal 100 as more than one type of work may have been ticked.

of the overhaul work for the estates and the R.D.A.s. Dealers handled most of the overhauls done for institutions and small farmers.

Accidents – The percentage of tractors involved in an accident ranged from none for the R.D.A.s to 13 for the institutions (Table 5).

Hours of Use – The annual number of tractor use hours varied both between and within the four ownership groups. The majority of the tractors used by the estates, R.D.A.s and small farmers worked from 250 to 500 hours annually. Most tractors used by institutions worked from 500 to 750 h annually (Table 6).

Cost Analysis

The data gathered varied considerably, so it is difficult to analyze properly the costs of owning and operating tractors in Swaziland. Nevertheless, fairly reliable estimates can be made. For the estates and R.D.A.s accurate records were available. Most of the small farmers were able to provide reasonable estimates, but it was impossible to obtain operating costs from the institutions.

Farm Size and Size of Tractor – In the scattergram (Fig. 1) it can be seen that the tractor size does increase with an increase in size of farm or enterprise. Out of the sample of 100 tractors, only four were found on farms of fewer than 3 ha.

Twenty five percent of the tractors were found on farms ranging in size from 3 to 7 ha. Six of these were purchased second hand. From the sampling another 19 tractors were found on farms varying in size from 7 to 10 ha while 17 were being operated on farms with areas varying from 11 ha to 65 ha. It is interesting to note that the Tinkabi*, a 12 kW (15 hp) tractor was being used on farms varying in size from 3 ha to 35 ha (Fig. 2). The Tinkabi tractor is used mostly for transport, pumping and for powering hammer mills.

Cost of Used Tractors – Although the used tractor business is in its infancy, a random sample was taken of prices paid for used tractors sold in Swaziland in early 1983.

Prices ranged from E400 (U.S. $348) for a 1968 M.F. 165 to E8000 (U.S. $6950) paid for a two-year old M.F. 135. Six (37.5%) of the tractors were five years old at the time of purchase, but three (19%) were older than 12 years. Prices of used tractors are, on the average, higher than those in the

*Brand of tractor manufactured locally.

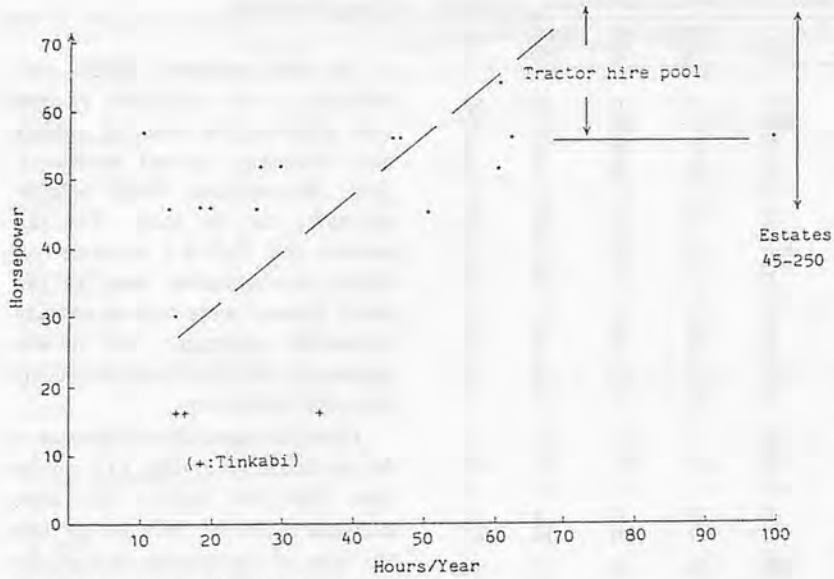

Fig. 1 Horsepower vs farm size (over 10ha).

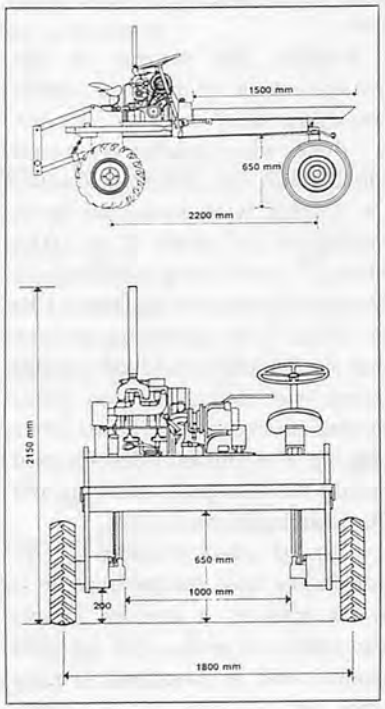

Fig. 2 A 15hp Tinkabi tractor.

developed countries.

Annual Costs – The annual costs of tractors are divided into fixed and variable costs. Fixed costs include depreciation, interest, repairs and taxes and insurance. Housing is not considered because, in Swaziland, most tractors are not kept under shelter.

The depreciation period for tractors on the small farms is 10 years, but on the estates and R.D.A.s the period is only 6 years. The residual value is not considered in Swaziland. The tractors are considered scrap at the end of the depreciation period. The used tractor business in the country is just getting a start.

The cost of interest depends on the type of financing, but the interest rate is between 16 and 20% for medium term loans. The estates, R.D.A.s and institutions work on a cash basis whereas the farmers on small and medium-sized holdings usually seek loans from the Swazi Development Bank. These loans cover as much as 50% or even more of the purchase price of the tractor. In calculations for this study, a 20% interest rate was used.

Table 7 Distribution of Tractor Overhauls by Cost

Costs (E)	Number	Percent
100 to 200	26	39.2
200 to 400	15	22.0
400 to 600	14	20.6
600 to 800	3	4.4
800 to 1000	3	4.4
1000 or over	7	10.3

Repairs may be considered either as fixed or variable costs. They depend upon hours of use per year, age of the tractor, kind of use and perhaps even the make. In this paper, repair costs are considered as fixed costs. Both regular overhauls and occasional repair expenses are included in the repair costs. Most of the small farmers have their tractors overhauled regularly. According to a sampling of 21 of these farmers, 7 overhaul their tractors every 2 years, 5–every 3 years, 4–every 4 years while 3 used a 5–year interval and 2 used a 6-year interval. Two-thirds of the small farm tractor owners have their tractors overhauled by the dealer's service center.

From **Table 7** it can be seen that most of the repair costs ranged from E100 (U.S.$87) to E600 (U.S.$520). Those costs of E1000 (U.S. $870) and more were for major overhauls which included such things as sleeve replacement, regrinding the crankshaft or replacing bearings.

The estates have excellent workshop facilities so they do not have a regular overhaul period and policy. Most work is performed as breakdowns occur. The R.D.A.s

also have their own workshop facilities so they have no set policy for periodic overhaul. The period between overhauls depends upon age, use and somewhat on workshop capacity. The tractors in the hire pools range from 50 to 70 hp. In 1982, the range in overhaul costs for eight of them was from E340 to E2020 (U.S. $295 to $1756), and that for repair costs was from E50 to E1000 (U.S.$43 to $845).

Repair Problems – According to the survey, the most serious repair problem was with the hydraulic system. Dirt and dust in the oil destroys gaskets in the cylinder, pumps and valves which results in oil leakage and excessive wear. The electrical system was the source of the second most serious problems. The starter motor (due to dirt and worn brushes) and the alternator (also worn out brushes) caused the most trouble. Other problems of consequence were rapid tire wear, broken wheel bolts, wheel bearings and fan belts. It is worthy of note that most of these problems are intensified by the considerable amount of transport use a tractor receives in Swaziland. Tires rarely last more than 3 years. Many drivers do not shift gears properly, and little attention is given to daily checking of such things as loose or missing bolts, belt tension and grease requirements.

Repair costs of tractors owned by the estates and R.D.A.s averaged 7% of the purchase price annually while those owned by the small farmers averaged only 5%. This is thought to be because of more intense use – especially on the estates plus the fact that with private ownership, the tractors are simply better maintained.

Taxes and Insurance –Both taxes and insurance are customary expenses for tractor use in Swaziland. Insurance figures used are from the 1982 rates as announced by the Royal Swazi Insurance Ltd. Taxes vary from E5 to E20 annually with an average of E10 (U.S.$8.70). These two items (insurance and taxes) make up 4% of the purchase price annually.

Variable Costs

Variable costs are those which fluctuate directly with the use of the tractor. These include fuel, lubrication and labor.

Fuel –Fuel consumption was found to average 120 g per hour per horsepower. The price of diesel fuel at the time of the survey was E 0.60 (U.S.$0.52)/*l* .

Engine Oil –Swazi tractors need an average of 7*l* of engine oil per 100 h of operation. At a price of El.50/*l*, this costs E 10.50 (U.S.$9.13) per 100 h of operation.

General Lubrication –General lubrication covers grease, transmission lubricant, hydraulic oil plus filters and other items. The costs equaled E21.00 (U.S.$18.25) per 100 h of operation or E 0.21/h of operation.

Labor –Wages for tractor operators vary all the way from E 0.25/h for a beginner to E 1.00/h for an experienced and specialized operator. The average wage was E 0.50/h.

Total Costs –After all the various factors are determined, the annual costs can be calculated. Contrasts between the annual costs of purchasing a used tractor (10 years old with an expected life of five more years) and purchasing a similar sized model new are shown in **Fig. 3**. The price paid for the used tractor was E2000 (U.S.$1740) while that for the new tractor was E10,000 (U.S.$8700). Costs for tractors surveyed from the R.D.A.s are shown in **Fig. 4**. Note the amounts devoted for administrative purposes.

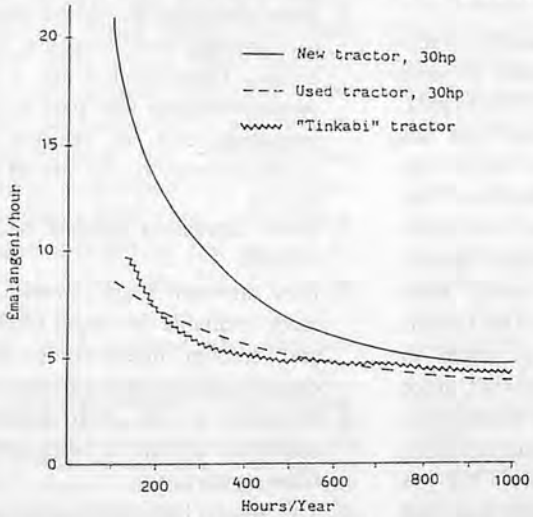

Fig. 3 Comparative costs of use for new and used tractors.

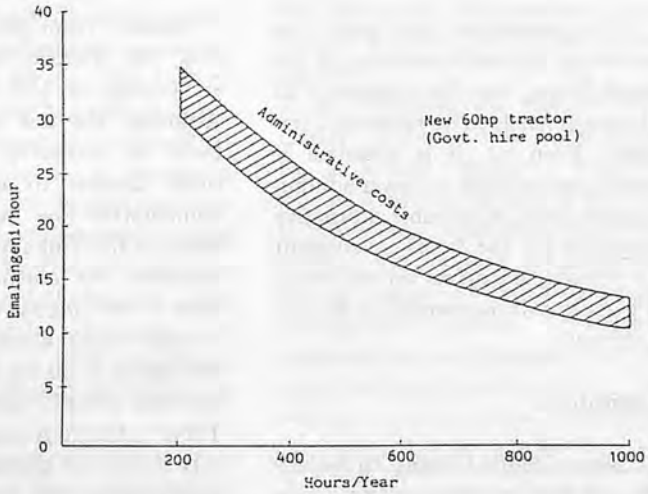

Fig. 4 Cost of use of RDA tractors.

Conclusions

The survery conducted in Swaziland reveals certain problems of tractor operation as well as patterns of costs within various types of ownership groups. These factors as well as personal observations of the authors have led to the following conclusions.

Swazi Nation Farms

On farms of under 10 ha, the use of contractors or custom hire services should be emphasized. Very few farms of this size can justify ownership of a tractor unless the owner has a lot of custom work. On farms of 8 to 10 ha with a high percentage of cash crops, a used low horsepower or Tinkabi tractor might be justified. On farms of 10 to 15 ha farmers may afford a Tinkabi, a used medium hp tractor or a new 30 hp standard tractor providing there is outside custom work. Farmers operating more than 15 ha often have tractors. They usually consider the Tinkabi too weak for their tillage operations. Again, custom work probably will be necessary to get sufficient hours of work for the tractor to pay for itself.

RDA Tractor Hire Pools

The government hire pools are necessary for mechanization of the small farms, but the economics of the pools needs to be reviewed carefully. Even so, it is doubtful if much can be done to lower administrative costs. A desirable alternative might be for the Swazi government to provide incentives for encouraging more private owners to do custom work.

Institutions

Better control needs to be exercised over investments in tractors for institutions in the public sector. Records are unavailable, equipment often has been purchased that is not adapted to the work, and experienced personnel is lacking. Often times the worst tractors on hand are assigned for teaching purposes; this can mean that students are being trained on an unsafe tractor.

Estates

From some standpoints, tractors owned by the estates are being used under optimum conditions. Tractors are often purchased in sufficient quantities that price discounts can be obtained. Experienced personnel are employed in the workshop so repair work is done professionally. The tractors are used mostly by one operator for relatively few purposes. On the other hand, the life of an estate tractor is relatively short. Annual use is low because of its specialized nature. The need for major repairs, particularly those involving transport, indicate a need for better trained operators. An interesting development (in the male oriented Swazi society) is the recent practice of hiring women operators. One estate now has 14 women among its total of 70 tractor operators.

Alternatives

Results from the survey reveal that the Tinkabi tractor is used an average of 150 to 250 h/year. Although the low initial cost has been an incentive to encourage small farmers to mechanize, the comparative low power and slow speed of the Tinkabi do not make it desirable for custom work. With such a low annual use the tractor actually costs nearly as much to operate as a 30 hp imported make that has a much higher initial cost. There is the additional (psychological) effect of appearance. To the Swazi farmer the Tinkabi does not "look" like a tractor.

Under the present conditions, it is doubtful if the manufacture of the Tinkabi tractor is economically feasible. A number of technical and marketing problems exist which cannot be solved unless there is substantial increase in price of the machine, or unless the government is willing to subsidize a portion of the manufacturing costs.

At the same time, several companies recently have developed a 22.5 kW (30 hp) tractor with 4-wheel drive. These models are well suited to Swazi conditions. Their greater speed and traction more than make up for the price differential (which is about 2½ times).

Strictly from an economic standpoint, it would be more practical for the government of Swaziland to invest in low interest loans or other incentives to assist the farmer to purchase imported tractors and machinery. This policy, however, must be weighed against development of local industry which can serve as a guarantee against the effect of trade barriers which might be imposed by another country.

Recommendations

1. Records should be kept so that owners can determine tractor costs.
2. More emphasis should be placed on training and selecting operators. Labor makes up a disproportionately low part of the operating cost in relation to its importance to the life of the tractor.
3. Good operators should be rewarded.
4. Low interest loans should be made available for small farmers and custom operators to purchase tractors and machinery
5. Tractors in the best possible condition should be assigned for training purposes.
6. The second hand tractor business should be encouraged. ■■

Animal-Drawn Wheeled Tool Carrier in India under On-Farm Conditions

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Abstract

Multi-purpose, animal-drawn wheeled tool carriers from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) were tested on farms representing three different soil types and agroclimatic conditions in India. A comparison was made between three machinery management systems and three cropping systems.

It was shown that wheeled tool carriers can perform operations 2-3 times faster than traditional implements when used for soil management on flat land ("flat management") which also saves bullock time. Wheeled tool carriers, when used on a broadbed-and-furrow (BBF) soil management system differed in the amount of bullock time used at the three locations.

A yield increase was observed in improved flat and BBF systems when compared with the traditional flat system. In Alfisols and deep Vertisols, an increased output of improved flat over traditional flat covered the cost of improved machinery used, leaving an additional net income in the range of Rs. 112-867 per ha.

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Introduction

Animals are the chief sources of power in Indian agriculture, with more than 64% of the energy input in farming originating from them (Ramaswamy 1978). This power should be utilized properly to boost agricultural production required to meet the needs of an increasing population. Crop production can be substantially improved by using improved animal-drawn implements for timely completion of field operations, better placement of seed and fertilizer, and appropriate weed control (Bansal and Srivastava 1981).

In the Indian Semi-Arid Tropics (SAT), most farmers use simple, traditional bullock-drawn implements. These include a wooden country plow, a blade harrow consisting of a mild steel blade attached to a wooden frame, and a two- or three-row seeder in which seeds are metered by hand. These implements seem to satisfy the farmer at low production levels (Bansal and Srivastava 1981). However, with technological improvements in soil and water conservation (ICRISAT annual report 1977), the increasing availability of high-yielding crops, and greater use of chemical fertilizers, the machinery requirements must change if crop production is to increase.

An animal-drawn wheeled tool carrier (Tropicultor)*, designed by a French engineer, was the first such machine used at ICRISAT. It proved very effective in performing all crop production operations on an improved land and water management system consisting of broadbeds and furrows, 150 cm wide. Wheeled tool carriers have

* Trade names are included as an aid to the reader and do not represent a product endorsement by the authors or ICRISAT.

Table 1 Some Characteristics of the ICRISAT On-Farm Research Sites, 1978-79

Characteristics	State - Andhra Pradesh Dist. - Mahabubnagar Village - Aurupalle	Maharashtra Akola Kanzara	Maharashtra Sholapur Shirapur
Distance from ICRISAT Centre (km)	100	500	300
Average rainfall (mm)	700	800	650
Soil type	Shallow to medium Alfisols	Shallow to medium deep Vertisols	Deep Vertisols
Important crops	Sorghum, castor, pearl millet, pigeonpea, paddy, groundnut	Cotton, sorghum, groundnut, pigeonpea, mungbean	Post rainy season sorghum, pigeonpea chickpea, minor pulses
No. of households in the village	476	169	297
Landless households (%)	28	32	23
Average size of operational holdings (ha)	3.5	6.1	6.5
Rainfed area to total cropped area (%)	88	95	92
Area under small scale experiment involving one farmer 1978-79 (ha)	3.0	3.0	3.6

Source: Report of Work, Agronomy and Weed Science, Farming Systems Research Program, 1980-81.

been described by Bansal and Srivastava (1981) and Thierstein (1983). They have been successfully used at the ICRISAT Center since 1976. Farm machines should be modified and tested by research stations, but their ultimate impact depends primarily on the extent to which they are adopted by farmers.

The results of the use of a wheeled tool carrier were obtained from small-scale on-farm research trials conducted during the cropping year 1978-79. These were used to obtain preliminary information on suitable cropping systems and appropriate land and water management technology, which are discussed in this paper. The experiments were conducted in three south Indian villages having different soil types and agroclimatic conditions. Some characteristics of the on-farm research sites are given in **Table 1**.

The objective of the on-farm research was to test and measure the performance of prospective farming systems technologies involving farmers in the technology testing process. This experiment was also used to assess the economic and technical performance of improved machinery management systems compared to traditional systems.

Table 2 Total Bullock Time Requirement of Three Machinery and Management Systems for Different Cropping Systems at Aurupalle, Kanzara, and Shirapur Villages (1978-79)

Village	Cropping systems	Machinery and management systems			
		Traditional flat with local implements	Improved flat with improved implements	Raised bed & furrow systems with improved implements	S.E. ±
		Bullock pair h/ha			
Aurupalle	*Intercropping[1)]	57	37	36	1.6
	Sole castor	70	32	30	1.7
Kanzara	Intercropping[2)]	34	31	31	1.2
	Sequential cropping[3)]	58	43	49	1.1
	Rainy season sorghum	37	34	32	1.0
Shirapur	Intercropping[2)]	68	29	44	1.1
	Sequential cropping[4)]	58	39	51	1.1
	Post rainy season sorghum	58	13	57	1.5

1) Sorghum/pigeonpea and pearl millet/pigeonpea (2;1); 2) Sorghum/pigeonpea; 3) Maize-saffower; 4) Mungbean-post rainy season sorghum.

* No difference was observed in bullock time use for sorghum/pigeonpea and pearl millet/pigeonpea intercropping at Aurupalle.

Methodology

In 1978-79 an experiment with nine treatments and three replications was conducted at Aurupalle, Kanzara, and Shirapur villages involving one farmer at each location. The experimental area was laid out before the rainy season at all locations. Three machinery management systems and three cropping systems were used:

1. Wheeled tool carrier on a broad-bed-and-furrow system (BBF)*;
2. Wheeled tool carrier on flat land (improved flat)**; and
3. Traditional implements on flat land (traditional flat).

The three cropping systems used at each location are given in **Table 2**. The average plot size at Aurupalle, Kanzara, and Shirapur was 0.10, 0.11, and 0.13 ha, respectively.

In treatments using traditional machinery, operations were done with local implements. This included plowing with a country plow, seedbed preparation with a local blade harrow, and sowing with a local wooden two, three, or four

* The broadbed-and-furrow (BBF) system consists of approximately 100 cm wide raised bed and 50 cm furrow, thus making 150 cm center to center. Furrows are used as the traffic zone for tool carrier wheels and animals, and the crop is raised on a bed. The furrows have a 0.4-0.8% grade.

** Flat land has an even uniform surface.

row seed drill (Figs. 1, 2, and 3). The seeds were covered with a wooden plank and interrow cultivation was done with a local blade hoe (Fig. 4).

The wheeled tool carrier operations on the BBF system included strip moldboard plowing, ridging, cultivating with duck-foot sweeps, bed shaping, planting with inclined plate unit planters, and inter-row cultivating (Fig. 5, 6, and 7). On the improved flat system, the plowing at Shirapur and Aurupalle villages was done by using right hand (RH) and left hand (LH) moldboard plows as on the BBF system. At Kanzara, traditional moldboard plowing with a wheeled tool carrier was done on flat land (Fig. 8). The time required to complete each operation in each plot was recorded to determine the total bullock pair hour (bph) requirement for all machinery operations at the three locations.

Results and Discussion

The performance of different machinery and management systems was evaluated on the basis of bph per ha, crop yields obtained from different machinery and management systems, and economic results.

Technical Performance

Table 2 presents the total bph required to cover 1 ha with each of the three machinery and management systems. The total bph/ha was calculated from effective field capacities (actual area covered in ha/h) for various operations under different cropping systems at all three locations.

In this paper the machinery and management systems were compared for different cropping systems. The first comparison was between the local and improved implements on the flat system, and the second between improved implements on the flat and BBF systems.

Fig. 1 Plowing with a traditional country plow.

Fig. 2 Cultivation with a blade harrow.

Fig. 3 Traditional wood seeder used for sowing.

Alfisols

When comparing traditional flat and improved flat with intercropping systems (sorghum/pigeonpea and pearl millet/pigeonpea) and sole castor at Aurupalle village, the use of 57 and 70 bph for the traditional flat system was much higher compared to 36 and 32 bph used for the improved flat system. A random block design (RBD)

Fig. 4 Interrow cultivation with a blade hoe.

Fig. 5 Strip plowing raised beds.

Fig. 6 Planter/fertilizer applicators in use.

Fig. 7 Interrow cultivation.

Fig. 8 Plowing on the flat.

analysis showed significant difference at the 5% level between bph used on traditional flat and improved flat systems. The higher bph requirement in the traditional flat is due to the lower field capacities of traditional implements.

The effective field capacity of farm machinery was determined by the width covered in one pass multiplied by the speed of operation. The animal-drawn wheeled tool carrier and implements covered a 150 cm width for most operations, while the traditional country plow is 15 cm wide, with a 60 cm wide blade harrow, and a 30 cm wide inter-row cultivation hoe.

The bph requirement in traditional flat also depended upon the seeding and interrow cultivation methods used. Seeding of the intercropping system and sole castor was done by dropping seeds manually into furrows made by a country plow (**Fig. 9**). The row spacings of intercrops and sole castor on traditional and improved flat systems were 45 and 60 cm, respectively. The interrow cultivation in traditional flat was done by using a local blade harrow between two rows of castor covering one row spacing as shown in **Fig. 4**. In the intercropping system, two blade hoes were used with one pair of bullocks at a time, covering two rows spaced at 90 cm. On the improved flat, the wheeled tool carrier covered a width of 150 cm for seeding and inter-row cultivation, as shown in **Fig. 6 and 7**, respectively. The total bph used in all three machinery and management systems depended upon the operational requirements of particular cropping systems.

Fig. 9 Traditional method of sowing at Aurupalle – dropping seed manually in a furrow made by a country plow.

The difference in bph used on improved flat and BBF systems was not significant at the 5% level. The improved flat required slightly more bph than the BBF system. This is probably because in the BBF system the forrows served as a traffic zone, providing a specific track for the bullocks and tool carrier wheel, thus effectively covering a 150 cm width in each pass (Thierstein 1979). In the improved flat, two successive adjacent passes might overlap or leave gaps which might marginally affect the bph used.

Vertisols

In Vertisols at Shirapur and Kanzara, different cropping patterns are traditionally followed because the rainfall pattern and water holding capacity of the soils are different. At Kanzara, rainy season sorghum and cotton are common crops, whereas at Shirapur, rainy season fallow and growing post-trainy season sorghum are common. In the Sholapur area of medium (750 mm/year), erratic, and undependable rainfall, a rainy season fallow system has been developed. The rainfall during the rainy season is too erratic to support a rainy season crop in most years. Farmers have long realized that it is better to grow a postrainy season crop on stored moisture than to grow crops during the rainy season. In areas of higher rainfall, (750-1250 mm/year), there is potentially enough moisture to grow both rainy and postrainy season crops if the soil has sufficient water holding capacity (Virmani et al 1981).

Kanzara Village

The difference in bph used for all three machinery and management systems for intercropping and rainy season sorghum was statistically not significant at the 5% level. As discussed earlier, though the field capacities of traditional implements were lower, the non-significant difference in bph was due to the difference in the number of operations on traditional flat and improved flat systems. At Kanzara, the Vertisols are normally deep-plowed (25-30 cm) once in 2-3 years using the system recommended by the Department of Agriculture. In other years only shallow cultivation with the blade harrow is done. Thus no plowing was done in the traditional flats. Other operations on the traditional flat were one cultivation with a blade harrow, sowing with the local seed drill, and two inter-row cultivations. Plowing was done in the improved flat.

The bph used in the improved flat and BBF systems were almost the same even though the additional operation of bed formation was done on the BBF system. As mentioned earlier, plowing on the improved flat was done using a single moldboard plow covering about 20 cm width in one pass as shown in **Fig. 8**. The greater time required for plowing on the improved flat made up for the extra operation of bed formation on the BBF system, resulting in non-significant difference in bph use.

The bph used in sequential cropping systems on traditional flat and improved flat systems was statistically significant at the 5% level. The remainder of the operations on both systems were the same for rainy and post-rainy season crops. The difference observed is mainly due to the lower field capacities of traditional implements. The BBF system required more bph compared to the improved flat, mainly due to the

additional operation of bed formation in the BBF system.

Shirapur Village

The bph used at Shirapur in the traditional flat system was significantly higher than in the improved flat system at the 5% level. In the intercropping system the number of operations done were the same for the traditional flat and improved flat. No plowing was done on either system. The significant difference in the bph used was due to lower field capacities of the traditional implements.

Fertilizer application on the traditional flat was done by using a local seed drill. Intercrop sowing was done by using a wooden bowl on a single bamboo tube having a metal piece at the bottom to open the furrow. This was pulled behind a blade harrow. Only one row was sown in one pass at 60 cm row spacing, which was the width of the blade harrow. Interrow cultivation was done by using a smaller-sized single blade harrow, thus covering one row spacing in each pass. On the improved flat all the operations covered 150 cm in one pass.

In the sequential cropping system on traditional flat, sowing and fertilizer application were done by using a local seed drill which covered about 90 cm in one pass. The major difference in bph use on traditional flat and improved flat in the sequential cropping system for post-rainy season crop, was due to separate operations of fertilizer placement and sowing in the former, and combined operations in the latter.

In the third cropping system (rainy season fallow and post-rainy season sorghum), the bph used in the improved flat was reduced drastically compared to that used in the traditional flat. The traditional practice of farmers in the Sholapur region is to repeat the blade harrowing 2-4 times during the rainy season. In this experiment, three cultivations with a 60 cm wide blade harrow were done, whereas the improved flat was cultivated only twice with five duck-foot sweeps covering 1 m. The fertilizer application, sowing, and seed covering were done as separate operations on the traditional flat. On the improved flat, the operations were combined using a wheeled tool carrier, thus greatly reducing bph use.

When the improved flat and BBF systems at Shirapur are compared, the RBD analysis of variance showed a significant difference at the 5% level in bph used. The bph requirement for the BBF system at Shirapur was much higher compared to that for the improved flat. This was mainly because of the additional operations of plowing, ridging, and bed shaping required in the BBF system. In the rainy season fallow and postrainy season sorghum, the improved flat seemed to be a better system because it required 78% less bph than both the BBF and traditional flat systems. In general, for all cropping systems, the improved flat needed minimum bullock labor because the ridging and bed shaping were not done. The wheel marks on the soil were so prominent that they were almost as visible as furrows. This might be an additional advantage for maintaining controlled traffic zones in improved flat systems.

Table 3 Cropping Yields under Different Machinery and Management Systems for Different Cropping Systems at Aurupalle, Kanzara, and Shirapur Villages (1978-79).

Village	Cropping systems	Machinery and management systems			
		Traditional flat with local implements	Improved flat with improved implements	Broad bed & furrow systems with improved implements	S.E. ±
		t/ha			
Aurupalle	Sorghum/Pigeonpea	1.3/0.2	1.7/0.4	1.7/0.5	0.02/0.02
	Pearl millet/ Pigeonpea	0.2/0.1	0.6/0.3	0.6/0.2	0.02/0.00
	Sole castor	0.4	0.6	0.7	0.01
Kanzara	Sorghum/Pigeonpea[1]	1.0/0.0	1.4/0.0	1.6/0.0	0.01
	Maize-safflower[2]	0.9-0.0	1.2-0.0	1.1-0.0	0.03
	Rainy season sorghum	0.9	1.0	1.2	0.01
Shirapur	Sorghum[3]/ Pigeonpea	0.0/1.3	0.0/1.7	0.0/1.7	0.02
	Mungbean-postrainy season sorghum	0.3-0.7	0.4-1.4	0.5-1.2	0.02-0.02
	Rainy season fallow-postrainy season sorghum	1.1	1.2	1.5	0.02

1) Pigeonpea crop failed due to dry spell at the time of flowering and pod formation and partly damaged by grazing cattle; 2) Safflower crop failed due to draught; 3) Sorghum crop failed due to severe shootfly attack.
Vertical line (/) indicates intercropping system.
Dash (-) indicates sequential cropping.

Crop Yields

The crop yields obtained from different machinery and management systems are presented in **Table 3**. On the traditional flat system at all locations, sowing was done by using traditional methods. On the improved flat and BBF systems, Ebra inclined plate planters were used with the wheeled tool carrier.

In Alfisols at Aurupalle, the sorghum and pearl millet yields from improved flat and BBF systems were the same and were 130% and 300% higher than on the traditional flat. The castor yield from the improved flat

system was 150% higher than the yield from the traditional flat. The yield difference between the improved flat and BBF systems was not significant at the 5% level. The yield of the sorghum pigeonpea intercrop on the improved flat was significantly lower than on the BBF system and significantly higher than on the traditional flat at the 5% level.

At Kanzara, the yields from the improved flat for sorghum/pigeonpea intercrop, sole maize, and rainy season sorghum were 127%, 133%, and 111%, respectively, of that obtained from traditional system. Yields on the BBF system for sorghum/pigeonpea intercrop, sole maize, and rainy season sorghum were 114%, 120%, and 91%, respectively, of that obtained from the improved flat system.

At Shirapur, sole pigeonpea yields on the improved flat and BBF were the same, and 130% of that from the traditional flat. The mungbean yield on improved flat was 133% of that from traditional flat, and on the BBF system it was 125% of that from improved flat. The yield of post-rainy season sorghum after mungbean on improved flat showed a 200% increase over the traditional flat. However, the post-rainy season sorghum grown after rainy season fallow on improved flat showed only a 105% yield increase. The yield of post-rainy season sorghum grown after mungbean, and rainy season fallow-post-rainy season sorghum grown on the BBF system were 85% and 125%, respectively, as compared to yield on the improved flat.

The yields of rainy season sorghum at Kanzara and rainy season fallow- post-rainy season sorghum at Shirapur in traditional flat showed very marginal differences compared to the yield on the improved flat. This might be due to the highly skilled persons being used for hand metering, and better seed placement. Yet the yield increases on improved flat were 111% and 109% respectively.

Table 4 Technology Components under Different Machinery and Management Systems at Aurupalle, Kanzara, and Shirapur Villages (1978-79).

Technology component	Machinery and management systems		
	Traditional flat	Improved flat	BBF
Crop varieties	Improved	Improved	Improved
Fertilizer	Improved	Improved	Improved
Row spacing	Traditional	Improved	Improved
Tillage implements	Traditional	Improved	Improved
Sowing implements	Traditional	Improved	Improved
Land management	Traditional	Traditional	Improved

An RBD analysis of variance for different crop yields showed a significant yield increase on improved flat when compared to traditional flat at the 5% level. The yield on the BBF system showed a significant increase compared to other management systems. The yield increase in the improved flat and BBF systems over traditional flat could be due to several factors such as better row-to-row spacing, improved tillage, and planting methods. **Table 4** shows the technology components under different machinery and management systems.

One of the reasons for significant yield increases on improved flat and BBF systems could be the precision seed placement by the Ebra planter. The Ebra planter has an inclined plate type metering mechanism which provides a considerable degree of planting precision. (ICRISAT annual report 1977). Roebuck and Trenerry (1978), Krall et al (1977), Farm Power and Equipment report of work (1978) have reported that precision planting increased the crop yield. This supports the hypothesis that precision planting and row-to-row spacings could be important factors to increase yield.

Economic Performance

The simplest way to compare economic performance is to compare the gross output from different machinery and management systems and compensatory yield increase (CYI) values. CYI is a value in Rs/ha required to pay for the increased cost due to improved machinery and management systems. The comparisons are made between traditional and improved flat systems, and between improved flat and BBF systems.

The gross output and CYI values in Rs/ha are presented in **Table 5**. Gross output values were calculated by using the yield data from **Table 3** and prices given in the footnote to **Table 5**. CYI values were calculated by using the bph/ha figures from **Table 2** and using the contract rate for bullock pair, operator, and implements as Rs. 15/day for traditional implements, a prevailing rate in villages used by Binswanger et al (1979) and Rs. 54/day for the wheeled tool carrier, bullock pair, and operator, assuming the machine is used for 80 agricultural days and 100 transport days as computed by Binswanger et al (1979).

The CYI value was calculated by using the following formula:

CYI= (bph/ha in improved flat) x (Contract rate, Rs/ha) – (bph/ha in traditional flat) x (Contract rate, Rs/ha) . . . . . (1)

CYI = (bph/ha in BBF system) x (Contract rate, Rs/ha) – (bph/ha in improved flat) x (Contract rate, Rs/ha) . . . . . (2)

The difference in the gross return minus CYI value gave an additional net income from one system compared to another and presented in **Table 6**.

At Aurupalle, CYI values (**Table 5**) were positive for all the three cropping systems, when improved flat and traditional flat are compared. This indicates that in order to shift from traditional to improved implements on flat, a yield

Table 5 Gross Returns and Compensatory Yield Increase Value (in parenthesis) in Rs/ha for Different Machinery and Management Systems (1978-79)

Unit: Rs/ha

Village	Cropping systems	Machinery and management systems		
		Traditional flat	Improved flat	BBF
Aurupalle	Sorghum/Pigeonpea	1670	2530 (227)	2780 (−10)
	Pearl millet/Pigeonpea	420	1260 (260)	1010 (−10)
	Sole castor	1000	1500 (157)	1750 (−18)
Kanzara	Sorghum (intercropping)	900	1260 (215)	1440 (0)
	Maize	720	960 (278)	880 (54)
	Rainy season sorghum	990	1100 (237)	1320 (−18)
Shirapur	Pigeonpea	3250	4250 (133)	4250 (135)
	Mungbean-postrainy season sorghum	1590	2680 (242)	2690 (108)
	Postrainy season sorghum	1320	1440 (8)	1800 (396)

Notes: a) Prevailing market prices during 1978-79 were used for calculation of gross return using yield data from Table 3. The prices in Rs/ton for different crops were hybrid sorghum −900, rainy season sorghum −1100, postrainy season sorghum −1200, castor, pigeonpea, and mungbean −2500, pearl millet −800, and maize −800. b) Pro-rated cost per day (8 h) for traditional implements with bullock pair and operator was Rs.15, Rs.54/day (5.4 h) for wheeled tool carrier and implements with bullock pair operator was used as calculated by Binswanger et al (1979). c) Figures in parenthesis are the compensatory yield increase (CYI) values required to offset the improved machinery and management systems cost. The bph figure in Table 2 are used for calculation of CYI.

Table 6 Net Income Difference between Machinery Management Systems.

Unit: Rs/ha

Village	Cropping systems	Machinery and management system	
		Improved flat* vs Traditional flat	BBF system** vs Improved flat
Aurupalle	Sorghum/Pigeonpea	633	260
	Pearl millet/Pigeonpea	613	240
	Sole castor	343	268
Kanzara	Sorghum (intercrop)	145	180
	Maize	−38	−134
	Rainy season sorghum	−127	238
Shirapur	Pigeonpea	867	−135
	Mungbean-postrainy sorghum	848	−98
	Postrainy sorghum	112	−36

* Increase or decrease in net income from improved flat compared to traditional flat;
** Increase or decrease in net income from BBF system compared to improved flat.

increase of castor, sorghum and millet/pigeonpea intercrops of Rs.157, 227 and 227 per ha, respectively, is necessary to compensate for the increased costs of improved implements. The net additional income (Table 6) indicates that the improved implements can replace traditional implements at Aurupalle without any economic loss.

When BBF and improved flat systems were compared, the CYI values were negative for all three cropping systems. This means that the BBF system can replace improved flat system even if there is no yield increase. The BBF system showed an increase in net additional income from castor, sorghum and millet/pigeonpea of Rs. 268, 260, and 240 per ha, respectively. Thus the data indicate the advantages for shifting to BBF system at Aurupalle.

At Kanzara, a comparison of the improved and traditional flat systems showed positive CYI values (Table 5) and the need for yield increase on improved flat from all three cropping systems. The net additional income (Table 6) from maize and rainy season sorghum was negative. This indicates that shifting from traditional flat to improved flat for these two crops was uneconomical. The net additional income from intercropped sorghum was positive.

A second comparison between BBF and improved flat showed zero CYI value for sorghum, so there was no need for a yield increase from the BBF system. The CYI value for maize was Rs. 54/ha, and negative for rainy sorghum. Maize from the BBF system showed a negative value when compared with improved flat. There was a Rs. 180 increase for intercropped sorghum and Rs.238 for rainy season sorghum from the BBF system over the improved flat.

At Shirapur, a comparison between improved and traditional flat showed positive CYI values (Table 5) for all three cropping systems. The CYI value for post-rainy sorghum was Rs.8/ha, which is marginal. The net additional income per ha (Table 6) from pigeonpea was Rs.867, mungbean/postrainy sorghum Rs.848 and postrainy sorghum Rs.112. This clearly indicates the economic benefits in shifting from traditional to improved flat.

When BBF and improved flat were compared, the CYI values were positive for all three cropping systems and the net additional income was negative. This indicates that at Shirapur the BBF system was not economical compared to improved flat.

Conclusions

1. In Alfisols at Aurupalle, the bph use was reduced by an average of 50% by using the wheeled tool carrier on flat and BBF systems compared to the traditional system. This was primarily due to the narrower width of coverage by local implements and thus lower field capacity.
2. In Vertisols at Shirapur, the improved flat system required the minimum bph because of fewer operational requirements than the BBF system and higher field capacities of the wheeled tool carrier compared to local implements.
3. In medium deep black soils at Kanzara, the difference in bph

used in intercropped and rainy season sorghum for all three machinery and management systems was not significant, primarily because there was no plowing operation, and comparatively fewer operations on the traditional flat. The significant difference in the sequential cropping system was due to higher bph used in the traditional flat (mainly the repeated blade harrowing), and lower field capacities of local implements.

4. Increased crop yields on improved flat over traditional flat might be due to several factors such as positive seed metering and placement by using a precision planter with the wheeled tool carrier, better row-to-row spacings, and improved tillage implements used in the improved flat system. In general, no significant yield increase was observed from the BBF system over the improved flat. Slight differences might possibly be due to land management factors referred to in **Table 4**.

5. Economic performance of different machinery and management systems indicates that at Aurupalle, the improved flat was more economical than the traditional flat, and BBF system was economically superior to improved flat for all three cropping systems. At Shirapur, the improved flat system was more economical than the traditional flat and the BBF system, due to lower field capacities of local implements and more operations required in the BBF system. At Kanzara, the improved flat did not show any economic benefit when compared to the traditional flat. The BBF system gave slightly higher benefits though not significant over the improved flat for intercropped sorghum and rainy season sorghum.

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Evaluation of Manual Planters for Selected Crops in West African Savanna

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Abstract

This paper compares three manually operated planters and the traditional method of planting by hand and heel commonly used in the region. The autofeed jab planter has no significant advantage over the traditional planting method while the two rolling punch planters have definite advantage in respect of man-h/ha requirement. However, some improvements in all these machines are required.

Introduction

Improvement in planting techniques can ensure adequate establishment of uniform crop stands and make subsequent operations more effective and thus increase yield. Variable climatic conditions in many areas of the West African Savanna regions cause available water to be a limiting factor and thus make timely planting an important operation. The slow traditional hand planting method limits the area that a farmer can plant at the optimum time. In addition, the traditional method is physically demanding; most farmers retire home after a day's planting with serious back pains.

In the Savanna regions of Africa the average farm size is from 1.0 to 3.0 ha, and generally mixed cropping pattern is followed (1). The hope for increased holding is not bright if the farmers continue with the physically taxing traditional methods of farming. The drudgery associated with this type of farming has also discouraged many young prospective farmers who have drifted into the urban areas. Thus the most serious production constraint is the acute shortage of labour during the peak periods, particularly for planting and weeding (1, 2).

Apart from labour requirement, farmer's constraints in production include cost and time and also inadequacy of proper tools and equipment. Thus, there exists a high potential for mechanizing some cropping operations to improve land and labour productivity and reduce physical drudgery.

Farmers with small holdings cannot afford to purchase expensive planters such as tractor/animal-drawn or integral planters. In addition, in these regions there are no feeder roads to transport such equipment to most farms. So efforts were made to design small manually-operated planters and manufacture them locally (7, 8). This paper presents the results of some experiments conducted with three manually operated planters and compares them with the most common traditional planting method used by farmers in the Savanna regions.

Review of Literature

Planting coupled with seedbed preparation is one of the most critical operations in crop production. It is a vital factor in obtaining dependable stands and it affects subsequent cultural practices, including harvesting. The optimum number of plants per unit area for different crops depends on a number of factors among which is the availability of plant nutrient (3). The optimum number of corn plant population varies between 3 and 5 plants/m^2. At a lower nitrogen level a lower population is required while at a higher nitrogen rate a higher population is required for maximum yield (4). Seventy five cm rows were found best suited for corn and lodging was found to be greater for plants in 100 cm rows (5).

The optimum plant population per unit area and spacing of sorghum are dependent on the amount of moisture available, the fertility

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of the soil and the size of the variety being grown. Depending on location within the Savanna zone, plant population varies from a low of 30 000 plants per ha in the Sahel zone to as high as 50 000 plants per hectare in the Northern Guinea Savanna (6). Optimum population is needed for optimum yield but farmers in savanna regions plant at 60 cm spacing in intra-row and 91 cm inter-row cultivation which gives about 18 000 plants per ha which is about half or one-third of the recommended population.

Though many types of planters and drills are available most of them are not suited to small scale farmers in the Savanna regions because of the reasons already stated and also including the high initial cost. A local firm developed some planters for local farmers, including an auto-feed jab planter. The same firm is also producing the IITA/VITA type rolling punch planter. Another version of the same IITA/VITA rolling punch planter is being marketed by the Masdar (Nigeria) Limited, but made in U.K. All these three machines were evaluated under Savanna conditions (Samaru, Zaria, Nigeria). Effects of planting techniques on time required for planting, seedling distribution along a row, operational difficulties, and planting depth were studied. The crops selected were maize and sorghum.

Description of the Planters

Auto-Feed Jab Planter

This is a hand-operated jab planter (**Fig. 1**) manufactured by the Pure-thought Engineering Enterprises. It has a handle, a seed box, a circular seed metering plate with holes and actuated by a ratchet mechanism, and the body of the planter which ends with lips. Four different seed plates are available for different crops, e.g., maize, groundnut, rice, soyabean, cowpea, sorghum, etc. It can be operated by pushing/jerking the lips into the ground gently and pushing the handle forward and then lifting off the ground briskly.

Rolling Punch Planters

Two makes (Pure-thought and Masdar) were studied (**Figs. 2-3**). Both were manufactured by adopting the IITA/VITA design. Each has six injectors which are installed on the periphery of a wheel is attached to the machine which closes the holes made by the injectors. The Pure-thought rolling punch planter has hexagonal wheel while the Masdar has circular wheel which is the major difference. Another difference is in the punch configuration: Masdar design has flat edges while the Pure-thought has edges at both sides looking rectangular. The metering rollers for Masdar is made of solid hard nylon while that of Pure-thought is made of hard wood.

Methodology

The three machines were used to plant either maize or sorghum in either flat bed or ridged fields along with the traditional method of planting. Initially, the field was prepared by disc plowing once (6″ deep), and disc harrowing twice. Then the ridged plots were ridged by a mouldboard ridger (90 cm ridge spacing). All these operations were done by a 35 kW 4-wheel tractor and the matching implements. No fertilizer or herbicides (pre- or post-emergence) were used. Experiments were laid out according to the randomized complete block design. Before field experiments, laboratory tests on each machine were conducted to calibrate the machines and to determine if any damage is done to the seeds after passing through the machines. The planting in the specified plots was done by the machines. Traditional planting by hand and heel were also done for both crops in both flat and ridged plots. Data were collected for clod size distribution, moisture content, plant stand count (after 10 to 15 days of planting), missing

Fig. 1 Pure-thought auto-feed jab planter.

Fig. 2 Pure-thought rolling punch planter.

Fig. 3 Masdar rolling punch planter.

stand and depth of planting.

Results and Discussion

In the laboratory the auto-feed jab planter dropped 0 to 6 maize seeds with an average of 1.6 to 4.0 seeds per drop and 0 to 9 sorghum seeds with an average of 2.5 to 5.7 seeds per drop. The quantity of seeds per ha depends on the row spacing and the plant to plant distance in a row. After passing through the machine the viability of the maize seed was not reduced while the vaibility of sorghum seed was reduced by 1.5%.

The Pure-thought rolling punch planter at the laboratory dropped 1 to 3 maize seeds/hill and 52 to 104 sorghum seeds/hill. When calculated for 90 cm ridges/rows it would give a seed rate of 18.3 kg/ha for maize and 129.8 kg/ha for sorghum. After passing through the planter the viability of maize seed remained the same while the viability of sorghum seed decreased by 3.5%. About 3% sorghum seeds were found broken when passed through the machine. It may be mentioned here that for sorghum the "Rice and Bean" metering roller was used as there was no specific sorghum roller.

In the laboratory the Masdar rolling punch planter dropped 0 to 5 maize seeds/hill and 2 to 5 sorghum seeds/hill when No. 4 and No. 2 metering rollers were used, respectively. Five metering rollers were supplied with Masdar: No. 1 being with smallest holes while No. 5 having the largest holes. When calculated for 90 cm rows/ridges, the seed rates given by the machine were 22.2 kg/ha for maize and 5.0 kg/ha for sorghum.

The clod size distribution of different plots are given in Fig. 4, and for all plots these were the same. The plant distribution for each planter and the traditional method are shown in Figs. 5, 6, 7

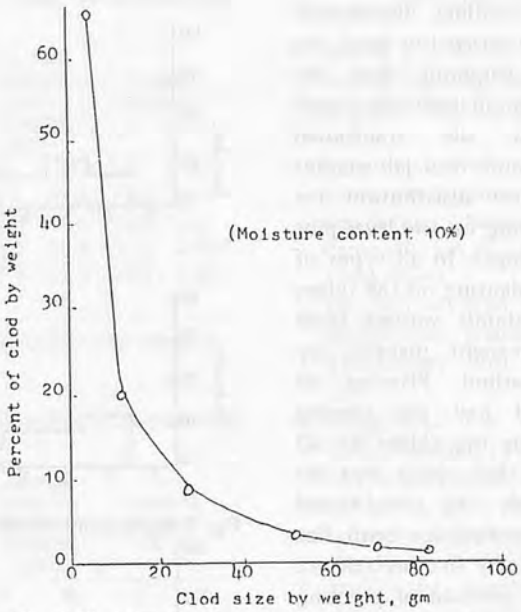

Fig. 4 Clod size distribution of plots.

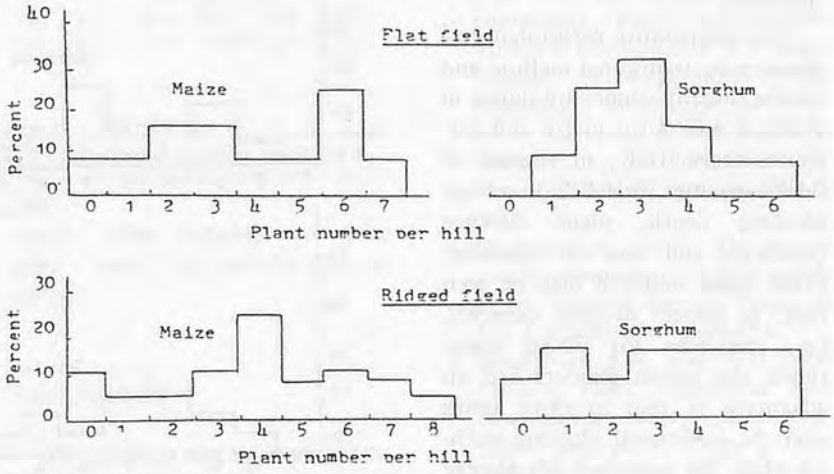

Fig. 5 Stand count distribution for auto-feed jab planter.

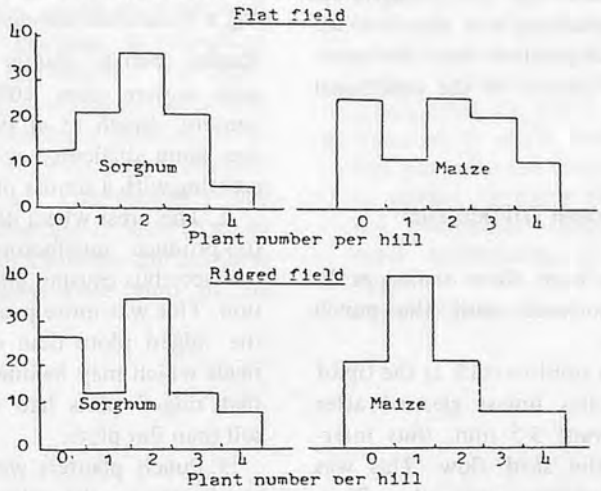

Fig. 6 Stahd count distribution for Masdar planter.

and 8. The seedling distribution along the row varied too much for planting of sorghum than for maize in cases of both the punch planters and the traditional method. The auto-feed jab planter gave a uniform distribution for sorghum planting on the level plot but not on ridges. In all types of planting, the planting on the ridges had missing stands varying from 10 to 28% except planting by traditional method. Planting on the flat field had less missing stands than on the ridges by all the machines but there was no missing stands by traditional method of planting for both flat and ridged plots. In this respect the traditional method of planting was better than all the three machines.

The comparative performance of planting by traditional method and by the three machines are shown in Tables 1 and 2 for maize and sorghum, respectively, in respect of field capacities (man-h/ha), average planting depth, plant distance (spacing), and cost of planting. From these tables it may be seen that, in respect of field capacity, i.e., man-h/ha for 90 cm rows/ridges the punch planters had an advantage of two to three times over the traditional planting method while the auto-feed jab planter had no advantage. Accordingly, the cost of planting was also low for the punch-planters than the auto-feed jab planter or the traditional method.

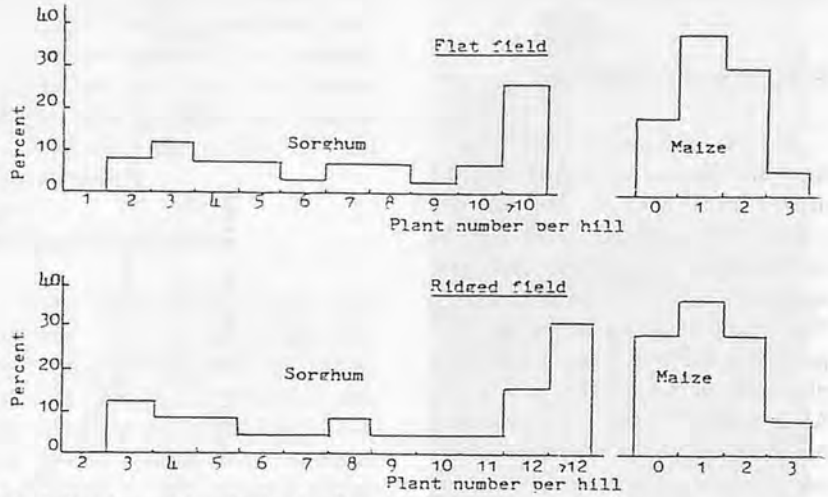

Fig. 7 Stand count distribution for Pure-thought rolling punch planter.

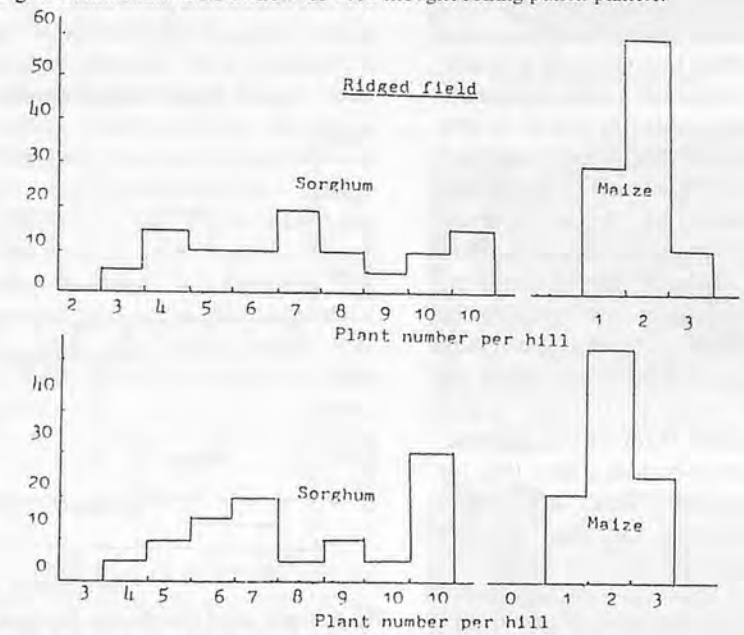

Fig. 8 Stand count distribution for traditional planting.

Operational Difficulties

There were three major problems associated with the punch planters:

1. Soil used to stick at the tip of the punches unless cleaned after almost every 3-5 min. thus interrupting the seed flow. This was more frequent with the Pure-thought punch planter than the Masdar punch planter and with soils wetter than 10% moisture content. Singh et al (9) observed the same difficulty while experimenting with a similar planter.

2. The press wheel did not seem to produce satisfactory seed-soil contact thus causing poor germination. This was more pronounced in the ridged plots than on the flat fields which may be due to the fact that ridged plots had more loose soil than flat plots.

3. Punch planters were difficult to operate on the ridged plots because of the difficulty in walking on the ridge crown. This difficulty was greater in the case of the Masdar planter than the Pure-thought planter.

Other problems associated with the planters were:

1. The Pure-thought auto-feed jab planter was difficult to operate in wet soil (15% m.c. or more) particularly because of its tip which would fill up with soil (blocked by mud) thus causing interrupted seed flow unless cleaned. It works better for loose and dry soil but not too loose soil where it bogs down too much. Once in a while the seed

Table 1. Comparative Performance of Planting Maize on Flat (F) and 90 cm Ridge (R) Plots by Different Method/Equipment.

Planting method/ equipment	Field capacity (man-h/ha.)		Average depth (cm)		Average plant to plant distance (cm)		Cost of planting* (N : K)	
	F	R	F	R	F	R	F	R
Traditional	10.5	10.6	2.5	2.6	79.5	83.4	7.96	8.03
Auto-feed jab	10.4	11.7	4.0	5.5	59.5	56.5	7.89	8.87
Masdar punch	2.8	6.5	3.7	4.2	38.7	30.9	2.12	4.93
Pure-thought punch	2.7	2.5	4.1	4.0	33.7	33.9	2.05	1.90

* Cost of planting is given on the basis of ₦4.55/day/person a 6-h day. One Nigerian Naira is equivalent to 1.5US$.

Table 2 Comparative Performance of Planting Sorghum on Flat (F) and 90 cm Ridged (R) Plots by Different Method/Equipment.

Planting method/ equipment	Field capacity (man-hrs/ha)		Average depth (cm)		Average plant to plant distance (cm)		Cost of planting* (₦: K)	
	F	R	F	R	F	R	F	R
Traditional	9.2	8.3	2.5	2.6	61.2	55.0	6.98	6.29
Auto-feed jab	8.7	10.3	3.5	5.5	50.0	66.0	6.60	7.81
Masdar punch	2.7	5.2	3.8	4.2	29.6	36.2	2.05	3.94
Pure-thought punch	2.6	3.5	4.1	4.3	5.0	10.0**	1.97	2.65

* See note in Table 1.
** Planting sorghum by Pure-thought punch planter was almost like a drill as the seeds were coming out from the sides of the roller. No adjustment could be made. As a result, plant to plant distance was small and there was no missing stand (see Fig. 7).

plate would jam due to seeds going under it and thus breaking them. The seed cutting mechanism has to be improved.

2. The Masdar punch planter was found to bog in a machine-prepared ridged field due to its weight. This was more pronounced for light soils than heavy soil or when the soil has settled after a heavy shower. However, it should be made lighter for proper functioning.

3. The Pure-thought punch planter was light enough and was easy to operate in ridged field but the assembly and disassembly of the machine was difficult due to its shaft sticking with other parts. Its press wheel was so light that it could not cover the seed, particularly when planting was done after a heavy rain and the soil had settled.

Conclusions

The performance of three manually operated planters was compared with the common traditional method of planting. In respect of man-h/ha requirement, the auto-feed jab planter had no advantage over the traditional planting method while the two punch planters (Masdar and Pure-thought) had definite advantage of about two to three times. However, all the three planters need some kind of improvement.

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Spray Characteristics of a Rotary Atomizer

by
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Abstract

The drop distribution pattern of a hand-held rotary atomizer (Herbi-Ulva, Micron Sprayers, U.K.) is examined. Results indicate that the drop size produced is dependent on the rheological properties of the liquid, and the rotor characteristics; and a very uniform drop distribution pattern was obtained.

Introduction

In contrast to conventional hydraulic nozzles, rotary atomizers produce sprays with a narrow range of drop diameters; and, therefore, offer the advantages of better drift control and more efficient utilization of spray chemicals. While a considerable volume of work has been conducted on this subject (Bals[1], Frost[2], Bode et al[3], Kamiya and Kayano[4]), it is difficult to evaluate the expected drop diameter for a specific system. For example, Frost[2] defined drop diameter (d) as follows*.

$$d = 1.87(Q^{0.44} \cdot \sigma^{0.15} \cdot \mu^{0.017}) / (D^{0.8} \cdot \omega^{0.75} \cdot \rho^{0.16}) \quad (1)$$

while Bals[1] quoted the following equation:

$$d = (3.8/\omega) \cdot \sqrt{6/D\rho} \quad (2)$$

On the contrary, Kamiya and Kayano[4] produced two different equations, depending on the viscosity of the liquid, as follows:

If $\mu < 20 mNs/m^2$ then

$$d = 2.D\,(6/\rho.\omega^2.D^3)^{0.5} \quad (3)$$

If $\mu > 20\ mNs/m^2$ then

$$d = 2.1\ D\,(6/\rho \cdot \omega^2 \cdot D^3)^{0.5} (\mu \cdot Q/\rho \cdot D^2)^{0.3} \quad (4)$$

This paper investigates the effects of various system parameters on the drop size distribution produced by a hand-held rotary atomizer (viz. Herbi-Ulva, Micron Sprayers, U.K.)

Experimental Work

Equipment

The present study evaluates the drop distribution pattern obtained from a Herbi-Ulva rotary atomizer: a battery operated hand-held rotary atomizer, with a simple on-off switch, offering no control over disc speed. The liquid is gravity fed to the rotating disc via a nozzle orifice; and the flow rate can be varied by altering the nozzle diameter used. The disc, which is made of plastic, has a grooved surface and serrated edge (**Fig. 1**). The latter produces needle-like points from which the liquid leaves the disc (viz. zero issue points). A laboratory rig was constructed (**Fig. 2**) in which the rotary atomizer (**Fig. 1**) was mounted on a bar-frame; and high speed flash photography was used to "freeze" the spray drops in flight. The speed of rotation of the disc was obtained using a non-invasive stroboscopic tachometer. The resultant photographic prints were analyzed using a Carl-Zeiss particle size analyzer (model cz 2378).

Technique

The drop size distribution produced by a rotary atomizer is dependent on the following parameters: liquid flow rate, viscosity, surface tension and density; and the disc speed, diameter and design. As the two latter items (viz. disc diameter and design) are fixed entities in this type of sprayer, these were excluded from the analysis. Dimensional analysis was used to evaluate the effects of the five remaining parameters on the drop size distribution obtained. This reduced the number of independent variables to two as follows:

* Notation:
d = drop diameter (m)
D = rotor diameter (m)
kd = vmd/nmd
nmd = number median diameter (m)
vmd = volume median diameter (m)
Q = liquid flow rate (m^3/s)
ρ = Density (kg/m^3)
σ = Surface tension (N/m)
μ = viscosity (NS/m^2)
ω = rotor speed (rad/s)

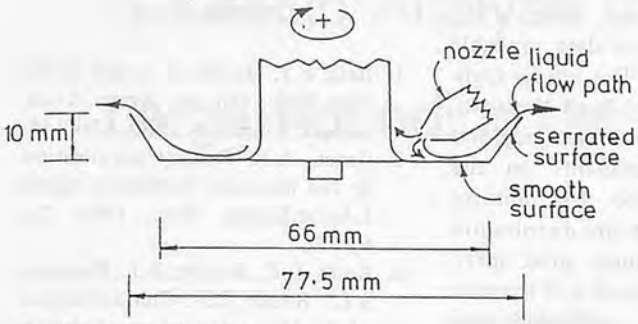

Fig. 1 Rotary atomizer cross-section.

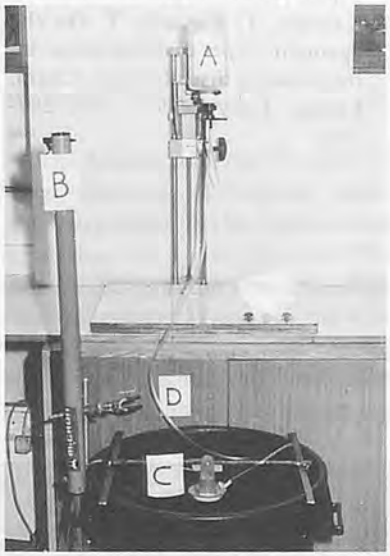

Fig. 2 The laboratory rig: The liquid in the container (A) is gravity-fed through the plastic tube (D) to the rotary atomizer (C) which is mounted on a bar frame. The batteries for operating the atomizer motor are housed in the tube (B).

$$F\left[\frac{\sigma^3}{\mu^3 \cdot \omega^2 \cdot Q}, \frac{\rho\sigma^2}{\omega\mu^3}\right] = 0 \quad (5)$$

The rheological properties of the liquid (viz. density, surface tension and viscosity) were varied by using different mixtures of water, glycerol and a non-ionic surfactant (Table 1). As indicated previously, no control mechanism was available to alter disc speed; however, variations occurred due to changes in liquid flow rate and viscosity.

Mode of Drop Formation

It is well documented (Frost[2]) that drop formation may take place at the edge of a spinning disc by three different modes as outlined below:

Mode 1 – Direct drop formation, where drops of fairly uniform size are produced directly from the edge of the disc, from the zero issue points.

Mode 2 – Mixed mode, which is a mixture of modes 1 and 3.

Mode 3 – Ligament mode, where ligaments of the spray liquid extend over the disc edge, and eventually disintegrate, with consequent drop formation.

The transition from one mode to another is dependent on many system parameters, but, in general, increasing the liquid flow rate (while everything else is constant) causes a progressive change from model 1, through 2 to 3. One of the major objectives of this study was to evaluate the criteria for transition.

Results

An examination of the photographic prints reveals that only two drop formation modes occurred in these experiments (viz. modes 1 and 2). This was primarily due to the relatively low flow rates (1 to 5 ml/s) and rotor speeds varied from 149 to 160 rad/s. The results indicate that direct drop formation (viz. mode 1) occurs if:

$$\omega Q \rho \sigma^{-1} < 6.7 \quad (6)$$

while the mixed mode (mode 2) occurs if:

$$\omega Q \rho \sigma^{-1} > 6.7 \quad (7)$$

Drop Size

An analysis of the drop size data shows that different criteria are obtained, depending on the mode of drop formation (viz. mode 1 or 2).

The number median diameter (nmd) was used as the measurement of drop size. In the direct drop formation mode (viz. mode 1) nmd is given as:

$$\text{nmd} = 3758\left[\sigma^{0.58}\ \rho^{-0.76}\ \mu^{0.18} \cdot \omega^{-0.64}\ Q^{-0.7}\right]\mu\text{m} \quad (8)$$

$R^2 = 0.89$

while in the mixed mode (viz. mode 2) nmd is given as:

$$\text{nmd} = 178\left[\sigma^{0.339}\ \rho^{-0.045}\ \mu^{-0.295} \cdot Q^{-0.143}\ \omega^{-0.241}\right]\mu\text{m} \quad (9)$$

$R^2 = 0.96$

For example, the expected nmd under the conditions outlined below, is 484 μm.

$Q = 5 \times 10^{-6}$ (m^3/s)
$\omega = 150$ (rad/s)
$\mu = 2.2 \times 10^{-3}$ (NS/m^2)
$\rho = 1.08 \times 10^3$ (kg/m^3)

Table 1 Properties of Liquids Used in the Present Study

Glycerol (kg/m^3 of solution)	Volume of "Nonidet" * (%)	Surface Tension $(N/m)10^{-3}$	Viscosity $(NS/m^2)10^{-3}$	Density $(kg/m^3)10^3$
0	0	71.5	0.8509	0.997
0	0.1	31.0	0.5678	0.9974
300	0	47.5	2.2492	1.0768
300	0.1	30.4	2.1847	1.0721
500	0	46.5	4.5412	1.1203
500	0.1	32.6	4.7062	1.1227

*"Nonidet" is a non-ionic surfactant (viz. an octyl phenol ethylene oxide condensate).

$\sigma = 48 \times 10^{-3}$ (N/m)

The variation in drop size produced during each test was evaluated by calculating the ratio of the volume median diameter (vmd) to the number median diameter (nmd): A value of less than 1.5 for this ratio (kd) implies quite uniform drop size distribution. In this study, the maximum and minimum values obtained were 1.14 and 1.03, respectively. This implies that, in all cases, a very uniform distribution of drop sizes was produced.

Discussion and Conclusions

The variations in transition and drop size equations reported in the literature make it difficult to predict the expected drop size distribution for this rotary atomizer. The results outlined in this study are specific to the rotary atomizer used (Fig. 1), and there is no directly comparable data available in the literature. The results highlight the effects of both the rheological properties of the spray and the sprayer adjustments on the drop size produced. The uniform nature of the drop size distribution (kd $\leqslant$ 1.14) ensures good spray utilization and reduced drift hazard.

The following conclusions can be drawn from this study:

1. Equations were developed which determine the mode of drop formation (viz. direct or mixed) (equations 6 and 7).

2. The drop size produced by this rotary atomizer is dependent on the rheological properties and flow rate of the liquid, the disc speed and the drop formation mode (equations 8 and 9).

3. The Herbi-Ulva sprayer produces a very uniform drop distribution pattern (kd $\leqslant$ 1.14).

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A Kinetic Analysis of Large Rounding Jet-Irrigation Apparatus

by
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Abstract

The kinetic analysis of a 417 m long rounding jet-irrigating apparatus was made. In the conventional apparatus, the driving motors often are burned and the main pipes are bent or cracked. Hence in the new innovation a new sensor for control signal was designed and the motion of irrigation apparatus became a normal operation.

Introduction

Jet-irrigation saves about 60% of the water used in comparison with application of the spread-irrgation. Hence, it is an important way for conserving energy. There are three classifications of jet-irrigating apparatus in China: i) a small jet-irrigation device, consisting of pump driven by 2.7-3 kW motor, and a single jet-gun. All the device sets on a vehicle for convenient transfer from one garden to another. This is a popular device in most vegetable gardens in the suburban areas; ii) a large jet-irrigation apparatus made of multi-jet pipes, the total length of which is 500 m. It is often equal to the width of strip of land reclaimed by the national farm recently. Between strips of land is an irrigation canal and the movement of thie jet-irrigating apparatus is parallel to the canals; iii) a large rounding jet-irrigation apparatus which is the subject of this paper. It consists of 10 joints of pipes, supported by moving supporting framework-pagodas: central pump station that draws water either from a well or through the canals, and a power source, – a diesel engine that provides electro-energy for the 10 driving motors each mounted on supporting frameworks (Fig. 1).

This kind of rounding jet-irrigation apparatus is appropriate for the multi-hill physical features of land in southeast China, including the province of Kwangsi. In the hillocks of Kwangsi sugarcane is planted which uses jet-irrigation apparatus. One rounding jet-irrigation apparatus may irrigate 54 ha: ($A = \pi L^2 = 417^2 \pi = 54$ ha)

These jet-irrigation apparatuses have been manufactured in 1978-1980. During operation some main pipes used in the apparatus often are bent or cracked and some electric motors, driving the supporting framework-pagodas, are burned due to overloading. Hence, a kinetic analysis that this paper reports on has been undertaken in solving these problems.

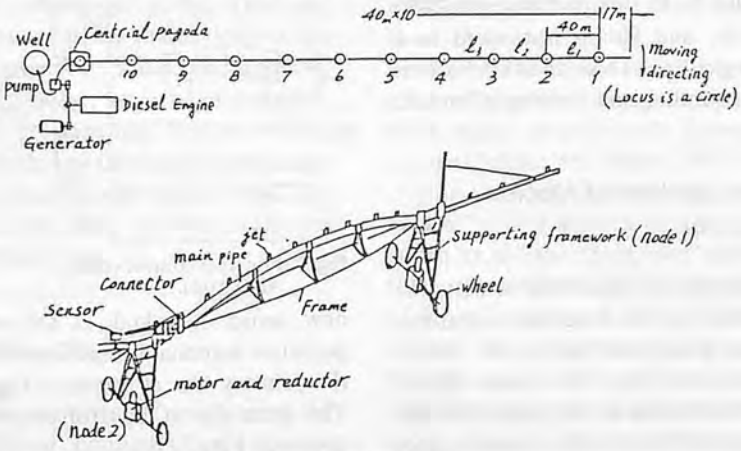

Fig. 1 Layout and assembled jet-irrigation apparatus.

Kinetic Analysis of Irrigation Device

Analysis of Movement – Assume that the rounding jet-irrigation apparatus moves on the level ground. Hence the nodes (i.e., the supporting frameworks) 1-10 are located in a straight line when the irrigation apparatus stands in static position. Now, a signal commanding the node 1 to move in Clockwise direction comes, if other nodes do not move, then the locus

of node 1 is a circle-arc S_1, corresponding to the center and radius are the node 2 and ℓ_1, respectively. Obviously, S_1 does not comform with the locus of all-over irrigation apparatus in motion S (**Fig. 2**).

Clearly, because of arc S_1 corresponding to angle ϑ, which is used for providing the information making the node 2 (i.e., the second supporting framework) in following the motion. Due to the fact that the speed of every supporting framework designed is identical, then $S_1 = S_2 = S_3 = ...$, i.e., the pipe ℓ_1 is moved from 2-1' to 2'-1" in parallel and the pipe ℓ_2 is turned around node 3 in a similar angle as ϑ.

It will be shown in **Fig. 2** that the bending line 1-2-3 is longer than straight line 1"-2'-3 and the wheels of supporting frame-pagoda 1 (i.e., node 1) cannot move in a direction normal to arc S_1 or S_2, then in both of pipes ℓ_1 and ℓ_2 must cause the axial force, which is a variable and it equals to zero as in state 1'-2-3 and equal to maximum as in state 1"-2'-3. This force deforms both pipes ℓ_1 and ℓ_2. Thus it is

$$F_1 = F_2 = k\delta \qquad (1)$$

Here F_1 and F_2 are the forces in the pipes ℓ_1 and ℓ_2, respectively; k is coefficient of stiffness of the main pipe with frame, it is

$$k = \frac{E \cdot A}{\ell} \qquad (2)$$

$E = 2 \times 10^6$ (kg/cm^2) is an elastic module for the steel; A = 21.6 (cm^2) is the section of the main pipe with the frame; ℓ = 4000 cm = $\ell_1 = \ell_2 = \ell_3$ and δ is the axial deformation of the main pipe.

From **Fig. 2** it is

$$\delta = \ell\,(1 - \cos\frac{\vartheta}{2}) = 4000 \times 0.001 = 4 \text{ cm} \qquad (3)$$

here the detecting angle $\vartheta = 5°$.

Clearly, the total deformation of the jet-irrigation apparatus equals to 40 cm, which makes the practical motion locus turn away from the ideal. Therefore, the axial deformation of the main pipes causes the bends and cracks.

To substitute (2) and (3) into (1) obtain

$$F_1 = F_2 = 43200 \text{ kg} \qquad (4)$$

In fact, these forces are provided by driving motors through the speed reducer and wheels. Hence, this force is a geometrical sum or can be represented as shown in **Fig. 3**.

$$F_{max} = 2F_1 \cdot \sin\frac{\vartheta}{2} = 3768.7 \text{ kg} \qquad (5)$$

Clearly, F_{max} decreases with a decrease in angle ϑ and equal to zero as ϑ=0, i.e., in case of condition 1"-2'-3. Due to the present force, F_{max} the driving motor is overloaded causing the motors to burn out.

Effect of Land Condition – As mentioned earlier, sugarcane in Kwangsi province where this irrigation device is used is planted on undulating surfaces and hillsides. Therefore, some supporting framework-pagoda need to be able to move without difficulty alongwith the contour. As illustrated in **Figs. 4** and **5**. In this moment the pipes ℓ_1, ℓ_2 and ℓ_3 do not stand in a straight line. This condition hastens pipe bending and burning of motor.

New Method of Motion Control

From the preceding section, the motion of the irrigation apparatus is an important key to its proper operation. But the main factor that determines the motion is the sensor of the motion control signal which needs to be modified. The new sensors, locked as the telegraphical antenna, is used instead of the primary one as shown in **Fig. 6**. The principle of control circuit is shown in **Fig. 7**.

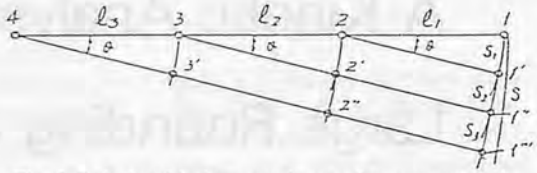

Fig. 2 Relationship between locus of movement and node positions.

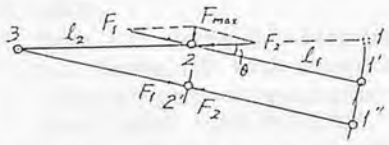

Fig. 3 Geometrical sum of force.

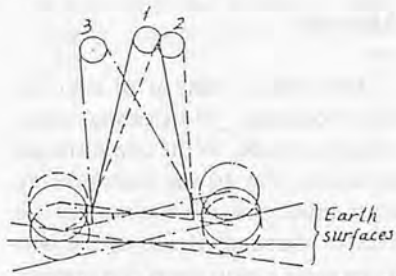

Fig. 4 Illustrated motion of nodes based on landslope.

Fig. 5 Undulating land surface that disables control signal to command node positions.

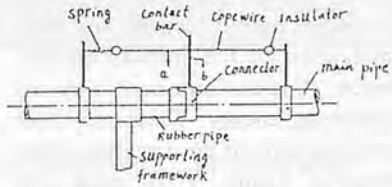

Fig. 6 Sensor of control on nodes 2-10.

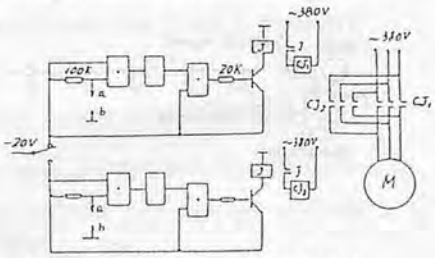

Fig. 7 Principal control circuit. ("·": AND gate).

Comparison of Axial-Flow and Centrifugal Pumps for Low-Lift Irrigation

by

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Abstract

Small engine-driven pumps are utilized for low-lift irrigation on small farms in many developing countries. Although centrifugal pumps are most common, axial-flow pumps are widely used in Vietnam and Thailand. The objective of the present study is to compare the performance and costs of centrifugal and axial-flow pumps for low-lift (less than 3 m) irrigation.

The pumping efficiency of the axial-flow pump is observed to be substantially higher than that of the centrifugal pump for lifts (static heads) of 3 m or less. Therefore, the fuel required to pump a specified quantity of water is lower for the axial-flow pump than for a centrifugal pump. This, and the fact that the initial costs of the two pumping units are approximately equal, have been considered in an economic analysis which demonstrates that axial-flow pumps have significantly lower total annual costs than centrifugal pumps for lifts of 3 m.

Introduction

The majority of small farms in developing countries are not serviced by irrigation systems and therefore must rely on rainfall which, in many instances, is supplemented by pumps or other small-scale irrigation technologies. For centuries, pumps have been an economically and culturally accepted technology in many areas (Wood, 1976), especially where the water source lies only a few meters below the field level. Consequently, there is a wide variety of designs of low-lift irrigation pumps, i.e., pumps for lifting water less than 3 m.

Low-lift pumps are powered by a wide range of power sources, including man, animal, wind, water, sun, internal combustion engines, and electric motors. Utilization of engine-powered pumps has increased markedly, partly because for intensive irrigation these units are generally more economical than human, animal, or solar powered pumps and have broader areas of potential application than wind, water, or electrically powered pumps (Eckaus and Potter, 1977).

For low-lift applications, the most efficient engine-powered pump is the axial-flow "propeller" pump (Streeter and Wylie, 1975). Because of its efficiency and ease of fabrication, the axial-flow pump has become popular in Vietnam and Thailand where there are extensive areas suitable for low-lift pumps and the technology is similar to that of boat engines which are serviced by thousands of workshops in both countries. The axial-flow pump is essentially an outboard motor with its propeller reversed and placed inside a tube which serves as the casing of the pump (**Fig. 1**). The pump is mounted so that it cannot move, hence the power delivered to the propeller goes to moving (pumping) water rather than to propelling a boat.

In Vietnam, the impact of the axial-flow pump has been remarkable. Four years after the pump was introduced in 1963, about 50000 units were being used in the upper delta region of the Mekong Delta, and it has been estimated that these pumps were responsible for a 40% increase in agricultural production (Sansom, 1969). By increasing cropping intensity, the pumps were extremely profitable (e.g., the initial cost was recovered in the first year of operation) and significantly increased the demand for farm labor. In Thailand, 1969 data indicate that the sales price of the axial-flow pump was approximately 1/3 that of a centrifugal pump of equivalent size, and the production was estimated to be 47000 units per year (USOM, 1970). In Vietnam and Thailand, the pumps are produced locally with keen competition among a

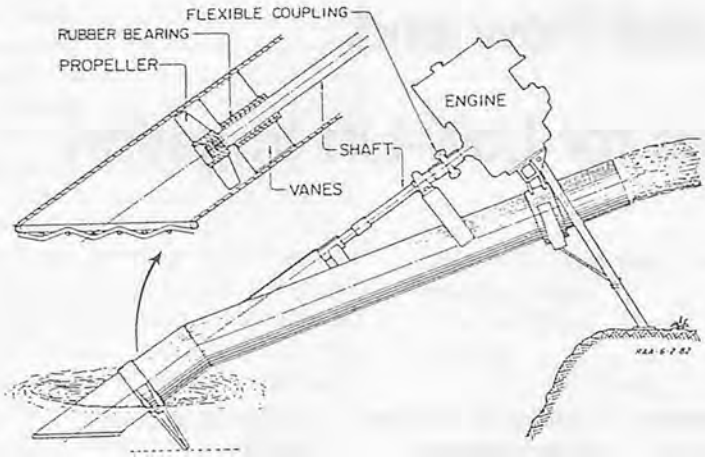

Fig. 1 Schematic drawing of axial-flow pump.

large number of manufacturers.

In the Philippines, low-lift irrigation pumps are economically attractive for certain areas and condition (Moya et al, 1981). The axial-flow pump is almost completely unknown, and farmers use centrifugal pumps for low-lift applications, even though these pumps are designed for medium lift and become increasingly inefficient at lower lifts. The purpose of this study is to compare the technical and economical characteristics of axial-flow and centifugal pumps under conditions of low lift (1 to 3 m), thereby providing a more rational basis for pump selection.

IRRI Axial-Flow Pump

In 1977, the Engineering Department of the International Rice Research Institute (IRRI) initiated a project to improve the efficiency of the axial-flow pump and to simplify the design in a manner that would reduce the cost and simplify fabrication by workshops in rural areas. The design illustrated in **Fig. 1** was developed and made available to interested manufacturers in late 1979. The principal components are:

High efficiency propeller, which may be fabricated by bending and welding, rather than by casting and grinding,

Vanes for straightening the spiral flow induced by the propeller, thereby increasing efficiency by reducing losses due to fluid friction,

Improved bearing for longer life in dirty or sandy water,

Tube fabricated from iron sheet by simple rolling and welding techniques, thereby avoiding the weight and expense of commercially available pipes or tubes, and

Direct-coupling of the propeller shaft to an engine mounted on the pump tube. (Alternatively, a pulley and V-belt may be used to power the pump by an engine mounted separately, such as the engine of a hand tractor).

Detailed information on technical specifications, fabrication procedures, and operations of this pump may be obtained from IRRI. Design drawings are available for two sizes:

Inside diameter of pump tube		Recommended engine size	Capacity at 1.5 m lift	
cm	in.	hp	l/s	gal/min
15	6	5	50	790
25	10	8	100	1,580

Test Procedure and Results

The pumping capacities of axial-flow and centrifugal pumps were measured for three levels of lift using the same engine. The axial-flow pump was 15 cm (6-inch) diameter unit (IRRI Design #PU-4). The centrifugal pump was representative of those manufactured in the Philippines, and the size was 10 cm (4-inch) diameter of inlet and discharge ports. [A 15 cm (6-inch) unit would have required a larger engine than needed for the axial-flow pump.] The same 5-hp gasoline engine was used to drive each pump during test runs.

The diameters of the V-belt pulleys on the pumps were adjusted to attain the desired pump speed (2200 to 2400 rpm) for engine speeds in the range of 3100 to 3300 rpm. To attain approximately equal engine power for both pumps at a particular lift, the carburetor throttle was adjusted to give the same value of vacuum pressure in the intake manifold.

Test runs were conducted for three values of the lift (or static head), which is the vertical distance measured from the surface of the water source to the center of the discharge tube. Each run lasted for 60 min, with the capacity (pump discharge) measured every 10 min by means of a calibrated cut-throat flume, and the fuel consumption measured before and after the run. The results were observed to be highly reproducible except for an unexplainable variation (±20%) in measurement of fuel consumption.

The results shown in **Table 1** are averages of three runs made for each value of lift. Note that at the lowest lift (1.07 m), the capacity of the axial-flow pump is 3 times that of the centrifugal pump. At the highest lift (2.8 m), the capacity of the axial-flow pump is 2 times that of the centrifugal pump. Based on linear extrapolations of the data plotted in **Fig. 2**, it is estimated that the capacities of the two pumps will become equal at a lift of

Table 1 Test Results for Comparison of Axial-flow and Centrifugal Pumps at Low Lift*

Static head (m)	Capacity (*l*/s)	
	Centrifugal	Axial-flow
1.07	15.0	46.0
1.51	14.3	40.0
2.80	13.4	26.8

* Average fuel consumption for all runs: 1.4 *l*/h.

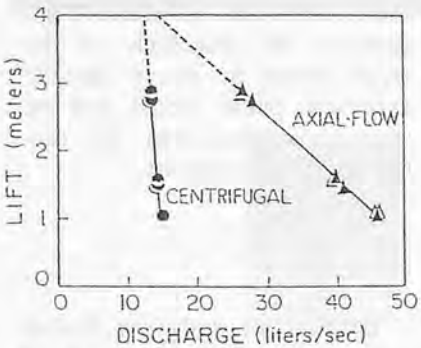

Fig. 2 Test results on pumping characteristics of 15cm axial-flow pump and 10cm centrifugal pump.

about 4 m. At higher lifts, the capacity of the centrifugal pump should exceed that of the axial-flow pump. It should be emphasized, however, that the lift at which the capacities of the two pumps are equal depends upon the design and operation details of the pumps (e.g., pitch of the propeller, shape of rotor passages, RPM, etc.). Consequently, the value of 4 m is not a general result for axial-flow and centrifugal pumps.

The capacity of the axial-flow pump is larger than that of the centrifugal pump in these test runs because: (1) for low lift, a propeller is basically more efficient than a centrifugal rotor; and (2) the fluid friction losses are greater for the centrifugal pump because it has higher resistance due to smaller diameter tubing, a 90°elbow, and a foot valve. These friction losses have been estimated using standard hydraulic tables (Berkeley Pump Catalogue, 1959) and the results are presented in **Table 2** as the "friction head" (Hf), together with the static head (Hs) from **Table 1**, and calculated values for the velocity head (Hv) and the total head (Ht = Hs + Hf + Hv). Also included are calculations of the power transmitted to the water:

Table 2 Estimates of Heads and Powers Corresponding to Test Conditions of Centrifugal and Axial-Flow Pumps*

Estimated values*	H_S, Static head					
	1.07m		1.51m		2.80m	
	Cent.	Axial	Cent.	Axial	Cent.	Axial
Hf, Friction head (m)	0.73	0.21	0.62	0.23	0.62	0.17
H_V, Velocity head (m)	0.17	0.31	0.15	0.23	0.13	0.11
H_t, Total head (m)	1.97	1.59	2.28	1.97	3.55	3.11
P_W, Water power (hp)	0.39	0.96	0.43	1.03	0.63	1.09

* See text for definitions of terms and estimation procedures.

Pw(horsepower) = 0.0131 Q Ht

where Q is the measured pump capacity in *l*/s (**Table 1**) and Ht is the total head in meters.

The results in **Table 2** illustrate that: (a) the fluid friction losses, represented by Hf, are 2.7 to 3.6 times higher for the centrifugal pump than for the axial-flow pump; and (b) for approximately the same power input to both pumps, the power transmitted to the water (Pw) is significantly greater for the axial-flow pump; and (b) for approximately the same power input to both pumps, the power transmitted to the water (Pw) is significantly greater for the axial-flow pump than for the centrifugal pump, indicating a higher efficiency for the axial-flow pump. It is not possible to calculate the pump efficiencies because the power input was not measured in these tests. However, based on power measurements for similar engines, the expected actual power output of the 5-hp engine was less than 2 hp for the present test conditions.

Economic Comparison

Although the purchase price of the 10-cm centrifugal pump is less than that of the 15-cm axial-flow pump, the total prices of the two are about equal if one adds the accessories required for the centrifugal unit (i.e., foot valve, pipe elbow, 10-cm hose in tubing, base plate). For example, in Iloilo City, Philippines in January 1982, the price of these centrifugal and axial-flow pumps were both about US $225, excluding cost of engine. The price of a 5-hp engine ranges from about US $190 for an air-cooled gasoline to US $750 for a water-cooled diesel engine.

Because the initial costs of the two units are essentially equal, the principal factors to consider in an economic comparison are differences in their operating costs and in their useful lives. In terms of operating costs, the main difference is that for low-lift applications the axial-flow pump requires less fuel than the centrifugal pump to pump the same volume of water. For example, assume that the pump will be used to irrigate 5 ha at an average rate of 10000 m^3/ha per year (100 ha-cm), which means the average volume of water pumped per year for 5 ha would be 50000 m^3. If the lift were 1.51 m, then the data in **Table 1** indicate that the capacities of the 10-cm centrifugal pump and the 15-cm axial-flow pump would be 14.3 *l*/sec (51.5 m^3/h) and 40 *l*/sec (144 m^3/h), respectively. Therefore, the centrifugal pump would have to operate 971 h/year to provide the requirement of 50000 m^3/yr, whereas the corresponding value for the axial-flow pump would be only 347 h/year – a saving of 624 h/year. Based on the average fuel consumption of 1.4 *l*/h, the fuel savings will be 874 *l*/yr. At the current price of gasoline (US $0.63/*l*), this amounts to a saving of US $550 per year. In this case, the savings in one year

Table 3 Estimated Fuel Savings of Axial-flow Pump vs Centrifugal Pump for Three Levels of Lift and Water Requirement

Lift (m)	Annual water requirement 1) (m^3/yr)	Annual operating time (h) 2)			Annual fuel savings 3)	
		Centrifugal pump	Axial-flow pump	Difference	(*l*)	(US $)
1.07	10,000	185	60	125	175	110
	50,000	926	302	624	874	550
	250,000	4,630	1,510	3,120	4,368	2,750
1.51	10,000	194	69	125	175	110
	50,000	971	347	624	874	550
	250,000	4,854	1,736	3,118	4,365	2,750
2.80	10,000	207	104	103	144	90
	50,000	1,037	518	519	727	460
	250,000	5,187	2,591	2,596	3,634	2,290

1) Assumed levels for representing low, medium, and high usage of pumps. 2) Computed from data on pump capacities (Table 1). 3) Based on average fuel consumption of 1.4 liters/hour (Table 1) and fuel cost of 5 pesos (US $0.63) per liter of gasoline.

Note: Exchange rate in mid-1982 was approximately 8 pesos per U.S.$

Table 4 Comparison of Estimated Annual Fixed Costs for Axial-flow and Centrifugal Pumps 1)

Components	Axial-flow pump			Centrifugal pump		
	Initial cost (US $)	Life (Years)	Annual cost 4) (US $)	Initial cost (US $)	Life (Years)	Annual cost 4) (US $)
Pump 2)	225	5	67	160	15	28
Engine (5HP GASOLINE)	190	5	56	190	2.5	95
Pipe elbow & fittings 3)	–	–	–	25	15	4
Flexible hose 3)	–	–	–	25	2.5	13
Foot valve 3)	–	–	–	12	5	4
Total annual fixed costs (Pesos)			123			144

1) Based on interest rate of 15% per year. 2) For 15-cm axial-flow pump and 10-cm centrifugal pump. 3) Components needed for centrifugal pump only. 4) See text for explanation.

Note: Exchange rate in mid-1982 was approximately 8 pesos per U.S. dollar.

alone is greater than the initial cost of the pump and engine.

Similar calculations have been made for a range of lifts and water requirements, and the results are summarized in **Table 3**. The savings are most impressive at low lifts and high water requirements, although the dependence on lift is smaller than expected.

An approximate economic comparison of the annual fixed costs of the two pumps is presented in **Table 4**. For each pump component the corresponding initial cost and useful life have been estimated. Other fixed costs, such as taxes, insurance, and maintenance, have not been included because these are of secondary importance in this comparison. The centrifugal pump is assumed to have longer life (15 years) than the axial-flow pump (5 years) because of its heavier construction. On the other hand, the life of the engine is estimated to be longer for the axial-flow pump (5 years) than for the centrifugal pump (2.5 years) because, as seen in **Table 3**, the operating time required to pump a given quantity of water is substantially less for the axial-flow pump. These estimates have been used to compute the values shown for the annual fixed costs.[1] These costs represent the annual payments that have to be made, assuming initial costs were financed by a loan at 15% annual interest for the life of each component. Note that the total annual fixed costs for the two pumps are nearly equal because the longer life of the centrifugal pump is counterbalanced by its shorter engine life.

If a diesel engine had been used instead of a gasoline engine in these tests and economic comparisons, the magnitude of the results would be altered but the axial-flow pump would still be more economical than the centrufugal pump at low lift.

Conclusions

Because this study was limited to a single model of centrifugal pump, the quantitative results apply only to the specific pumps and conditions of the tests. On the other hand, it is expected that the economic advantage of the axial-flow pump over the centrifugal pump at low lifts is a qualitative result which will be generally valid for various designs of axial-flow and centrifugal pumps, although the quantitative magnitudes of the capacities, costs, and critical lift will depend on design details and operating conditions.

The axial-flow pump has other advantages relative to the centrifugal pump: (1) it is easily fabricated in small workshops; and (2) it is suitable for operation in dirty and sandy water. Moreover, the benefits of axial-flow pumps to small farmers in Vietnam and Thailand provide a sound basis for promoting the technology in other countries where low-lift irrigation is common.

1) Annual fixed cost = $i \cdot C \cdot (1+i)^n / [(1+i)^n - 1]$, where i = interest rate, and n = initial cost, and n = useful life in years. (De Neufville and Stafford, 1971)

(Continued on page 42)

Efficiency of Resource Use in a Tube Well Irrigation Scheme in Sri Lanka

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Abstract

The efficiency of resource use in the 0.8 and 2.0 ha farms with tube well irrigation facilities were investigated in this study using a Cobb-Douglas production function framework. Field data relating to production, input use and prices were collected through a field survey. The aggregate production function analysis indicates that the use of resources such as irrigation water, labour and capital in the 0.8 ha farms is more efficient than that of the 2.0 acre farms. In the 2 ha farms land, labour and irrigation water are underused. When crop specific production functions are investigated there appears greater inefficiency in factor use in both cases. It is recommended that any increase in production through the 0.8 ha farms involve expansion of area itself. However, in the 2.0 ha farms expansion of output is possible by further use of irrigation water, labour and reduction of capital inputs.

Introduction

Peasant colonization was introduced in Sri Lanka in the 1940s in order to increase food production and also to provide land to the peasantry (Farmer, 1956). In 1976, the Government of Sri Lanka planned to provide lands of the earliest unsuccessful colonization schemes to new youth schemes(Amarasinghe, 1977). The Mulankavil colonization scheme which is situated in the northwest part of the Jaffna district in Sri Lanka, was one such scheme and the plan was to develop 200 ha of land with irrigation water from hand-dug wells. A hundred colonists were settled with 2 ha of highland. The wells dug gave poor yield of water and farmers gave up their effort to cultivate them on their own. Nearly 90% of the allottees vacated the land. Rainfed cultivation also failed due to poor rainfall in the area. The remaining cultivators continued small scale cultivation of subsidiary food crops. The main income source, however, was off-farm employment.

In 1978, the northwest Dry Zone Project of the Ministry of Lands and Land Development started a few youth settlement schemes based on tube wells (Robertson et al, 1978). The Mulankavil educated youth settlement project situated in the northwest part of the Jaffna district is one of the schemes started under this project. This area experiences monsoonal rains during October-December and occasional rains in April-June. The average annual rainfall is 600-900 mm. Basically the plan was to develop about 200 ha of forest land with irrigation water facilities from underground water. The Ministry of Lands of Sri Lanka with the assistance of the Overseas Development Administration of the United Kingdom established irrigation infrastructure. These were mainly drilling tube wells, construction of rising main, forebays, channels and other structures required for irrigation. The scheme was divided into blocks of 8-10 ha and a deep tube well services 10 farms. Each farmer was given 0.8 ha of land with irrigation. The main objectives of this project are to increase incomes and employment of the educated youth through the production of subsidiary food crops. The aim of this paper is to compare the efficiency of resource use

on 0.8-ha and 2-ha sized farms.

Method of Analysis

The efficiency of factor use was examined using a formal production function model of the Cobb-Douglas type, represented as follows:

$$\ln Y = b + b_i \ln X_i$$

where, subscript i indexes a particular observation and X_i's represent the different variables. Two types of functions were fitted here, one for the total farm where incomes and expenses for all crops were aggregated and the other for individual crops separately.

The Data

All data for this study were collected through a field survey of selected farmers in the scheme using a structured questionnaire. Interviews were conducted with two groups of farmers in order to provide a circumstance for comparison. The two groups are:

a) Youth from the youth scheme with 0.8 ha holdings and deep tube well irrigation facilities (state owned),
b) Old colonists with 2.0 ha holdings and hand dug or hand drilled tube wells (privately owned).

The details of the selected samples are given in **Table 1**.

Data pertaining to production and input use for different crops were collected over a period of six months during 1981-1982 from the above farms.

The output was measured in terms of the value of crop output per farm. Land was measured as a physical stock variable by the actual amount of land allocated for a crop or crops. The human labour variable combines family labour and hired labour. The labour variable was incorporated in terms of man-day equivalents by taking 8 h of work as a day. In computing equivalent man-days of work per farm, a woman-day and a child-day were considered to be 0.75 and 0.5 of a man-day, respectively. Irrigation variable is represented by the actual costs paid for water. Capital variable includes costs of inputs such as fertilizer, herbicides, pesticides, etc measured in rupees.

Table 1 Information on Samples Selected

Type of farm	No. of original settlers	No. of present settlers	Size of sample selected
0.8 ha farms	78	43	34
2.0 ha farms	100	20	11

Results and Discussion

The estimated coefficients of the Cobb-Douglas production function for the total farming system are presented. in **Table 2**. The estimated parameters reveal that all the factors except land are positive and significant in the 0.8 ha farms. The coefficient of land is positive and significant in the 0.8 ha farms. The coefficient of land is positive but not significant. It also appears that in the 2 ha farms, the labour and irrigation coefficients are posi-

Table 2 Cobb-Douglas Estimates for the Study Farms

Variable	Coefficients	
	0.8 ha farms	2 ha farms
Intercept	2.8159	2.3575
Land	0.0181 (0.5717)	0.1012 (0.6875)
Labour	0.4319** (10.1889)	0.5886*** (1.7526)
Irrigation	0.2237* (7.8494)	0.3274** (1.5262)
Capital	0.3124* (3.0931)	0.1870 (0.8342)
R^2	0.9971	0.9894
Returns to scale	0.9861	1.2039
F value	1116.9861*	69.5787
Sample size	31	11

Note: The coefficients of each variable refers to the logarithm of the relevant variable. One, two and three asterisks mean that the regressor is significant at 1, 5 and 10%, respectively. t - statistics are in parentheses below each estimated coefficients.

Table 3 Marginal Value Products and the Ratios of Marginal Value Products to Factor Cost in Study Farms

Input	Marginal value products (Rs. per unit of input)		Ratios of marginal value products to factor costs	
	0.8 ha farm	2 ha farm	0.8 ha farm	2 ha farm
Land (ha)	533.71	3564.28	0.22	1.49
Labour (man-days)	26.07	55.63	1.04	2.23
Irrigation water (Rs.)	1.10	1.85	0.92	1.54
Capital (Rs.)	1.07	0.86	0.89	0.72

Note: Geometric mean of the gross value of farm output is Rs. 16218, and Rs. 35954 for 0.8 ha and 2 ha farms respectively.
Land Rent: Rs. 2470 per ha
Wage Rate: Rs. 25 per man-day
Interest on Capital: 20%

tive and significant at 10% level.

The results of the tests of economic efficiency performed by equating the Marginal Value Products (MVP) to the marginal factor cost (MC) are given in **Table 3**.

The results show that the factors are used more intensively in the 0.8 ha farms whereas, in the 2 ha farms, land, labour and irrigation water appear to be under-utilized, with fertilizer and agro-chemicals being over-used. The deviations of the ratio from one are more marked in the 2 ha farms than the 0.8 ha farms. This supports the fact that the 0.8 ha farms are more efficient in the allocation of resources than the 2 ha farms and scope for further increase in the use of these inputs is less. The results also suggest that the efficiency of resources used could be improved by increasing labour and irrigation in the 2 ha farms rather than increasing expenditure on fertilizer or agro-chemicals.

Table 4 illustrates the results obtained from the Cobb-Douglas functions for each crop for the 0.8 ha farms: land has negative elasticity for chillies and for all other crops but has a positive but an insignificant elasticity; and labour has a positive elasticity for all crops, significantly for brinjals. In case of irrigation, except brinjals and bananas elasticity is positive and it is significant only for chillies. Capital has a positive elasticity for chillies, brinjals and cabbage and significantly for chillies.

Table 5 presents the results for chillies and brinjals in the 2 ha farms. The results show that the elasticity of land in the case of chillies is positive but insignificant. The elasticity of land in the case of brinjal is negative but not significant. Labour has a negative elasticity for both crops but they are not significant. Irrigation has a positive elasticity for both crops as its use is limited by the low water levels in most of the wells. Other capital inputs are also not used intensively as the elasticities show.

Table 4 Cobb-Douglas Estimates for Each Crop on the 0.8 ha Farms

Variable	Coefficients					
	Chilli	Brinjal	Onion	Cabbage	Tomato	Banana
Intercept	−3.5632	4.3845	6.3050	4.5605	6.3880	4.8371
Land	−0.4008*** (−1.4457)	0.1763 (0.4405)	0.4602*** (1.2029)	0.6064 (0.9523)	0.3181 (0.2472)	0.2124 (0.4847)
Labour	0.2949**** (1.0757)	0.9537* (2.9774)	0.3203 (0.5958)	0.4299 (0.5445)	0.2777 (0.2226)	0.1726 (0.2846)
Irrigation	0.7668* (3.5096)	−0.2191 (−0.5990)	0.5199**** (1.1796)	0.0338 (0.0463)	0.0985 (0.1433)	−0.1221 (−0.2700)
Capital	0.5031** (1.7064)	0.1108 (0.7672)	−0.4335 (−0.8042)	0.3270 (0.4974)	−0.0856 (−0.1108)	0.6042 (0.9804)
R^2	0.8633	0.9803	0.7075	0.7996	0.8229	0.7218
F	19.0136*	61.6355*	3.2573**	2.2167	1.0491	2.1750
Returns to scale	1.1640	1.0217	0.8669	1.3971	0.6087	0.8671
Sample size	31	15	18	10	07	13

Note: The coefficients of each variable refers to the logarithm of the relevant variable. One, two, three and four asterisks mean that the regressor is significant at 1, 5, 10 and 15% level. t - statistics are in parentheses below each estimated coefficients.

The ratios of the marginal value products to the factor costs for individual crops are presented in **Table 6**. It is seen that most of the ratios are different from one and the deviations are more marked than where the whole farming system is investigated. Thus the inefficiency observed where individual crops are examined is much more pronounced. Land appears to be underutilized for most of the crops except bananas. Underutilization of land under short term crops like cabbage and onions appear to be even more prevalent in the 0.8 ha farms.

An over-utilization of labour for chillies is evident for both groups of farms and for tomatoes and bananas in the 0.8 ha farms. Brinjals, cabbage and onions exhibit an under-utilization of labour in these farms.

An under-utilization of scarce resources, water for chillies, onions, and brinjals is evident in the 0.8 ha farms whereas an over-utilization of water for chillies is observed in the 2 ha farms. The labour use for cabbage, tomatoes and bananas appear to be more intensive.

Table 5 Cobb-Douglas Estimates for Crops of the 2 ha Farm

Variable	Coefficients	
	Chillie	Brinjals
Intercept	1.0302	−1.5338
Land	0.7854**** (1.3321)	−0.0868 (0.1123)
Labour	−0.0432 (−0.1138)	−0.3027 0.3224)
Irrigation	0.0363 (0.0671)	0.7512 (1.1552)
Capital	0.7122** (2.5852)	0.7063 (1.0471)
R^2	0.9572	0.9268
F	13.6596*	4.5647
Returns to scale	1.4907	1.0680
Sample size	10	8

Note: The coefficient of each variable refers to the logarithm of the variables. One, two, three and four asterisks mean that the regressor is significant at 1, 5, 10 and 15% level. t - statistics are in parentheses below each estimated coefficients.

The operating variable cost on other inputs such as fertilizers, agro-chemicals and seeds show an over-utilization for onions, brinjals and tomatoes in the 0.8 ha farms. It appears that these inputs are under-utilized for chillies, cabbage and bananas. In the 2 ha farms, these inputs are under-used for both crops.

Table 6 Marginal Value Products and the Ratios of Marginal Value Products to Factor Costs for Crops in 0.8 ha and 2 ha Farms.

Crops	Ratios of marginal value products to factor cost			
	Land (ha)	Labour M-days	Water (Rs.)	Capital (Rs.)
0.8 ha farms				
Chillies	−7.30	0.82	4.90	2.02
Onions	6.90	1.17	6.08	−0.52
Brinjals	3.96	3.72	2.08	0.68
Cabbage	11.11	1.89	0.65	1.95
Tomatoes	4.62	0.76	0.86	0.73
Bananas	0.76	0.25	0.25	2.61
2 ha farms				
Chillies	16.07	0.13	0.14	3.07
Brinjals	2.16	1.12	4.29	3.05

Note: Land rent – Rs 2470/ha; Wage rate – Rs. 25.00/ man-day; and Interest on capital – 20%.

Conclusions

The aggregate production functions indicate that irrigation water, labour and capital are used more efficiently in the 0.8 ha farms than the 2.0 ha farms. Land use intensity is also very high. In the 2 ha farms land, labour and irrigation water are under-utilized. This is also indicated by the elasticities of the different factors obtained. The results obtained for the individual crops indicate that most of the factors are not used efficiently both in the 0.8 ha and 2 ha farms. One could surmise that the differences in the results may be because farmers look at their crops as a total system and not as individual crops. Thus the system as a whole appears more efficient than the individual components. The results also imply that any expansion of production should involve expansion of area in the 0.8 ha farm. However, in the 2 ha farms expansion of output is possible by further use of labour and irrigation water and reduction of capital inputs.

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Comparison of Axial-Flow and Centrifugal Pumps for Low-Lift Irrigation

(Continued from page 38)

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Effect of Irrigation on Cotton Yield in Southern USSR (Tashkent)

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Abstract

Field experiments were conducted for two years to determine the effect of irrigation on yield, water use and water use efficeincy of seed cotton in the southern part of the USSR (Tashkent). The results indicate that maximum water use efficiency can be achieved with 16.0 cm to 18.5 cm water accrued from stored soil water and irrigation water. The seed cotton yield and total water use data show that maximum yields of seed cotton were obtained with 16.0 cm and 18.5 cm of water used in 1975 and 1976, respectively. The data also reveal that there was a trend of reduction in yield with an excess of water use amounting to 19.3 cm and 19.5 cm as well as with decreased amount of water use of 12.4 cm and 15.7 cm in 1975 and 1976, respectively. It was observed that during tillering stages (pre-flowering) only 3.7 cm (20%) of water was required, but during flowering and boll forming stages 13.3 cm (72%) of irrigation water was required. However, at the period of maturation of bolls, water requirement was very low, amounting only 1.5 cm (8%).

Introduction

Irrigated agriculture is obviously a costly venture and calls for appropriate water management skills on the part of the extension workers and farmers. With the introduction of large-scale cultivation of cotton during early April to late September the irrigated area in USSR has increased. During the growing season of cotton when the rainfall is inadequate water stress is likely to develop and reduce seed cotton yield, hence it is necessary to apply supplementary irrigation to cotton fields in order to get maximum production.

Determination of irrigation water requirement and its frequency for different soil types and vegetation is a basic research problem of major interest. Various research activities are under way to investigate the static and dynamic behaviour of soils concerning irrigation requirement and its frequency. From the various studies it is apparent that the quantity of irrigation water and its frequency depend on various factors, namely; climate, available soil moisture, plant cover, soil type and structure, land management, stages of plant growth, etc. How frequently irrigation should be applied to the cotton field to obtain maximum yield is a question of real and practical significance. Megnic, M.P. (1973) found that cotton responds with increased yield when irrigation is applied at critical growth stages, i.e., at blooming and flowering stage, bolling and post bolling stages. Yelsukov, I. (1962) experimentally found that supplemental irrigation is needed when the soil water content in the 10-30 cm soil layer approaches 50% of field capacity. Gerad et al (1958, 1964) found that it was possible to obtain satisfactory yield on loam soil with pre-planting irrigation followed by an irrigation about 30 days after appearance of first bloom.

Materials and Methods

A field experiment for two years, 1975 and 1976, was conducted at the Central Scientific Research Institute of Cotton, Tashkent, USSR to study the effect of irrigation on cotton yield during the cotton growing seasons and to determine the amount and frequency of irrigation in order to optimize cotton yield. The characteristics of soil is one of the factors for determining the amount and frequency of irrigation. The soil of the experimental field was clay loam non-saline soil and the ground water table was situated 10 m below the soil surface. The coefficient of infiltration (constant infiltration rate) was 0.378 mm/

Table 1 Soil Characteristics of Experimental Field

Depth cm	Field capacity % by volume	Bulk density g/cm³
0 - 50	21.8	1.38
0 - 70	21.7	1.41
0 - 100	21.6	1.44
0 - 150	20.7	1.48

min and the average values of field capacity and bulk density up to a depth of 150 cm of the experimental soil were 21.45 and 1.43, respectively.

A split plot design was followed having three main plot treatments for irrigation with three replications each. The size of each plot was 24 m x 120 m. Three treatments of soil moisture T_1, T_2 and T_3 were considered. The active root zones of 70,100 and 70 cm were considered for the periods of preflowering, flowering and ball formation and post flowering, respectively. The treatments for the years 1975 and 1976 are shown in **Table 2**.

The variety of cotton seeds selected was Tashkent – 1. The rate of application of manures and fertilizers are shown in the **Table 3**.

The quantity of irrigation water was calculated on the basis of deficit from pre-determined field capacity level of soil water content of the upper 70,100 and 70 cm soil during pre-flowering, flowering and bolling stages and post bolling stage, respectively, with the help of the following formula by Kostiakov, A.N (1960):

$$M = H\gamma\,(B_{max} - B_0)\ m^3/ha \qquad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where,

M – Quantity of water for each irrigation, m^3/ha

H – Active root zone depth, cm

γ – Specific gravity of soil, g/cm^3

B_{max} – Field capacity of irrigated field, % by volume

B_0 – Available soil moisture within the active root zone just before irrigation, % by volume.

From the above equation (1) it is clear that the quantity and frequency of irrigation depend on the available soil moisture within the active root zone and the climatological condition in the experimental area as well as on the active root zone depth of the cotton plant during the time of irrigation (1).

The cotton plant has a deep and extensive root system when grown on deep, well-drained fertile soil. The root system develops rapidly and within 70 to 80 days penetrate vertically to a depth of 1.8 m and laterally to the same extent. Magnic, M.P. (1973) experimentally found that the active root zone for non-saline, clay loam soil were 50 cm, 70 cm and 100 cm during the periods of before blooming, blooming and flowering and maturation of cotton boll, respectively. Cotton can extract most of the soil moisture to the depth of rooting and this characteristic has an important influence on irrigation of cotton. Sufficient water should be added to the soil by supplementary irrigation to ensure that the entire root zone is brought to field capacity early in the growing season, i.e., during pre-flowering.

The method of irrigation system is also an important factor for efficient distribution of water in the field. The irrigation water was supplied in the experimental field by furrow irrigation system. The quantity and frequency of irrigation water was also measured. The length, depth and distance between the two adjacent furrows were 200 m, 20 cm and 60 cm, respectively. Experimentally it was found that the capacity of the stream in the furrow varied from 0.25 to 0.30 l/sec.

During the experimental years (1975 and 1976) the cotton seeds were planted in the third week of April and harvested in the middle of September. Soil water content was determined by oven dry method. Calculation of total water and water use efficiency (WUE), soil water depletion (SWD) and raw cotton yield were made by using standard procedures.

Table 2 Soil Moisture Levels with Active Root Zone at Different Stages of Growth of Cotton Plant at Different Treatments

Treatment (T)	Soil moisture, % of field capacity			Active root zone, cm		
	Pre-flowering period	Flowering & bolling period	Post flowering period	Pre-flowering period	Flower & bolling period	Post flowering period
T_1	75	75	60	70	100	70
T_2	70	70	60	70	100	70
T_3	65	65	60	70	100	70

Table 3 Rate of Manures and Fertilizers/ha

Period of Application	Rate		
	P_2O_5	K_2O_5	N
At the time of final land preparation	100	50	–
Just after germination of cotton plant	–	–	60
During blooming stage	–	50	50
Just before flowering stage	40	–	50

Results and Discussion

Table 4 Avarage Yield, Plant Height and Number of Bolls per Plant of Experimental Cotton Plants

Irrigation regimes (treatment)	Yield kg/ha		Plant heights cm		Number of bolls per plant	
	1975	1976	1975	1976	1975	1976
T_1	4830	4830	897	940	6.8	7.4
T_2	4730	4750	75.8	77.0	6.8	7.2
T_3	4450	4480	68.6	69.8	6.2	7.0

Table 5 Frequency and Quantity of Irrigation Water with Respect to Yield in Different Treatments

Year	Treatment (T)	Water required in different growing stages, m^3/ha: Tillering April-middle May	Frequency of irrigation	Flowering and bolling middle May-middle August	Frequency of irrigation	Maturation of bolls middle August-September	Frequency of irrigation	Total amount of irrigation water, m^3/ha	Yield, kg/ha
1975	T_1	1837(20%)	2	6586(72%)	7	730(8%)	1	9153	4830
	T_2	1256(14.7%)	1	6353(76.6%)	6	715(8.7%)	1	8284	4730
	T_3	1256(17.1%)	1	5167(65.9%)	4	715(17%)	1	7098	4450
1976	T_1	1537(19.5%)	2	5423(68.9%)	5	915(11.6%)	1	7875	4830
	T_2	783(11.6%)	1	4801(71%)	4	1171(17.4%)	1	6765	4750
	T_3	925(14.5%)	–	4206(65.9%)	3	1247(19.6%)	1	6378	4480

The effects of irrigation on yield, plant height and number of bolls per plant for different treatments are summarised in **Table 4**.

The results show that the yield of seed cotton and plant height in both the years 1975 and 1976 were significantly higher in treatment T_1 than in treatments T_2 and T_3.

From **Table 5** it is evident that the frequency of irrigation water was higher in treatment T_1 for both years numbering 10 and 8 in 1975 and 1976, respectively, in which maximum raw cotton yield was obtained. The table also reveals that the distribution of frequency of irrigation was not uniform over different growth stages of cotton. Maximum number of irrigation was needed during flowering and boll formation stages. The quantity of irrigation water was also higher in treatment T_1 over treatments T_2 and T_3. In all the treatments, the quantity of water was also different in different periods of growth stages. In treatment T_1 where maximum yields was obtained the quantity of irrigation water used by the plants were 20% in pre-flowering stage, 72% in flowering and boll formation stage and only 8% in the period of boll maturation stage.

The effect of irrigation regimes on cotton seed yield water use and its components, and water use efficiency (WUE) are shown in **Table 6**. The maximum yields of cotton seed were obtained with 16.0 cm and 18.5 cm of water used in 1975 and 1976, respectively. The data also reveals that there was a trend of reduction in yield with an excess of water use amounting to 19.3 cm and 19.5 cm as well as with decreased amount of water use of 12.4 cm and 15.7 cm in 1975 and 1976, respectively. The water utilization by crop is generally described in terms of WUE. The total water use was computed as the sum of post-sowing irrigation, effective rainfall, and soil water depletion (SWD) to a depth of 0-100 cm. The total water use was higher in treatment T_2 followed by treatments T_1 and T_3 in both years, but the WUE was comparatively less. **Table 6** also shows that the WUE was higher in treatment T_3 where total water use was minimum at 12.4 cm and 15.7 cm in 1975 and 1976, respectively, and decreased with an increasing quantity of irrigation water as in treatments T_1 and T_2 for both the years.

Table 6 Cotton Seed Yield, Water Use Components and Water Use Efficiency (WUE) for Cotton during two Growing Seasons

Year	Treatments	No. of irrigation	Cotton seed yield kg/ha	Rainfall, cm	Soil-water depletion (SWD)	Irrigation water cm	Total (ET) cm	WUE, kg/ha/cm Total water
				Water use components				
1975	T_1	10	4830	–	6.9	9.15	16.00	300.90
	T_2	8	4730	–	11.0	8.28	19.28	245.30
	T_3	6	4450	–	5.2	7.15	12.35	397.30
1976	T_1	8	4830	3.4	7.2	7.87	18.47	261.50
	T_2	6	4750	3.4	9.3	6.76	19.47	244.00
	T_3	5	4480	3.4	5.9	6.30	15.68	285.70

The soil moisture content by volume to a depth of soil 0-100 cm throughout the growing seasons is shown in **Fig. 1**. including the periodic rate and cumulative soil water depletion (SWD) for the period of 153 days from the date of sowing to the date of harvest. The results shown in **Fig. 1**, including the peri- the highest SWD occured in treatment T_1. The rate of SWD in different treatments was minimum during the month of April to June and thereafter it started increasing sharply in all the treatments thus attaining a maximum in August.

Conclusions

1. The maximum water use efficiency can be achieved with 16 cm to 18.5 cm water accrued from stored soil water and irrigation water.
2. The maximum yields of cotton seed can be obtained with 18.5 cm of water.
3. The yield in cotton seed decreased when the use of water was in excess of or less than 19.3 cm or 12.4 cm, respectively.
4. The maximum yield in cotton seed is obtained by applying 3.7 cm, 13.3 cm and 1.5 cm of

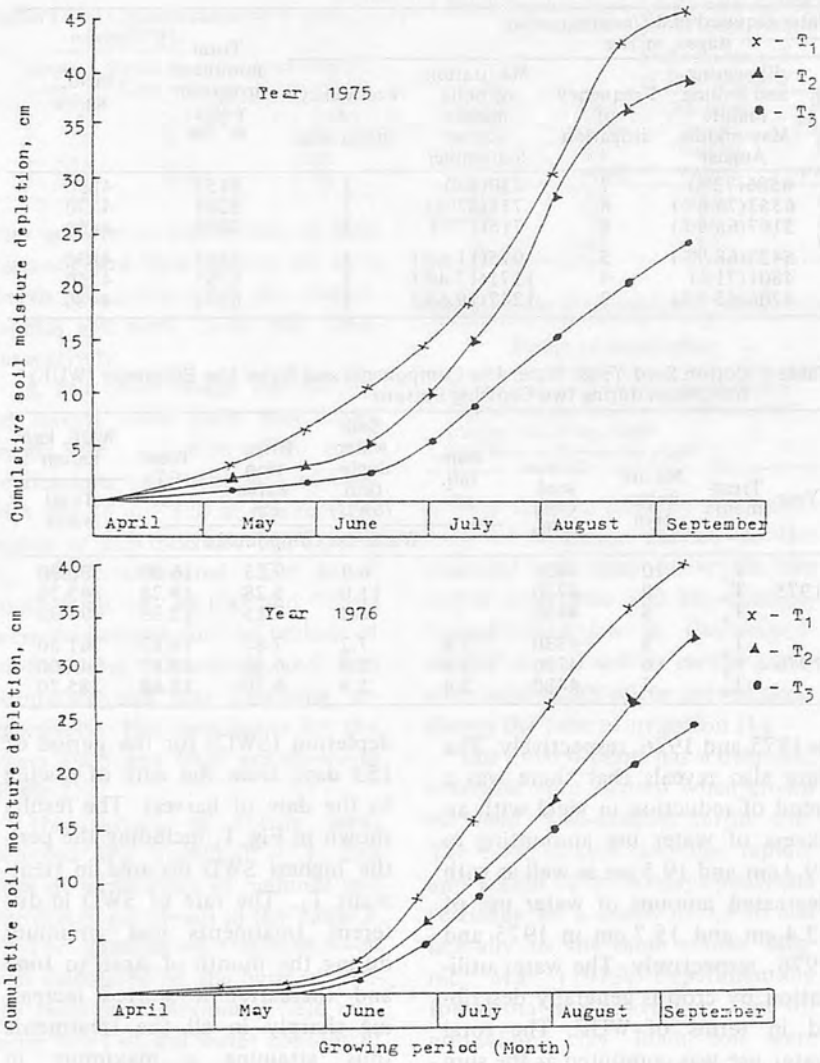

Fig. 1 Cumulative soil moisture depletion of 0-100cm depth.

water during the period of pre-flowering, flowering and bolling and maturation of boll formation stages, respectively.

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Performance of Indigenous Hand Weeders in Bangladesh

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Abstract

Four hand weeders (locally called "niri") were tested in order to evaluate their field capacity (ha/h) and ease of operation. Under identical operating conditions (soil type and weed density) there was no significant difference in field capacities, the average being 42 m^2/h (0.004 ha/h) and 26 m^2/h (0.003 ha/h) in clay loam and sandy loam soil, respectively. The weed densities were 240 weeds/m^2 in clay loam soil and 750 weeds/m^2 in sandy loam soil. After the weeding operations, 90% of the weeds were eliminated. The "pasun" (Rajshahi) type of hand weeder was most suitable both in sandy and clay soil whereas the "pasun" (Bogra) was suitable in sandy soil. The costs of the latter and former types, including the types of "pasun" (Rajshahi), "kathalpata niri" (Jessore) and "seni" (Mymensingh) are $US 0.32, $US 0.28, $US 0.24 and $US 0.24, respectively.

Introduction

Weeding is very important for increased crop production. Weeds directly reduce crop yield by competing with the crop in respect of space, sunlight, water and nutrient. They also adversely affect the micro-climate around the plant, harbour diseases and pests, increase the cost of production, plug irrigation and drainage canals and lower the quantity and quality of the crop (Grist, 1975). Depending on the weed density 20% to 30% losses in grain yield are quite usual and may increase to 50% when the crop management practices are not properly followed (Gill et al, 1981).

Chemical control of weeds may have toxic effect on crop plant. Many herbicides are effective against many weeds but the weeds which are not affected by herbicides must be eliminated mechanically. Weeds which survive the herbicides treatment may grow more vigorously due to less competition from other weeds (Vega et al, 1975). A study in the United States showed that the competition of one grass plant (Echinocloa crusgalli) per square foot reduced yield of rice by 25% (Grist, 1976). In Africa the most common and, perhaps, most effective way to control weed is pulling them by hand or destroying them by short-handled hoe (De Datta et al, 1975). Though manually-operated, the Japanese weeder has higher field capacity (0.038 ha/h) (Islam et al, 1982) but its sophisticated manufacturing technique and comparatively higher cost ($US 6.0)* could not replace the indigenous niri. Besides, the Japanse weeder is only suitable for lowland transplanted rice crop in rows.

In comparison, the niri is suitable for both row and broadcast upland crops. Its simple design and construction is an added advantage. It is available in different regions of Bangladesh in varying design and local name.

This study was undertaken with the following major objectives:

1. To study the constructional details of different types of niris available in different regions of Bangladesh;
2. To test and evaluate their field performances,
3. To identify deficiencies in design, if any; and
4. To recommend the most suitable ones for different soil conditions.

Materials and Methods

Twenty one niris were collected from different districts of Bangladesh and based on their designs, they were grouped into five categories with their local name followed by the name of the districts they came from as follows:

*Price list of Comilla Cooperative Karkhana Ltd

Category–1
Pasun (Bogra)
Pasun (Pabna)
Pasun (Rangpur)
Pasun (Jamaipur)

Category–2
Pasun (Rajshahi)
Dopata niri (Kushtia)
Akpata niri (Kushtia)
Kastey niri (Khulna)

Category–3
Kathalpata niri (Jessore)
Kalmipata niri (Khulna)
Chandpata niri (Jessore)
Kalmipata niri (Jessore)

Category–4
Seni (Mymensingh)
Nirani kachi (Barisal)
Niri (Comilla)
Niri (Habiganj)
Krishi nirani (Patuakhali)

Category–5
Khurpi (Rangamati)
Khurpi (Dinajpur)
Khurpi (Barisal)
Khurpi (Feni)

Of these five categories four are widely used in field crops. However, those in category 5 are mostly used only in gardens and hence, excluded from the experiment. After a preliminary test, pasun (Bogra), pasun (Rajshahi), kathalpata niri (Jessore) and seni (Mymensingh) were selected from categories 1, 2, 3 and 4, respectively, for performance evaluation. Four operators and two different soil types (clay loam and sandy loam) were selected for the test. The design used in the test was RCB and the treatments were replicated thrice. Following were the treatments:

T_1 = with niri N_1 and operator O_1
T_2 = with niri N_1 and operator O_2
T_3 = with niri N_1 and operator O_3
T_4 = with niri N_1 and operator O_4
T_5 = with niri N_2 and operator O_1
T_6 = with niri N_2 and operator O_2
T_7 = with niri N_2 and operator O_3
T_8 = with niri N_2 and operator O_4
T_9 = with niri N_3 and operator O_1
T_{10} = with niri N_3 and operator O_2
T_{11} = with niri N_3 and operator O_3
T_{12} = with niri N_3 and operator O_4
T_{13} = with niri N_4 and operator O_1
T_{14} = with niri N_4 and operator O_2
T_{15} = with niri N_4 and operator O_3
T_{16} = with niri N_4 and operator O_4

The specification of four niris are shown in **Table 1** and a brief description is given below.

Pasun (Bogra) – The body of the pasun is made of steel and has a wooden handle. The cutting blade is thin, wide and semi-circular in shape. The handle is attached to the shank at an angle of 35° which is its

Table 1 Specification of the Study Niris.

Type	Length mm	Length of blade mm	Width of blade mm	Surface area of blade cm^2	Av. thickness of cutting blade mm	Length of the handle mm	Dia. of the handle mm	Dia. of shank mm	Length of shank mm	Wt. g
N_1*	405	135	57	64.5	1.4	180	36 max 26 min	9.6	175	190
N_2	449	138	33 max	40.9	2.1	175	36	13.1 max 9.3 min	160	290
N_3	310	116	37	34.2	2.8	136	30	X-section 18.3×5.3 max 9.1×5.3 min	220	205
N_4	310	110	56	68.4	2.0	110	29	9.2	75	130

* N_1 = Pasun (Bogra); N_2 = Pasun (Rajshahi); N_3 = Kathalpata niri (Jessore); and N_4 = Seni (Mymemsingh).

ALL THE DIMENSIONS ARE IN mm

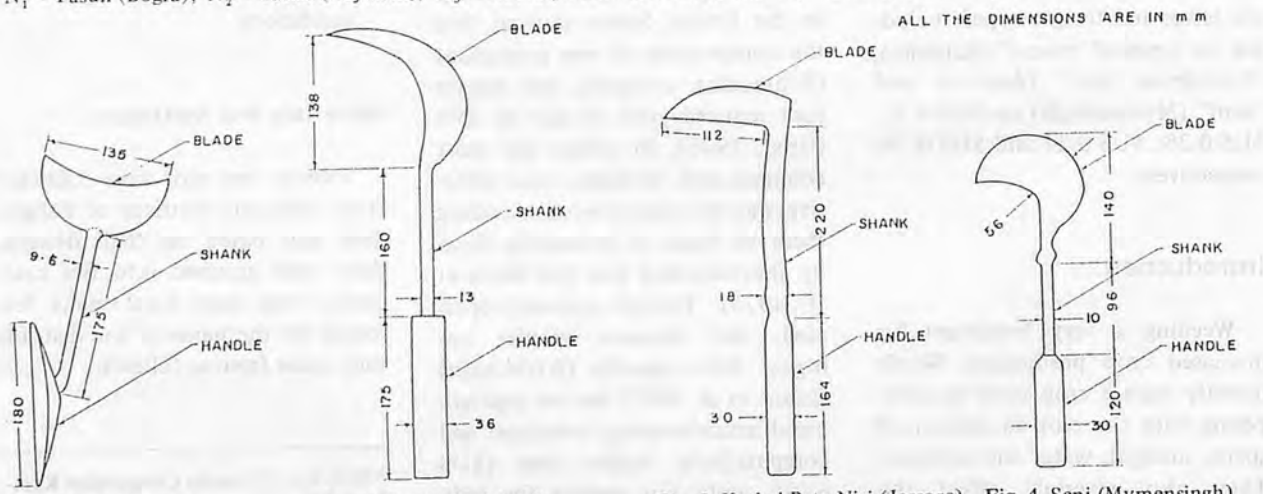

Fig. 1 Pasun (Bogra) Fig. 2 Pasun (Rajshahi) Fig. 3 Kathal Pata Niri (Jessore) Fig. 4 Seni (Mymensingh)

most distinctive feature (Fig. 1).

Pasun (Rajshahi) – This niri is made of wood and steel. The shank is somewhat long and slender. The cutting blade is sharp both in the outside and inside (Fig. 2). The inside cutting edge works just like a hand sickle. This is the heaviest among all the study niris and weighs 290 g.

Kathalpata niri (Jessore) – This is also made of steel and wood. The shape of its cutting blade is just like a leaf of a jack fruit tree (Kathalpata) (Fig. 3). Shank is long and rectangular and the cutting blade is narrow.

Sent (Mymensingh) – This is also made of wood and steel. The cutting blade is thin and rounded (Fig. 4). It is very light.

Test Observation

Pasun (Bogra) – This is light and easy to operate except in dense broadcast crop because of its wide cutting blade, and easier to operate in sandy soil than clay soil. It is suitable to operate in row crop.

Pasun (Rajshahi) – It is very effective and smooth in operation, and easy to operate both in sandy and clay soil. Both inside and outside of the cutting blade are sharp, and can also be used as a sickle. It is effective both in row and broadcast crop because of its narrow cutting blade.

Kathalpata niri (Jessore) – This type is very useful in uprooting the rhizomes of weeds like "Nutha" *(Cyperus rotundus)* even as it is hard to operate as its cutting blade is abnormally heavier than the shank and handle. However, it is easier to operate on sandy soil than in clay soil.

Seni (Mymensingh) – The cutting blade of this type is wider, hence it is difficult to operate in a broadcast crop. But it is very light and easier to operate in sandy soil than in clay soil.

Results and Discussions

In clay loam soil with a weed density of 240 weeds/m^2 and at 14.55% field moisture the average field capacities of N_1, N_2, N_3 and N_4 were 42.69 m^2/h, 39.09 m^2/h, 41.77 m^2/h and 44.59 m^2/h (Table 2), respectively.

In clay loam soil it was observed that the replication has significant effect on field capacity at 5% level of significance (Table 3). The average field capacity of replications R_1, R_2 and R_3 are 35.71 m^2/h, 45.9 m^2/h and 44.50 m^2/h, respectively. These difference in field capacities may be attributed to the time of day at which the replications were done in the field. R_1 was done in the morning when the crops were moist which in turn caused discomfort to the operators. During R_2 the crop was dry and the soil became friable which probably helped increase the field capacity. While R_3 was done at noon it was very hot which may be the reason for decreased field capacity.

In clay loam soil with a weed density of 240 weeds/m^2 and at 14.55% moisture, the treatment, niris (N), operator (O) and the interaction between niri and operator (NxO), had no significant effect on field capacities (Table 3). The insignificant interaction between niris and operators implies that the performance of a particular niri is not dependant on the operator.

In sandy loam soil with a weed density of 750 weeds/m^2 and at 12.99% moisture the average field capacity of N_1, N_2, N_3 and N_4 were 26.16 m^2/h, 27.21 m^2/h, 25.94 m^2/h and 25.82 m^2/h, respectively (Table 4). Both in clay loam and sandy loam soil 90%

Table 2 Field Capacity (m^2/h) of four Different Niris with four Different Operators in Clay Loam Soil at 14.55% MC

Unit: m^2/h

Niri	Operator				Average
	O_1	O_2	O_3	O_4	
N_1	40.44	37.60	36.45	56.28	42.69
N_2	35.23	37.87	37.90	45.37	39.09
N_3	51.48	36.10	43.53	35.95	41.77
N_4	48.79	43.73	37.72	48.11	44.59
Average	43.99	38.83	38.90	46.43	

Table 3 Analysis of Variances of Field Capacities of four Different Niris with four Different Operators in Clay Loam Soil at 14.55% MC

Source of variation	df	SS	MS	F	F5%	F1%
Replication	2	1035.13	517.57	4.74*	3.32	5.39
Treatment	15	1096.53	127.10	1.16 ns	1.99	2.66
NIRI(N)	3	246.99	82.33	0.75 ns	2.92	4.51
Operator(0)	3	557.52	192.50	1.76 ns	2.92	4.51
N x O	9	1082.02	120.22	1.10 ns	2.21	3.06
Error	30	3274.80	109.16			
Total	47	6216.46				

CV = 25%

Table 4 Field Capacity (m^2/h) of four Different Niris with four Different Operators in Sandy Loam Soil at 12.99% MC

Unit: m^2/h

Niri	Operator				Average
	O_1	O_2	O_3	O_4	
N_1	21.18	27.89	25.95	29.60	26.16
N_2	26.33	24.17	32.06	26.28	27.21
N_3	24.17	27.20	24.29	28.11	25.94
N_4	27.50	26.23	27.03	22.53	25.82
Average	24.80	26.37	27.33	26.63	

Note: Plot size = 1 m x 5 m.

Table 5 Analysis of Variance of Field Capacities of four Different Niris with four Different Operators in Sandy Loam Soil at 12.99% MC

Source of variation	df	SS	MS	F	F5%	F1%
Replication	2	23.49	11.75	1.92 ns	3.32	5.39
Treatment	15	319.03	21.26	3.47 **	1.99	2.66
NIRI (N)	3	14.50	4.83	0.79 ns	2.92	4.51
Operator(O)	3	41.21	13.73	2.24 ns	2.92	4.51
N x O	9	263.32	29.26	4.79 **	2.21	3.06
Error	30	183.35	6.11			
Total	47	844.90				

CV = 9%

Table 6 DMRT (5% level) for Average Field Capacity (m^2/h) in Sandy Loam Soil for NxO Interaction

	O_1	O_2	O_3	O_4
N_1	$21.18\ ^{b}_{B}$	$27.89\ ^{a}_{A}$	$25.95\ ^{b}_{A}$	$29.60\ ^{a}_{A}$
N_2	$26.33\ ^{a}_{B}$	$24.17\ ^{a}_{B}$	$32.06\ ^{a}_{A}$	$26.28\ ^{ab}_{B}$
N_3	$24.17\ ^{ab}_{A}$	$27.20\ ^{a}_{A}$	$24.28\ ^{b}_{A}$	$28.11\ ^{a}_{A}$
N_4	$27.50\ ^{a}_{A}$	$26.23\ ^{a}_{AB}$	$27.03\ ^{b}_{A}$	$22.53\ ^{b}_{B}$

N.B. Small letters in each column shows comparison of niris(N) with each operator(O). Capital letters in each row shows comparison of operator(O) with each niri(N).

weeds were eliminated.

Treatment and interaction between each niri and operator had a significant effect on field capacity at 1% level of significance (Table 5). But the replications, niri and operator had no significant effect on field capacity.

The performance of operator O_1, N_2, N_3 and N_4 are significantly better in field capacities than N_1 (Table 6) and from the same table with operator O_2, there is no significant difference in field capacities among the four niris. With operator O_3, N_2 performing better over N_1, N_3 and N_4 and with operator O_4, the performances of N_1, N_2 and N_3 were significantly higher than that of N_4.

Conclusions

There was no significant difference in field capacities among the four study niris hand weeders. It is, therefore, difficult to say which one is the best. On the basis of ease of operation, pasun (Rajshahi) may be considered good as it is suitable for both sandy and clay soils. However, with a slight design modification, the performance can be further improved. The shank and handle of the niri should be made shorter which in turn should reduce weight and cost. In sandy soil Pasun (Bogra) works better but it also needs some modification. The curvature at the point of shank and handle should be large and the handle should be somewhat longer for easier operation.

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Mechanical Harvesting of Cotton in the Sudan

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Introduction

Agriculture is the dominant sector of the economy in Sudan. It is the mainstay of more than 80% of the population and its share in the G.D.P. is approximately 40%.

Cotton is the main cash and export crop accounting for about 51% of all exports. The government has intensified efforts in developing more interest in cotton growing among tenants and farmers in irrigated and rainfed areas.

Picking is the most critical and labour demanding operation and to its success or failure the final yield is attributed.

In the last 10 years Sudan has witnessed a considerable development in agriculture which is marked with severe competition for hand labour. Shortage of picking labour during harvesting of cotton is now a problem to all irrigated and rainfed cotton producers in the Sudan.

Mechanical means for harvesting cotton were considered when cotton began to be produced on a large scale in U.S.A. The first patent on a cotton harvesting machine of the picker type was issued in the U.S.A. in 1850.

Two types of cotton harvesters have been improved and became popular in places where mechanical harvesting is practiced. These are the picker and the stripper types.

Cotton strippers are used in harvesting low-growing and short-limbed type of cotton crop which produces storm-proof bolls and short lint. Cotton strippers are seldom used in irrigated areas.

The picker-type harvester picks the mature seed cotton out of the open bolls, the empty bur is left on the plant. The picker can operate without serious damage to the plants or unopened bolls and, consequently, can harvest the cotton as it opens in as many pickings as is economically justifiable. The spindle-type picker has attained great popularity and several thousands of them in U.S.A. cotton belt are now in operation.

Chemical defoliation of cotton has been used in various parts of the world as a preharvest practice to facilitate mechanical harvesting. A wide variety of chemicals have been used. Calcium cyanamide, magnesium chlorate, sodium chlorate and amino triazole are among those used in various formulations and under different trade names.

Trials of Mechanical Harvesting

Nuba Mountains Trial, 1959

A one-row, tractor-mounted, Rust make, cotton picker was the first machine introduced in the Sudan in 1959. This machine was used to pick cotton at different selected locations in Nuba mountains area where rainfed, short-staple cotton is grown. The performance of the machine was technically satisfactory. However, the husbandry and cultural practices were not appropriate for machine picking. No defoliant was applied. The quality of the lint was inferior to that of the hand-picked cotton (1).

Abu Naama Trial, 1962

A one-row, tractor-mounted John Deere 22 machine was tested in Abu Naama Research Station in 1962. A randomized experiment was conducted and four types of chemicals were used as defoliants according to the Gezira Research Station recommendation. The results indicated that the hand-picked cotton was by far better than the machine-picked cotton. The machine losses were significantly higher than hand losses (**Tables 1-3**). The reasons for the inadequate performance of the machine was likely due to bad cultural and husbandry practices, especially the seedbed preparation and defoliation of the crop prior to harvesting. It could also be due to unskilled machine operators and inaccurate machine adjustment (2).

Tambul Pilot Farm Trials, 1969-74

The Tambul farm was chosen in 1969 as the pilot farm for the Rahad Irrigation Project. It was entrusted to the ILACO of Netherlands for the first three seasons to carry out research on agronomy, irrigation and drainage practices,

and mechanization for, at that time, the future Rahad agricultural scheme. Cotton picking was conducted on a limited scale. John Deere 22 machine (the same machine used in Abu Naama) was used. The objective of the trials was to investigate the technical and economical feasibility of mechanical harvesting of cotton. The most promising defoliants as recommended by the Agricultural Research Corporation (ARC) were also tested. The results indicate that mechanical harvesting of cotton was technically feasible but economically unjustifiable (abundant and cheap labour was available in Tambul area) (3).

The trials were continued in Tambul farm, after the termination of the ILACO contract in 1972, for another three seasons. The results confirmed ILACO findings. Quality tests of the lint showed that the deterioration in lint due to mechanical picking was insignificant (4).

Both trials indicate that the defoliation was indispensable for machine picking. The quality of the defoliation depend upon the method of application, the time, environmental conditions especially the temperature and the moisture content of the soil. Best results were obtained when the defoliant was applied where more than 90% of the bolls were open.

New Halfa Trials, 1970-72

A complete system of cotton harvesting based on a Russian tractor-mounted harvester, was tried for two seasons in the New Halfa Agricultural Scheme. The system includes also a sprayer for defoliant application, a pre-cleaner to remove the trash and debris prior to ginning, and a loss collecter machine to sweep the dropped lint from the field after picking.

This trial was closely followed up and assessed by a selected, well-qualified team from the Department of Agricultural Economics and Statistics, Ministry of Agriculture, Food and Natural Resources. The economic analysis shows that the mechanical picking was more expensive than hand-picking, about 20% more, and the machine-picked cotton was lower in grade than hand-picked cotton, though the difference was insignificant. The study confirms the importance of the husbandry practices such as seedbed preparation, weeding and defoliation, for the success of mechanical picking. Also, it pointed out the importance of skilled personnel to run such a sophisticated system of production (5).

Rahad Scheme Trials, 1979-81

The Rahad Agricultural Scheme Management has been faced with the problem of labour shortage, particularly at cotton harvest time, since the first production season in 1977 due to continuously tightening labour situation in the country. Encouraged by the results obtained in the Tambul pilot farm, the Rahad administration thought of machine-picking as one of the solutions to labour shortage problem. A technical committee was set up in 1979 to study the possibility of mechanization of cotton picking operation.

Three cotton harvesting machines, namely; John Deere 9910, International Harvester 782 and Ben Pearson 827 were procured to investigate the technical and economic feasibility of machine-picking and hence to advise the Rahad Corporation on the best machine under Rahad conditions. The trials show that mechanical picking in Rahad scheme was technically feasible. The results confirmed that the spindle-type picker was the most suitable machine for irrigated acala cotton under Rahad conditions. Several of the cultural practices such as seedbed preparation, weed control and cotton stand establishment were more critical and required better management for machine-picking than for hand-picking. The results indicate that defoliation was of vital importance for mechanical picking and that more studies and investigation were needed to determine the most suitable defoliant (s), the rate, time and method of application (6).

Cost estimates indicate that hand-picking would have been cheaper than mechanical picking had the required number of hand pickers been secured in the optimum time.

The trials show that the operator and skilled service and main-

Table 1 Machine Losses vs Hand Losses (Abu Naama Trial)

Treatment	Hand-picked	Machine-picked
(1)	6.6%	24.9%
(2)	7.2%	21.2%
(3)	5.5%	24.4%
(4)	7.8%	26.6%

Table 2 Machine Field Capacity (Rahad trials)

Machine	Area picked	Total time	F.C.*
John Deere 9910	20	11.6 h	1.72
International Harvester	20	12.1 h	1.65
Ben Pearson	20	14.4 h	1.4

*Unit: Feddan/h (1 Feddan = 1.03 acre)

Table 3 Seed Cotton Losses

Machine	Ground losses	Tree losses	Total losses
John Deere	2%	7.2%	9.2%
International Harvester	2.7%	8.2%	10.9%
Ben Pearson	5.2%	14.8%	20.0%

tenance crew were the most important factor in achieving the best machine performance. Operator skill and, perhaps more importantly, motivation, were essential in obtaining the highest machine capacity and best harvesting performance.

Conclusions

There are several factors which have a considerable effect on the performance of cotton harvesting machine. Some of these factors depend on the machine itself and its operator, others are connected with the variety of cotton to be grown, the cultural and husbandry practices applied.

The mechanical factors which affect the machine mainly concentrated on the picking part of the machine, namely, the number and spacing of the picking zone, shape, size, sharpness and angle of the spindles, and the mechanism of cleaning of the spindles.

The ideal variety for the spindle-type cotton picker should combine the following characteristics:

1. Plant of medium size with a relatively narrow space, growing in more or less upright position.
2. Fruits distributed evenlly all over the plant, but beginning well off the ground. In this way the picker drum can be operated higher thereby reducing the amount of the soil and dirt collected with the lint.
3. Wide opening bolls with fluffy locks.
4. Maturity should take place early and in comparatively short time.

The efficiency of the spindle-type picker, which seems to be the most appropriate machine for irrigated cotton in the Sudan, depends on the cultural methods applied. The ridges should be straight, uniformly and evenly spaced (38-40 inches). In irrigated cotton, harvesting efficiency increases significantly as plant population increases to the optimum population. This fact was observed during the Rahad trials. The characteristics of the cotton plants were materially altered by plant spacing and polulation. As plant population increased, plant height also increased, but the length of the limbs and the height of the fruiting increased.

One of the most important cultural practices which affect mechanical picking is the complete control of weed.

Defoliation is essential for mechanical harvesting of cotton. The type of chemical, rate, time and method of application are very critical for successful defoliation. The moisture content of the soil is essential for effective defoliation because the chemical is absorbed through the plant roots.

The human factor is the most important consideration in achieving the best machine performance. The operator's skill, service and maintenance crew, and perhaps more importantly, motivation, are very essential in obtaining the highest machine capacity and the best harvesting performance.

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Study of a Segmented Paraboloid Type Solar Heat Collector

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Abstract

Solar energy has considerable potential to substitute the conventional sources of energy in some fields. The objective of the project was to design, fabricate and test the performance of a paraboloid type concentrating solar collector.

A segmented paraboloidal type concentrating collector was designed and fabricated. Tracking of the sun was accomplished by rotating the collector about its two axis. Plane mirrors were used as reflecting surface. Collector characteristics were observed without water and with different quantities of water in the absorber. Collector efficiency was calculated by heating different quantities of water. Tests were conducted from 8:00-16:00 hrs of day to evaluate the effect of radiation intensity.

The maximum surface temperature of the absorber without water was 330°C at 11:30 hrs on the test day. It was found that the reflector efficiency was maximum, *i.e.*, 42% at 11:30 hrs while heating 500 cc of water for generating steam.

Introduction

Solar energy can be converted into mechanical energy for performing farm operations like pumping water for irrigation. It can give sufficient heat for drying agricultural products, including grain, fruits, timber, forage, etc. For household use this energy can be utilized for air conditioning, refrigeration, heating water and cooking. Similarly, it can be used for lighting and distillation.

Since solar energy is widely dispersed, its direct use is governed by two basic collection concepts: flat plate collectors and focussing collectors. In focussing the collectors, the basic element is either parabolic or a Fresnel mirror. In such collectors, the temperature ranges from 200°C to 3000°C and above. But focussing collectors should be designed to track the sun diurnally and seasonally and orient themselves to the incoming beam radiation.

The research is needed to develop economical and lighter collectors to make the application of solar energy more practical, especially in agriculture. With this in view, the design and development of a paraboloid type focussing collector was undertaken with the aim of evaluating the collector's performance.

Review of Literature – Gupta (1975) reported that in focussing collectors, temperature ranges from 200°C to 3000°C and above but focussing collectors should be designed to track the sun diurnally and seasonally or they must have adjustable foci elements.

Sirohi (1975) studied the performance of a parabolic cylinder type solar collector which was manually tracked to follow diurnal motion of the sun. The reflector was constructed by pasting aluminium foil on a cardboard base shaped to form a parabolic cylinder type solar collectors. He performed experiments on different sizes of absorber pipes made of different metals.

A theoretical model of the collector was used to examine the thermal performance of the collector. The model and experimental measurements were used to determine the sensitivity of the collector to such variables as ambient temperature, mass flow rate, isolation rate, wind, glazing and cleanliness. It was found that the ambient temperature and wind are the two major variables which influence the collector's performance.

Tabor (1978) suggested a simpler method of determining the collector efficiency equation in terms of isolation and mean temperature rise above ambient.

Garg (1978) reported that the solar water heater-cum-solar steam cooker was developed at C.A.Z.R.I., Jodhpur. This device can supply

100 *l* of hot water at a temperature of 60°-70°C. It can be used for cooking cereals, rice, dal, potatoes and vegetables.

Methodology

Solar Collector Design – The solar collector consists of a reflecting surface and an absorber placed at the focus of a parabolic reflecting surface. For high temperatures a paraboloidal type focussing collector is generally used. The important design consideration was to generate the steam at 100°C at atmospheric pressure to run a fluidyne pump.

The data assumed were:

Efficiency of pump, 2%

Efficiency of heat transfer from steam to pump system, 50%

Efficiency of solar collector, 30%

Pump discharge, 400 *l*/h

Head, 3 m

Av. solar heat input, 1 kW/m^2

Output of pump = 3.27 W

Area of incidence for collector, 1.105 m^2

Hence, the diameter of collector was 1.18 m.

The size of the absorber is expected as follows:

$$\text{Concentration ratio} = \frac{\text{Area of incident rays on collector}}{\text{Area of absorber surface}}$$

For generating steam at atmospheric pressure 50 to 60 concentration ratio is prefered. In this study, the ratio is 55, hence the diameter of spherical absorber is calculated as 16 cm and 120°, included angle at focal point.

Concept of Reflector Design with Respect to Absorber – Within the constraints of materials and fabrication, the study developed a reflector with the reflector surface made of plane glass mirrors. The configuration of collector surface, absorber and the paths of incident and reflected rays are shown in **Fig. 1**. The glass mirrors were oriented in such a manner that all the reflections should fall within the absorber. The inclinations and the lengths of the mirros can be calculated as:

$$(F^2 - Y^2)\sin^2 A - 2\,Fr \sin A + (r^2 - y^2) = 0$$

where,

A – Inclination of mirror

r – Radius of absorber, 8 cm

y – Diameter of absorber, 16 cm

F – Focal length, 50 cm

Hence $\sin^2 A - 0.3565 \sin A - 0.855 = 0$

Therefore, A can be calculated and y cos A gives the length of the mirror so as to have a 1.2 m diameter for the collector.

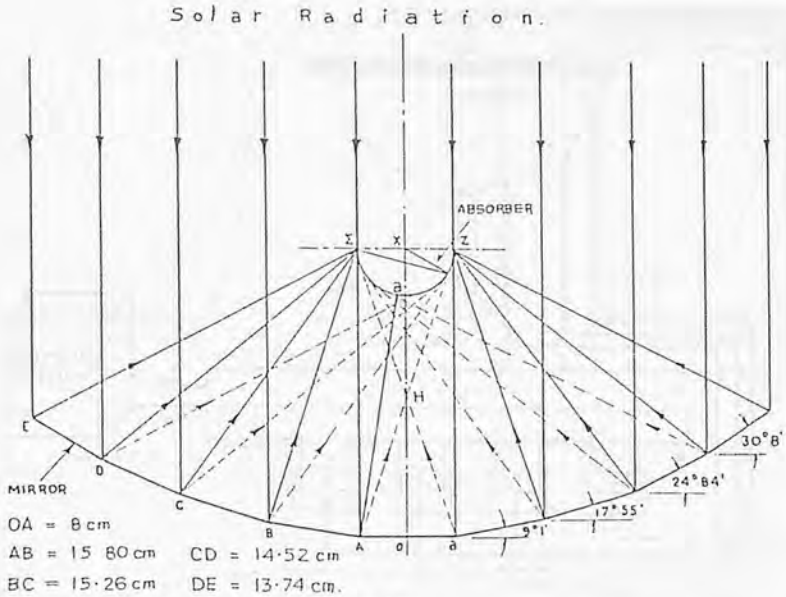

Fig. 1 Collector, absorber and the path of rays.

Collector Stand Design – The stand was designed to mount the collector. Diurnal tracking and seasonal tracking arrangements were provided on the stand to orient the collector according to position of the sun.

Experimental Technique – The aluminum hollow hemispherical absorber coated with a dull black paint on the outer surface was used for testing purpose. The three copper-constantan thermocouples were attached on the surface of the absorber. A fourth one was inserted inside the absorber. **(Fig. 2)**.

Testing of Collector – The temperature of the four thermocouples attached to the absorber were recorded after every 15 min interval. The corresponding ambient temperature and radiation intensity was measured.

The absorber performance was studied by filling different quantities of water in the absorber. The test was carried out for three days using 750 ml, 500 ml and 250 ml volume of water.

The rubber tube was connected to the steam outlet on the top of the absorber and the other end of the rubber tube was dipped in a graduated measuring cylinder kept in a trough filled with cold water acting as a condenser.

To start with, the test collector was oriented towards the sun. After a few minutes steam generation was started at the atmospheric pressure and condensed steam accumulated in the measuring cylinder.

The readings were taken after every 5 min until the entire quantity of water was converted into steam. The collector efficiency for generat-

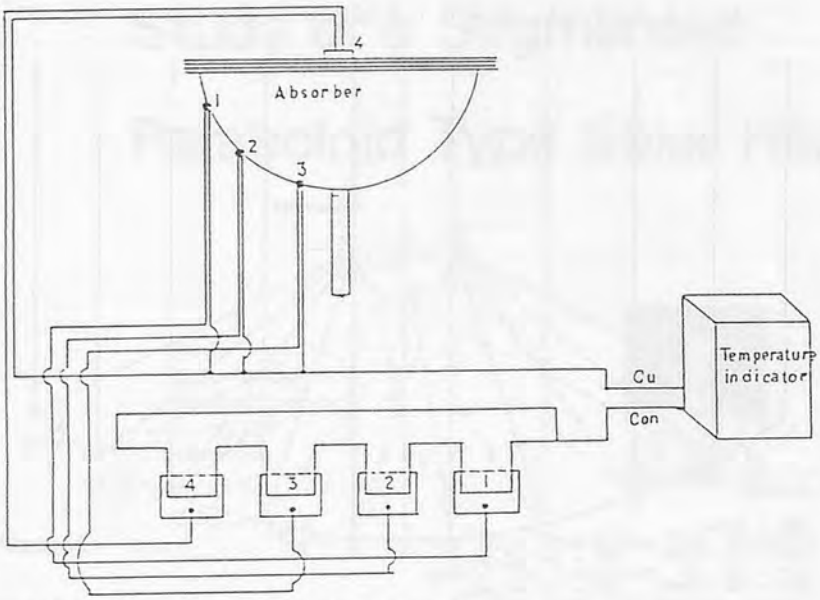

Fig. 2 Thermocouple positions and circuit diagram.

Fig. 3 Paraboloid type solar heat collector.

ing the steam with respect to time for each quantity of water was calculated from the above test (Fig. 3).

Result and Discussion

Collector Characteristics without Water in the Absorber

As shown in Fig. 4 all the thermocouplers exhibited the same trend with the different configurations. The fourth thermocouple initially showed lower temperature but when the air inside the absorber was superheated, temperature increased rapidly and then decreased gradually as the absorber temperature went down in afternoon hours. The first thermocouple give the lowest temperature because it was attached farthest from the centre and the diurnal tracking was done after every 0.5 h interval. The shade used to appear regularly on the upper portion.

Ideally, the first three thermocouplers should have given the same temperature if there were a uniform focussing throughout the absorber surface and if an absorber had a perfect hemisphere.

It was observed from the same graph in the morning and afternoon hours that radiation had to travel through the longer atmosphere where more dispersion, defraction and absorption took place and intensity decrease. But at noon time the rays fell perpendicular so the radiation losses were comparatively less.

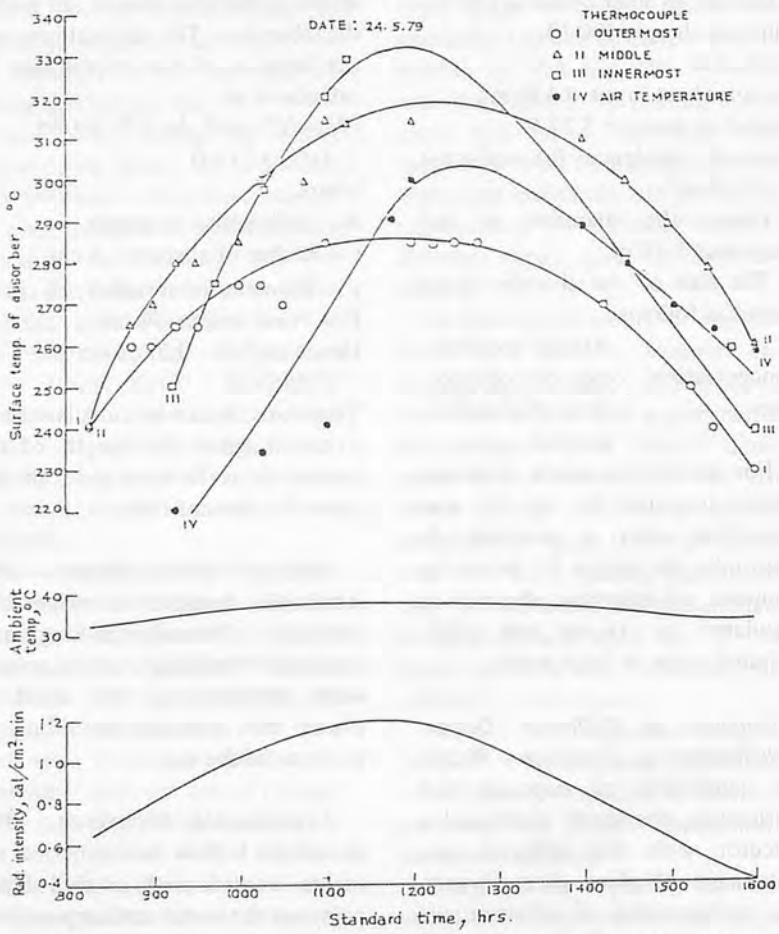

Fig. 4 Surface temperature of absorber without water (top), ambient temperature (middle) and radiation intensity (bottom) vs standard time, respectively.

Collector Characteristics with Water in Absorber

The first and second thermocouples have shown similar temperatures because as the collector was tilled towards the east in the morning, the absorber was also inclined through the same angle. Also, the thermocouples were attached to the northern part of the absorber the first and second thermocouples were nearer to the surface of the water. It is obvious that due to convection current, the surface zone of water will be at higher temperature than the lower zone. Similarly, the thickness of the absorber was not uniform, hence the first and second thermocouples indicated 110°C temperature and the third thermocouple indicated 100°C. As soon as the water level receded below the thermocouples a significant rise in temperature was observed. The same trend was observed in all three sets of readings (Fig. 5).

The amount of steam generated with respect to time for the three sets of reading is plotted in Fig. 6. It will be seen that the rate of steam generation is slow in all sets of readings in the initial stage of heating and steam formation.

This is obvious because first the water was heated from ambient temperature to 100°C and the sensible heat is used to raise the temperature of water up to 100°C. Similarly, at the end of steam generation process the quantity of water decreased and so did the rate of steam generation. In this way three sets of the readings were taken which showed the same trend.

The steam generation test was carried out by taking 250 cc of water in the absorber. It was observed that the rate of steam generation was also affected by the following: i) While adjusting the collector for diurnal tracking after every 0.5 h the movement of absorber was producing impulse to the water in the absorber thus causing oscillating movement; and ii) As the diurnal tracking was done every 0.5 h, the shade used to appear on the same portion of the absorber regularly.

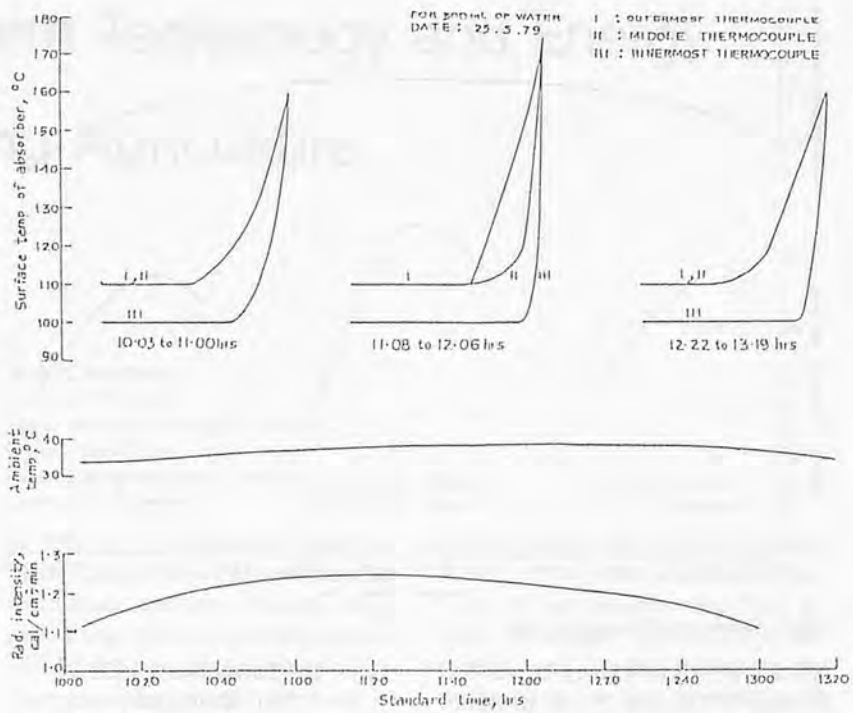

Fig. 5 Surface temp. of absorber with water inside, ambient temp. and radiation density vs standard time, respectively.

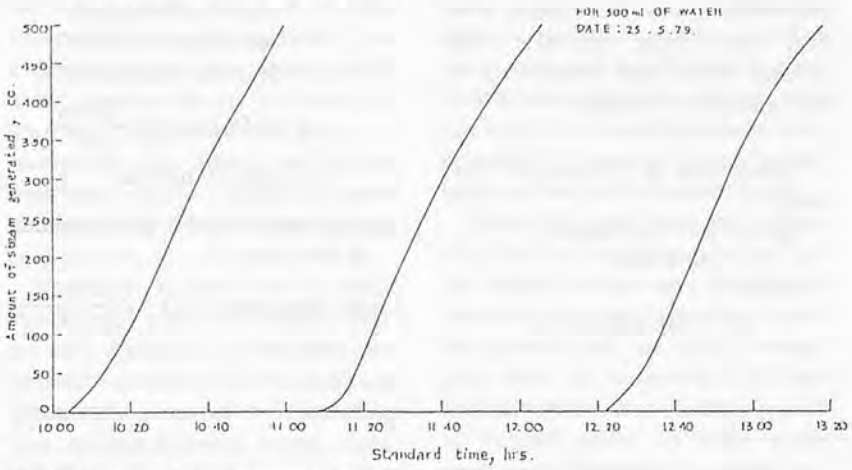

Fig. 6 Amount of steam generated vs standard time.

Evaluation of Collector Performance

The collector efficiency curves for heating 500 cc of water were plotted as shown in Fig. 7. It is observed from the graph that the efficiency curve rose steeply then formed a peak and then decrease sharply. It is obvious because rate of steam generation is slow initially and the sensible heat used to heat the water up to 100°C. Then efficiency reached maximum and again started declining. It is obvious at the end of the process that the quantity of water decreased hence the heat loss from the absorber increased resulting in a decrease in

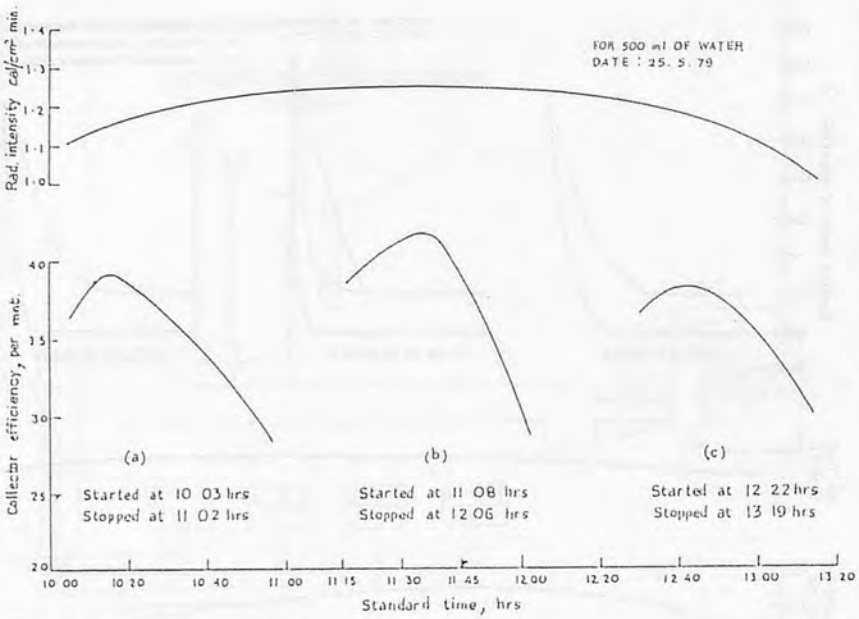

Fig. 7 Collector efficiency vs time.

efficiency. All efficiency curves for heating 750 cc and 250 cc of water show the same trend.

Factors responsible for giving less efficiency to the collector were heat losses from absorber, wind cooling effect and reflectivity of the concentrator surface.

Calculation of Efficiency of Collector –

$\sin A = \text{cost} \cos d \cos H + \sin L \sin d$

Where

A = Solar altitude

L = Latitude angle (22.3° for Kharagpur)

H = Hr angle = 15 x hrs measured from solar noon (At Kharagpur solar noon: 11.30 hr)

d = Seasonal declination.

$$= 23.45 \sin \left(360 \frac{284+n}{365}\right)$$

n = Day of the year.

Incident angle = 90° – Solar altitude at that time

$$\text{Local mean time} = \text{IST} + \left(\frac{L-82.5}{15}\right)$$

$$\text{Incident energy In} = \frac{\text{Ih}}{\cos(\text{Incidence angle})}$$

Ih = Incidence energy measured on horizontal surface, hence total incident = Intensity of incident energy x Area of incidence energy. It gives input energy. While generating steam from solar energy output = sensible heat + latent heat of vaporization. From the above equations efficiency was calculated.

Conclusion

The following conclusions can be drawn from the collector characteristics and collector performance.

i) Higher surface temperatures of the absorber were achieved as the radiation intensity increased with the time of day. The maximum temperature was found to be 330° at 1130.

ii) The highest efficiency achieved was 42% while heating 500 cc of water.

iii) The maximum and minimum time taken by 250 cc of water to convert into steam was 43 and 37 min, respectively, for 500 cc it was 59 and 58 min, respectively, and for 750 cc it was 110 min and 105 min, respectively. ■■

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Impact of Farm Technology and Energy on Developing Agriculture

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Introduction

Most developing countries lie within approximately 30° on either side of the equator – a region within both the sub-tropical and tropical areas. The state of agriculture in this region is not fully developed, and crop yields are some of the lowest in the world. Underdevelopment of agriculture in the area is often associated with unfavourable climates and lack of capital. While such factors may have some impact on the rate of agricultural development, it appears that stagnation in productivity is correlated with the lack of energy inputs and with the use of traditional methods and inputs. It is not difficult to see, even at the more basic levels, that the use of indigenous agricultural implements reflects ignorance and illiteracy among the farmers in terms of modern agricultural development.

Impact of Climate and Technology

Various climatic factors can significantly affect agricultural practices. Intensive rainfall can play havoc on soil stability and enhance erosion, particularly on sloping ground. Lal[1] has determined that soil erosion on a 10% slope can be as high as 1 t/ha/month under a maize crop sown by conventional cultivation methods. He also suggested that erosion could be reduced to 0.02 t/ha/month where crops were grown by "no-till" methods.

In humid tropics (e.g., West Africa, Indonesia), overcast weather can reduce solar radiation to half that which may be available, for example, to an Australian farmer in the growing season. So farmers in the wet tropics would have to manipulate solar energy and rain so that they may be utilised for maximum photosynthesis for maximum crop growth.

Increased erosion due to high run-off also enhances nutrient losses and destroys soil structure. In semi-arid countries where crops are completely removed by harvesting and grazing between crops, traditional tillage methods are encouraging erosion and nutrient losses.

Weed competition is another problem. It is estimated that tropical farmers spend up to 60% of their time eradicating weeds[2]. Increased cultivation brings the dormant weed seeds to the surface and when these germinate they compete with the growing crop, effectively reducing the final crop yields.

Developing agriculture can be divided into three distinct stages in terms of machinery use for crop production. Firstly, a major part of the farming still revolves around a pair of bullocks and manual labour. It has become clear that in these situations, productivity has peaked and further increases in productivity are not possible until sufficient power can be provided to break the subsoil pan. The problem has been that subsoil nutrients and soil moisture potential are not being fully exploited because root proliferation appears to be impeded. Improved tools and increase power, if properly used, can rectify and improve these adverse conditions.

Secondly, some areas are in what is called the "transitional stage". In this stage an increased number of tractors are used to tine-cultivate the ground and for other on-farm jobs such as stationary threshers and pumping water. Tractor power is utilized either to bring more areas under cropping (as pressure to grow more is increasing) or to cultivate a given area more intensively, which results in "over-cultivation". In such conditions soil structure is deteriorating and increased soil erosion and nutrient losses are generally reducing crop production in the long run.

Thirdly, in some areas where high capital resources are available, high-powered tractors and big machinery are used. Gross misuse of this power is occurring on the land where increased sub-surface

soil compaction could seriously limit the crop productivity in the long run.

It is evident that proper and rational use of on-farm equipment is required to manipulate the adverse climatic and soil conditions for optimum crop production.

Rational Mechanization

A biologically efficient food and farming system must exploit the productive potentials of land with the prudent use of ecological, economic and scientific resources.

Agricultural production is dependent upon solar energy conversion by the process of photosynthesis. Other inputs include fossil fuels in the form of fertilizers, herbicides and insecticides, and liquid fuel to operate machines. Thus to achieve maximum efficiency of solar energy utilization, added energy is required as shown below.

Consumable energy (food) = added energy x solar energy conversion efficiency

Conversion efficiency depends upon geographical location, climate and the optimum use of added energy. There are three major farming systems in various regions of the developed agriculture, which are presently most efficient solar energy conversion systems.

Firstly, in countries where land is expensive and ha/worker is low (e.g., Japan, Korea), high output/ha is achieved by increasing energy inputs in the form of fertilizers, insecticides, etc. Machinery input is mostly in the form of low horsepower, walking-type tractors.

Secondly, in broad acre cropping regions (e.g., Australia) increased crop production has been achieved by increasing energy inputs by using high horsepower tractors and machinery. Crop production per worker and per ha is low. However, there is potential for increased crop production by crop intensification and by other technological inputs.

Thirdly, increased crop production has been achieved by increased mechanical and biochemical inputs (e.g., U.S.A. and West Europe). Such inputs have increased crop production per farm worker and per ha. For example, the U.S.A. uses about 66 times more energy per capita than African countries according to one survey[3].

Mistakes have often been made by importing agricultural systems from the developed countries (mostly temperate) to suit developing agriculture (mostly tropical). While scientific and management principles might be able to be transferred from some location to another, it would be folly to extrapolate agricultural data from one climatic zone to another as important environmental restrictions impose problems when such "systems" are applied in a tropical climate. There is a simple explanation. For example in the temperate climate during winter periods, precipitation exceeds evaporation, and the soil profile is charged with a reserve of water. During a growing season when rainfall is less than evapotranspiration, crops draw reserve moisture and less water and nutrient leaching occurs. On the other hand, crops grown in the tropical agricultural growing season draw most of the reserve soil moisture, and drought usually occurs towards the end of the season. Each new season starts with little reserve ground water, and any drought that occurs during the early stages of plant growth adversely affects plant establishment. However, during the growth period, higher precipitation and less evaporation (monsoon and overcast weather) result in excessive leaching and soil erosion due to high run-off.

This shows that in tropical regions, technology development and management requirements have to revolve around moisture conservation, erosion control and suitable equipment development to achieve consistent crop production.

Major crop production operations (i.e., planting and harvesting) are very much dependent upon climate and soil conditions. Crop yield reductions and failures can be avoided by the timely and efficient use of these two major farming operations. Hence, it is necessary to devise methods to utilise favourable climatic conditions and avoid situations where these factors can have adverse effects. Power-operated farm machinery can help increase productivity as follows:

(1) Bring unutilized land into cultivation through heavy operations such as land clearing and deep tillage.
(2) Speed up seed planting operations to optimize timeliness and reduce the spread of harvesting times, thereby decreasing the chances of crop losses.
(3) Farm machinery use certainly reduces human drudgery. Recent trends in polulation shifts already suggest a labour shortage, particularly at peak requirement times.

To achieve rational mechanization, it is necessary to evaluate the requirements of given conditions and develop technology based on local research to utilize indigenous resources.

One of the problems which could effectively limit the use of increasing farm machinery is the need for liquid fuel to propel the tractors. Gasoline and diesel are not only expensive but their availability is a limiting factor in some circumstances. Therefore, measures need to be taken to find alternative sources of energy and liquid fuels which can be substituted for on-farm fossil fuel usage.

On-Farm Energy

It is not within the scope of this paper to review the alternative sources of energy for national development. The paper briefly looks at the potentials of various energy options for agriculture in developing agriculture.

Agricultural economic development is hightly correlated with the amount of energy used. This is true for both developed and developing agriculture. A United Nations survey[3] shows that world per capita consumption of "commercial" fuels doubled in the 25 years ending 1974. However, the survey also showed a tremendous gap between developed and developing countries in their total energy used. Developing countries have 70% of the world population while their energy share is only 17% of the total energy consumption. Such a disparity, when extrapolated to on-farm energy, clearly explains the lower farm productivity in developing countries.

Table 1 shows the energy consumption by the agricultural sector of some selected areas. It appears that agriculture uses approximately 3.5% of the total energy demand of the world. The figures vary from 3 to 6% depending on the size of the primary agricultural industry. Further breakdown of such figures shows that, in New Zealand, for example, about 15% of farm energy input goes into crop production operations.

Table 1 Estimated Agricultural Use of Commercial Energy, 1972/73

Country	Percent use in agriculture	Per capita consumption (GJ)	Per agricultural worker
North America	2.8	333	555.8
West Europe	4.8	119	82.4
Oceania	5.6	154	246.8
Africa	4.5	5	0.8
Latin America	3.8	28	8.6
Asia	3.2	54	1.7
World	3.5	59	

Source (3)

Energy sources and their utilization vary within rural communities of developing countries. At present most developing countries, with the exception of OPEC nations, are heavily dependent upon imported liquid fuels for on-farm machinery operations. Rural populations usually use wood, coal and animal and crop wastes for domestic purposes while bullocks are used as draught animals for crop production.

In some areas uncontrolled logging for firewood is occurring which is contributing to widepsread erosion of soil. In hill country regions, soil erosion is reaching serious levels and causing irreversible losses.

Animal and crop wastes are almost exclusively utilized as domestic fuels in some areas where wood or coal are not available or are not at affordable price levels for rural communities. It is worth noting that recycling farm wastes back onto paddocks contributes to higher soil surface residues, carbon and nitrogen levels and generally improves soil fertility by virtue of nitrogen fixation by clovers and by increased microbial and worm activities.

In some developing countries, the use of tractors has increased recently. This has increased the demand for liquid fuels, i.e., gasoline and diesel. These fossil fuels are expensive and limiting, particularly for oil-importing countries. Therefore, research and development is urgently needed to exploit alternative energy sources for other on-farm and domestic uses.

Solar Energy

Current applications of solar energy that can appropriately be used in rural areas, depending on local conditions, include heating and cooling of water for both domestic and commercial use, drying of agricultural products and desalination of water. Technically, many other uses of solar energy are possible. However, such applications may not be economically appropriate at this stage.

Use has been made of direct and indirect sunlight for crop drying. In arid and semi-arid tropics there is almost unlimited solar energy available, and it can be used for diverse purposes.

Direct conversion of the visible part of the solar spectrum (sunlight) to electricity is perhaps the neatest and most aesthetically pleasing of all uses for the exploitation of solar energy. The photovoltaic devices (solar cells) are wafers of crystalline material which, when exposed to sunlight, supply an electric current capable of useful work. The output energy is stored in batteries (store houses). One of the biggest problems encountered in solar technology is storage of electricity because large capacity and long-term facilities are not available. Currently, work is continuing to improve batteries and solar cells in these respects.

By far the largest use of solar energy known to mankind is crop production by photosynthesis. Improved production of cover crops can also be converted photobiologically to useful fuels. In high intensity rainfall tropics, cover crops can also reduce soil erosion.

In brief, solar energy offers the greatest potential for long-term solutions of developing agriculture. Effective implementation of policy would require development programmes on solar energy to be substantially expanded.

Wind Energy

The wind is a mechanism for dissipating, as kinetic energy, potential energy accumulated in pressure differences generated by temperature gradients.

Wind energy has been used in

the East, for time immemorial, to propel ships, grind grain and pump water. To be more specific, the predominant uses for wind energy include pumping water for domestic and livestock use, and for irrigation in remote hilly regions.

Windmills, as a source of mechanical power, continue to be an appropriate technology for rural applications. Limitations of wind energy may be evaluated in terms of reliability and capital cost of the component and, more realistically, in terms of the amount of power generated. The minimum speed of wind at which windmills start to produce useful energy is considered to be about 6 m.p.h. (2.4 m/sec). Manufacturers rate their equipment for speeds up to 15 m.p.h. (6-7 m/sec).[4]

Limitations for the use of wind energy include a general lack of information on wind speeds and frequency. Therefore, steps should be taken to collect wind speed data at potential sites for installation of suitably sized windmills. Maintaining and encouraging development of wind machines can result in an increased energy supply for selected rural communities.

Water Energy

Hydropower is well known for its use in generating electricity around the world. In many countries a major part of the electricity supply for domestic and commercial use is generated by hydropower.

The potential energy of water dropping from a height is converted into mechanical energy using turbines which, by their rotation, convert such energy into electricity through generators. The amount of energy thus produced is calculated by the amount of water falling per unit time multiplied by the drop in elevation, 'head'. The actual power output is determined by multiplying the theoretical power by the conversion factor which represents the efficiency of the hydro-system.

Small scale (up to 10 kW) turbine designs are available which accommodate variations in head requirements between 3 and 8 m. In China, for example, small scale hydro-power turbines are commonly used in rivers and irrigation canals for generating electricity. The simple and efficient designs of hydro-power generating devices suggest that they can be used with minimum running costs in remote hill country where an ample supply of water is available.

In brief, the above-mentioned three major alternative energy sources are available for use in developing agriculture. However, utilization of such enrgy sources depends upon the technology available in a given situation, and local research and development would be required to determine the feasibility of each resource.

On-Farm Alternative Fuels

A lot of research and development work is trying to find competitive fuels, particularly in those countries which are totally or partially dependent upon imported petroleum. Some of the potential alternative fuels which may be beneficially utilized in developing agriculture are as follows:

Biogas

Biogas is not new to developing agriculture. Already in some countries its use is well recognised. Biogas is a mixture of 50-70% methane (CH_4) and 30-50% carbon dioxide mixed with trace impurities of sulphur gases. Biogas is produced by the action of anaerobic bacteria and organic matter. Gas is produced in a digester at an ideal temperature (37°C) and in neutral acidity. It takes about 15 days to convert organic material into biogas.[5]

All kinds of organic farm wastes (i.e., remains of crops, leaves and animal wastes) can be used to feed the digester. Uses of biogas include vehicle fuel, direct heating fuel, hot water heating, crop drying, etc. Safety precautions have to be taken when using biogas for any particular purpose. For example, carbon dioxide (CO_2) and corrosive sulphur gases should be removed before biogas can be efficiently and safely utilized as fuel for vehicles.

The use and cost of biogas would depend on many factors, including digester size, cost and types of feeding material, climate, potential uses and the capital cost of the system.

Methanol

This is a liquid fuel manufactured from biomass or natural gas. The calorific value of methanol (methyl alcohol, CH_3OH) is half (16 MJ/l) that of gasoline. This means that gas cylinders of double the gasoline capacity would be needed to achieve the same range or work capacity. Methanol has, however, a higher octane rating than premium grade gasoline and hence more power can be expected if a higher compression ratio is used. In one study, methanol in blends with gasoline, appeared to have similar performance to petrol but with cleaner burning. However, there are certain disadvantages which need careful attention when considering methanol production.

There are other fuels which have shown considerable potential. However, such fuels might have little application in developing agriculture. One alternative source of fuel is vegetable oil. Studies on sunflower, safflower and oil seed rape suggest that the oils of these seeds could be used as a substitute for diesel in certain environments. The opportunity cost is that less land is in food crops. Therefore, this alternative may not be attractive where high priority is to grow enough

staple food. Another source is ethanol (ethyl alcohol, C_2H_5OH) a liquid that can be used as a petrol substitute and is manufactured from biomass. The advantages and disadvantages of ethanol are not dissimilar to those of methanol. At least in one developing country, Brazil, a large amount of ethanol is produced for motor fuel using sugarcane as the feeding material for production. The utilization of ethanol as an alternative fuel would probably have little acceptance in the Moslem world on ethical and religious grounds.

Another minor resource is tallow (animal fat). Esters of tallow can be prepared simply and cheaply by heating the fat with methanol (or ethanol) using a catalyst which can be recycled. Oil or fat molecules can be broken down into simpler molecule chains in a similar manner to diesel. Results to date indicate that tallow is viable as a substitute.[6]

However, large stocks of animal fats are required if this source is to be economically feasible, and it appears that in developing agriculture, animal populations may not be high enough to supply such an alternative.

Fig. 1 shows a relationship between the farm production and energy input/worker in various agricultural regions. It is clear that farm output is directly related to the energy input per worker. It also shows that those farm workers who utilize high energy inputs are also

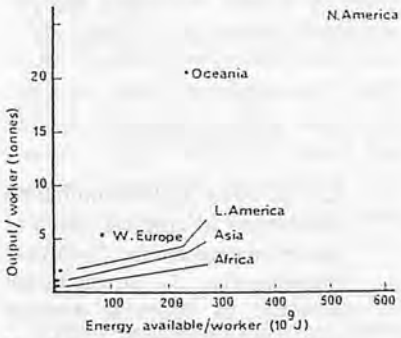

Fig. 1 Farm production and energy input/worker.

progressively more inefficient in converting such energy into useful output. For example, a North American farmer who utilizes 5 times more energy compared with his Western European counterpart, produces only twice as much. Therefore, it is imperative to develop energy efficient farming methods in Asia and Africa, where farmers have less energy available to them. One of such farming systems is the conservation tillage.

Conservation Tillage

Traditionally, ploughs have been used advantageously to help control weeds, insects and manage trash and crop residues. Lists of benefits have been advanced in favour of the plough ever since Thomas Jefferson, a farmer and later a President of the United States, designed and tested the first plough nearly two centuries ago. Since then, ploughs have been redesigned and modified. They have been used successfully in bringing virgin lands into production. It was only recently (1943) that Edward Faulkner in his "Plowman's Folly" first questioned the wisdom of using a plough when he declared "no one has ever advanced a scientific reason for ploughing". As farm mechanization has gathered pace since the 1940's, a renewed interest in conservation of natural resources has taken place in developed agriculture.

The I.C.I. Ltd first developed non-residual herbicides in the 1960's which successfully controlled weeds, thus eliminating the need for ploughing. Since then, others have followed. Insecticides are also available now which can reduce the impact of harmful pests and soil-borne insects. Such chemical developements have helped develop alternative forms of crop production in which the plough was redundant.

The oil shock of the 1970's gave further momentum towards introducing fuel conservation tillage techniques into high energy farming in developed countries, where up to 20% of the liquid fuel used on the farm was used for tillage.

Conservation tillage farming has become an established and viable system both for pastoral and cropping farming in most developed countries. Recently some research in developing countries, notably at the International Institute of Tropical Agriculture, Nigeria, has also taken place in an effort to help replace laborious indigenous agriculture.

It is often confusing to a new audience or reader when various terms are used to describe the latest techniques. The following terms cover most of such contoversy:

Direct Drilling – Direct drilling refers to drilling of seeds (and fertilizer if required) for cash crops into previously untilled or fallow ground where existing vegetation had been suppressed by herbicides. No-tillage and zero-tillage terms are sometimes synonymously used with direct drilling. However, these terms only describe the state (untilled) of the seedbed.

Over-drilling – The drilling of seeds into previously untilled or fallow land to establish new pastures, improve "run-out pastures" or develop native country with or without the use of herbicides refers to over-drilling. Undersowing and sod seeding is also used synonymously with over-drilling. However, oversowing is not the same as over-drilling. The former involves broadcasting or spreading of seeds manually or by planes to rejuvenate pasture on flats or hill country.

Minimum or Reduced Tillage – Conventional tillage practices which involve reducing the number of cultivation operations needed to prepare acceptable seedbed.

Conservation Tillage – As the dictionary meanings suggest, conservation tillage refers to the pre-

servation or protection of critical natural resources through a planned tillage system to prevent exploitation, destruction or neglect. Conservation tillage embodies wider aspects of tillage including the above-mentioned specific techniques. It may mean different things to different people in various parts of the world pertaining to specific conditions and purposes for its adoption.

Some of the most prominent advantages of farming by conservation tillage methods are listed below:

1. Reduction in liquid fuels use. (up to 80%)[9]
2. Reduction in labour required. (up to 75%)[10]
3. Sowing times less affected by weather
4. Less soil erosion. (up to 95%)[1]
5. Increase in earthworm population (up to 5 times)
6. Improvement in soil structure and increase in organic matter near the soil surface.[1]
7. Increased water infiltration, water holding capacity and moisture conservation.[1]
8. Decrease in soil surface temperatures in the semi-arid tropical situation.[7]
9. Better utilization of soil moisture under drier soil and ambient conditions.[11]
10. Improved soil bearing capacity for machinery traffic.
11. Reduction in capital investment in machinery.
12. Reduction in chemical usage with time.[10]
13. Increased acreage and longer utility of land.[10]
14. Cleaner environment.
15. Greater flexibility and more recreational time.

In various agricultural regions, acceptability of conservation tillage has been dependent upon specific requirements. For example, in the U.S.A. where soil erosion is a major problem, due to continuous soil cultivation, conservation measures are being taken. Conservation tillage practices as one of such measures are being adopted. Over a period of 10 years between 1973 and 1982, increases of 437% and 381% in no-tillage figures show that the area under conservation tillage and no-tillage were 100.3 million and 11.5 million acres, respectively, which was about 54% of the total cropped area in the U.S.A.[12]

In New Zealand, in spite of a very favourable climate and generally conservative farming community, about 3% of total crop and pasture production is done by direct drilling and over-drilling techniques. This figure is increasing at an annual rate of 80% according to one estimate.

In Australia, that vast country where the climate varies from temperate to semi-arid tropics, 800 000 ha were direct drilled in 1981. This represents about 8% of the total cultivated area. The Northern Territory of Australia is climatically a part of semi-arid tropics with similar agricultural constraints. This region is only recently opened up for commercial cropping. To increase the efficiency of labour and capital, and also to conserve soil, systems centred around no-tillage farming are being successfully adopted.[7]

Experiments with no-tillage in humid tropics (Nigeria) have already shown tremendous success in increased crop production, and in soil erosion control.[1] In the semi-arid zones of the U.S.A. and Australia, results with no-tillage techniques suggest increased soil moisture conservation, decreased wind and water erosion of soil, increased surface residue, lowering soil temperatures and generally improved crop production.

One recent study[8] suggests that there is great potential for increased crop production and for reducing soil erosion by utilizing no-tillage techniques in Pakistan. The Pakistan Agricultural Research Council is already planning to experiment with such techniques at selected sites in Pakistan.

The most significant apsect of no-tillage systems in developing agriculture is that, by virtue of the present state of art in these regions, it is possible to devise more rational systems of crop production without having to progress through indigenous agriculture to the more elaborate systems of high energy mechanization.

The developing countries, by adopting such technologies, may unknowingly benefit by not making the mistakes that developed countries have made in the last half century. Developed countries are now re-examining alternative methods of growing crops.

Summary

Low farm productivity in developing agriculture is the result of increasing pressure on farmers to produce more by intensifying tillage and over-grazing continuously degrading soils.

Urgent measures need to be taken to adopt rational mechanisation policies, not only to reduce labour drudgery on the farm but to increase productivity.

Technology is becoming available to utilize alternative fuels and energy sources for on-farm use.

An alternative farming system, "conservation tillage", is available, and local research and development is needed to exploit the potentials of this proven technology.

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(Continued on page 68)

Status of Mechanization on Hilly Farmlands of Puerto Rico

by

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Abstract

A survey of 325 small hilly farms was conducted during 1978-83 to determine the crops grown, the degree of mechanization currently employed on these farms and to have a basis for mechanization requirements under existing conditions and desires of the farmers. There is a potential for using walking type power tillers with accessories, especially Japanese machines, on these farms.

Introduction

Traditionally, agriculture in Puerto Rico has been labor-intensive, especially on small hilly farms, thus limiting the production capacity per man to subsistence levels. Sugarcane and coffee employed most of the workers. Under this system, sugarcane production is in the order of 10 to 20 t of sugar per worker per year equivalent to an input of 100 to 200 man-h/t of sugar, while picking and drying coffee ordinarily absorb approximately 75% of the crop value during 1975. A ready market for sugar resulted in the best level lands being utilized for sugarcane by large land holders, whereas the small farmers produced the local food crops largely utilizing the steeper and less productive lands. To a great extent, the large land owners have been better able to adjust to changes imposed by changing world conditions and markets, but the small farmers lacked the necessary resources – financial, technical, and land – to improve their lot, thus remaining at subsistence production levels. This type of farming is in dire need of help to increase its productivity, not only for the subsistence of the small farm families, but to increase the food supply of Puerto Rico as a whole. Appropriate machines, devices, techniques, and systems need to be developed and introduced in order to make these small hilly farms more productive and more efficient.

Research and development efforts aimed at resolving the mechanization problems of small hilly farms have been extremely limited throughout the world. Research and development projects have largely delt with slope modification and minimum tillage for erosion control (2, 3, 4, 5). Emphasis has been placed on increasing farm size with a view to decreasing farm labor input per unit area, coupled with the development of larger and more powerful equipment for more efficient tilling, planting, cultivating, and harvesting of crops on the more productive soils. As a result, the technology and equipment for keeping small farms, particularly on hill land areas, competitive in production costs and productivity levels are generally lacking in our society and research programs (1). On the other hand, other areas of the world have placed some emphasis on producing equipment for small growers. Japanese manufacturers offer small power units of both the walking and riding types that are advertised to till, cultivate, plant, and perform other agricultural operations. Such type of equipment needs to be tested and

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Table 1 Elements of Farm Mechanization in Puerto Rico, 1969 and 1974

Description (1)	All farms				Economic classes			
	1974		1969	1969-74	1974		1969	1969-74
	Nos.	% Total	Nos.	% Change	Nos.	% Total	Nos.	% Change
Number of farms . . . . . total	29 650	–	32 687	−9.3	11 452	–	7 431	+54.1
Cuerdas in farms . . . . . total	1 259 917	–	1 334 800	−5.6	1 040 247	–	1 001 333	+ 3.9
per farm	42.5	–	40.8	+4.2	90.8	–	134.8	−32.6
Cuerdas of cultivated cropland . . total	352 600	–	362 642	−2.8	285 022	–	290 541	− 1.9
per farm	14.8	–	14.1	+5.0	29.8	–	46.9	−36.5
Number of farms by size (1 cuerda = 0.9712 acres)								
Under 10 cuerdas	14 318	48.3	17 238	−16.9	2 547	22.2	881	+189.4
10 to 19 cuerdas	6 083	20.5	6 579	− 7.5	2 442	21.3	1 382	+ 76.7
20 to 99 cuerdas	7 078	23.9	6 728	+ 5.2	4 460	38.9	3 292	+ 35.5
100 to 259 cuerdas	1 299	4.4	1 193	+ 8.9	1 160	10.2	981	+ 18.2
260 cuerdas and over	872	2.9	949	− 8.1	843	7.4	895	− 5.8
Machinery and equipment on farms-specified items (number):								
Jeeps and pickup trucks, and motor trucks	10 792	–	(NA)	–	7 960	–	5 491	+ 68.9
Tractors	3 143	–	(NA)	–	2 996	–	4 117	− 37.4
Value of agricultural products sold (dollars)								
total	293 346 491	–	172 944 896	+69.6	287 216 033	–	163 213 582	+ 76.0
per farm	9 894	–	5 291	+87.0	25 080	–	21 964	+ 14.2
Crops[1]	155 796 004	53.1	84 397 351	+84.6	151 076 189	52.6	76 922 350	+ 96.4
per farm	7 591	–	3 498	+117.0	16 104	–	12 475	+ 29.1
Liverstock, poultry, and their products . . . . . total	137 550 487	46.9	88 547 545	+ 55.3	136 139 844	47.4	86 291 232	+ 57.3
per farm	13 405	–	6 631	+102.2	23 644	–	20 487	+ 15.4
Farm income from farm-related source[2] (dollars) . . . . . total	16 231 710	–	(NA)	–	13 818 726	–	10 448 734	+ 32.2
per farm	2 194	–	(NA)	–	3 063	–	4 023	− 23.8
Farm production expenses-specified items (dollars):								
Feed for livestock and poultry	59 023 451	–	31 558 736	+ 87.0	56 882 515	–	30 407 449	+ 86.9
Commercial fertilizer	11 153 139	–	12 353 975	− 9.7	10 086 808	–	11 125 007	− 9.3
Chemicals (insecticides, herbicides, and fungicides)	4 314 565	–	(NA)	+ 49.9	4 141 611	–	2 877 899	+ 43.9
Wages and salaries	76 216 028	–	50 320 083	+ 51.5	73 316 267	–	48 285 491	+ 51.8
Number of farms by value of agricultural products sold:								
Under $1,200 (Economic class 7)	18 198	61.4	25 256	−28.0	(X)	–	(X)	–
Under $500	13 014	–	17 167	−24.2	(X)	–	(X)	–
$500 to $1 199	5 184	–	8 089	−35.9	(X)	–	(X)	–
$1 200 and over (classes 1–6)	11 452	38.6	7 431	+54.1	11 452	–	7 431	–
$1 200 to $2 499 (Economic class 6)	3 955	13.3	2 890	+36.9	3 955	34.5	2 890	+36.9
$2 500 to $4 999 (Economic class 5)	2 851	2.6	1 651	+72.7	2 851	24.9	1 651	+72.7
$5 000 to $7 999 (Economic class 4)	1 103	3.7	667	+65.4	1 103	9.6	667	+65.4
$7 500 to $9 999 (Economic class 3)	617	2.1	316	+95.2	617	5.4	316	+95.2
$10 000 to $19 999 (Economic class 2)	997	3.4	537	+85.7	997	8.7	537	+85.7
$20 000 and over (Economic class 1)	1 929	6.5	1 370	+40.8	1 929	16.9	1 370	+40.8
Value of agricultural products sold by farms having sales of (dollars)								
Under $1 200 (Economic class 7)	6 130 458	2.1	9 731 314	−37.0	(X)	–	(X)	–
Under $500	(NA)	–	3 124 712	–	(X)	–	(X)	–
$500 to $1 199	(NA)	–	6 606 602	–	(X)	–	(X)	–
$1 200 and over (classes 1–6)	287 216 033	97.9	163 213 582	+76.0	287 216 033	–	163 213 582	–
$1 200 to $2 499 (Economic class 6)	6 922 991	2.4	5 090 960	+26.5	6 922 991	2.4	5 090 960	+35.9
$2 500 to $4 999 (Economic class 5)	10 018 120	3.4	5 697 645	+43.1	10 018 120	3.5	5 697 645	+75.8
$5 000 to $7 499 (Economic class 4)	6 687 513	2.3	4 043 080	+39.5	6 687 513	2.3	4 043 080	+65.3
$7 000 to $9 999 (Economic class 3)	5 314 380	1.8	2 722 875	+48.8	5 314 380	1.9	2 722 875	+70.6
$10 000 to $19 999 (Economic class 2)	13 937 920	4.8	7 525 524	+46.6	13 937 920	4.9	7 525 524	+48.2
$20 000 and over (Economic class 1)	244 335 109	83.3	138 133 498	+43.5	244 335 109	85.0	138 133 498	+76.9

Remarks: 1) Includes income from sales of nursery and greenhouse products, hay, and forest products.
2) Includes income from agricultural services provided, recreational services provided on the place, renting out farmland, and payments received for participation in Government farm programs.

Source: Puerto Rico Department of Agriculture.

evaluated for performing some of the needed tasks on hilly farmlands in Puerto Rico. The objectives of this study were to evaluate farming techniques and practices currently used on small hilly farms in Puerto Rico. The procedures involved direct farm visits and observations to identify work inputs and production levels per man-h.

Results and Discussion

Tables 1 and 2 indicate the elements of farm mechanization in Puerto Rico. These tables reveal information on number of farms by size; number of machines on the farm; farm income from sale of crops, live-stock, poultry and their products, and other farm-related sources; classification of farms based upon value of agricultural products sold; farm production expenses; and percentile distribution of farms based upon expenses, and of farm operators based upon age, tenure and work days on the farm. These tables show that the number of farms and acreage decreased by 9.3 and 5.6%, respectively, during 1969-74. The number of farms with 0-19 cuerdas (1 cuerda = 0.9712 acre) decreased by 24.4% during 1969-74 compared to a 14.1% increase in farms with 20-259 cuerdas. Total sale of agricultural products increased by 69.6%. The number of farms based upon sale of agricultural products were classified into seven economic classes (class 7 = under $1200, class 6 = $1200-2499, class 5 = $2500-4999, class 4 = %4000-7499, class 3 = $7500-9999, class 2 = $10000-19999, and class 1 = $200000 and over). The number of farms in class 7 decreased by 28.0% during 1969-74 compared to 40.8 - 95.2% in other classes. The number of farms in class 7 was 61.4% compared with 38.6% in other classes. The value of agricultural products sold by farms in class 7 was 2.1% compared to 97.9% for classes 1 to 6, indicating that Puerto Rico agriculture is characterized by small farms. Farm production expenses increased for feed, chemicals, wages and salaries in contrast with a decline for fertilizers. Fifty percent of the farms had production expenses of less than $1000 and 86% of these farms were tilled by 45 to 65 year old owners. Forty percent of farm operators worked off the farm in addition to their farming duties.

Table 2 Profile of Puerto Rico's Agriculture, 1974

Item	Percent of total
I All farms	
Farms by amount of total production expenses	
None	4.8
$1 to $499	42.3
$500 to $999	15.6
$1 000 to $4 999	23.8
$5 000 to $9 999	3.1
$10 000 and over	5.3
Farm operators by age	
Under 25 years	0.8
25 to 34 years	6.2
35 to 44 years	14.3
45 to 54 years	22.0
55 to 64 years	27.8
65 and older	28.8
Farm operators by tenure	
Full owners	86.0
Part owners	7.4
Tenants	5.7
Managers	1.0
Farm operators by number of days worked off farm	
No days	60.1
1 to 99 days 8.0	8.0
100 days and over	30.3
Not reported	1.7
II Economic classes 1–6	
Farms by type of farm	
Sugar cane	15.2
Coffee	19.7
Tobacco	3.3
Grain and farinaceous crops	3.2
Fruit and nut	18.4
Livestock	26.9
General crop	5.9
Crop and livestock	1.5
Miscellaneous	5.9
Farms by type of organization	
Individual of family	86.2
Partnership	2.2
Government corporation or agency	1.7
Other corporation	1.2
Other types	7.5

Source: Department of Agriculture, Puerto Rico.

A survey of 325 small hilly farms during 1978-1983 reveals that the crops planted in the order of the number of farms producing these crops are yams, taniers, plantains and bananas, coffee, dasheens, and cassava. The percentage of farms planting these crops were 93.5, 80.5, 56.5, 43.5, 18.0 and 5.0, respectively. According to the area planted, the crop ranking was coffee (40%), taniers (21%), yams (19%), plantains (17%), vegetables (11%), dasheens (2%), and cassava (1%). Farm mechanization was almost nil. Primary tillage equipment was rented from regional offices of the state Agricultural Department (AFDA) by 62% of the farmers; however, none owned such equipment. None of them used planters,

cultivators, fertilizer attachments, or specialized harvesting equipment. Most did use hand-operated sprayers for control of weeds and insects. Only 3% had power sprayers. Eighty two percent of the farmers tilled 5 ha or less, 69% tilled 2 ha or less, and only 13% tilled over 10 ha mainly for coffee. The farmers were not satisfied with the tillage furnished by AFDA, largely because of the timeliness factor since they were unable to get the equipment when needed, having to wait sometimes more than 6 months for the needed service. As a result of the survey, it was concluded that the crops needing mechanization on these farms are taniers, yams, plantains and coffee.

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Impact of Farm Technology and Energy on Developing Agriculture

(Continued from page 64)

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Machinery Selection Concerning Farm Sizes

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Abstract

In the last few years techniques of agricultural production at some places in India have changed considerably, generally resulting in substitution of labour by machinery. Another trend at present is that the cost of inputs has tended to rise relative to the price of the products. The net effect of these changes is that farming and farm management in a developing country like India has to change from a way of life to a business way requiring the discipline of business management to make decisions regarding the selection of farm machines and equipments. The methods and machines in use at different stages of production give a very large number of feasible combinations. Twenty-five combinations have been identified for each farm size ranging from 2 to 25 ha.

Introduction

Paddy is the leading crop in India. It occupies 37% of the total cultivated area. India is also the second largest producer of paddy in the world. The area planted to this crop is about 38 million ha.

Most of the farmers use the age-old traditional methods of farming involving human and bullock power. In recent years the attention of Indian farmers has been drawn to the use of tractors, power tillers, and implements, etc to give a new dimension to farming. Agricultural production systems are made up from combinations of unit operations and each operation may be performed by different methods or machines. These methods and machines can be combined in different ways and the number of feasible systems are likely to be very large for each farm size. Computer algorithms based on network analysis and on simple applications of dynamic programming have been used to determine the optimum and near-optimum cost combinations. Some 25 combinations were identified for each farm size of 2 to 25 ha. The present study is limited to the harvest and post-harvest operations in paddy production. This may enable the farmer or farm manager to readily select a particular combination depending on the farm size, avail-

Table 1. Details of Operations and Methods

Method of Operation	Description
Harvesting	
1. Manually	Twenty workers
2. Bullock drawn reaper	One unit
3. Bullock drawn reaper with engine operated cutter bar	One unit
4. Power tiller harvester	One unit
5. Tractor operated self raking reaper	One unit
6. Tractor front mounted reaper windrower	One unit
7. 10 hp self-propelled reaper binder	One unit
8. JF Vicon Combine	One unit
9. 12 hp combine harvester	One unit
10. 105 hp GDR combine	One unit
Threshing	
1. Manually (beating on the plank)	Twenty workers
2. Pedal thresher	Twenty workers
3. Kubota Power Thresher (electric motor operated)	One unit
4. Kubota Power Thresher (Power tiller operated)	One unit
5. Jyoti Multicrop Thresher (electric motor operated)	One unit
6. Jyoti Multicrop Thresher (Power tiller operated)	One unit
7. Double drum thresher (10 hp diesel engine)	One unit
8. Double drum thresher (power tiller operated)	One unit
9. Vicon thresher	One unit
Drying	
1. Sundrying	80*, 50**
2. Sundrying	80*, 100**
3. Sundrying	24*, 50**
4. Mechanical drying	80*, 100**
5. Mechanical drying	80**, 150**

Note: *capacity, t/day; **operation period, days/year.

ability of facilities and other physico-economic limitations.

Materials and Methods

The details of some of the alternative methods in the harvest and post-harvest operations for paddy production are presented in **Table 1**. The principle of dynamic programming has been applied to identify the combination of methods or machines to give the optimum (minimum) and near-optimum cost of production. The capacities of machines, threshers and dryers were obtained from test reports as well as from the information supplied by the manufacturers. The costs of harvesting and threshing were taken from farm records.

The harvesting cost per unit of the product for a given method or machine was calculated by the equation 1.1 and that of threshing was calculated by the equation 1.2.

$$C1(MI) = AH(I) + BH(I)/F(J) \quad \ldots\ldots\ldots\ldots\ldots\ldots 1.1$$

where,

C1(MI) = Cost per unit produced by I at harvesting stage, \$/T;

AH(I), BH(I) constants for *I*th machine;

F(J) = holding size, ha;

I = 1, 10

and

$$C2(MI) = ATH(I) + BTH(I)/F(J) \quad \ldots\ldots\ldots\ldots\ldots 1.2$$

where,

C2(MI) = cost of unit produced by I at threshing stage, \$/T;

ATH(I), BTH(I) = constants for *I*th machine at threshing stage;

I = 1, 9.

The unit cost of drying were taken from the report of the National Cooperative Development Corporation. The performances of machines were calculated for each farm size by identifying the capacity of individual machines. The available period for harvesting was 15 days and that for threshing and drying was 18 days.

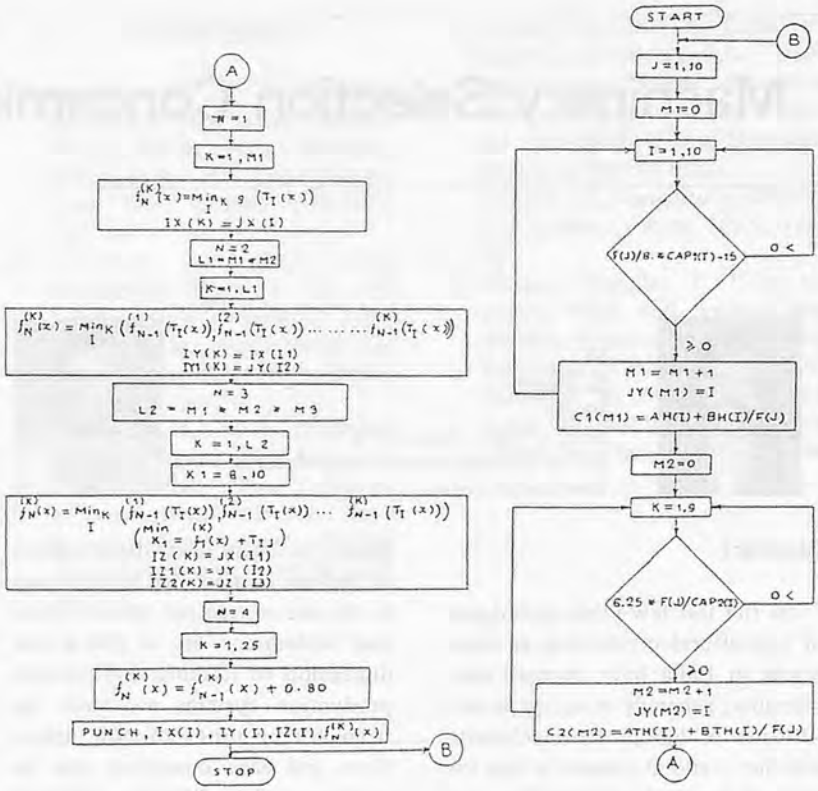

Fig. 1 Flow chart for evaluation of the optimum routing network.

Model and Computation

In the present context, the lowest cost path gave the combination of methods or machines that, in

Table 2. Optimum and Near-Optimum Systems and their Respective Costs for 2.0 ha and 5.0 ha Farm Size

2-ha Farm Size				5-ha Farm Size			
Harvesting	Threshing	Drying	Cost \$/T	Harvesting	Threshing	Drying	Cost \$/T
2	2	5	13.20	2	8	5	10.21
2	2	2	13.33	2	8	2	10.33
2	2	4	13.45	2	8	4	10.45
4	2	5	13.52	2	2	5	10.56
2	2	1	13.65	2	8	1	10.65
4	2	2	13.65	2	2	2	10.68
5	2	5	13.66	2	2	4	10.81
4	2	4	13.77	2	8	3	10.83
5	2	2	13.78	5	8	5	10.99
2	2	3	13.83	2	2	1	11.00
5	2	4	13.90	5	8	2	11.11
4	2	1	13.97	2	2	3	11.19
2	1	5	14.09	4	8	5	11.19
5	2	1	14.10	5	8	4	11.24
4	2	3	14.15	4	8	2	11.31
2	1	2	14.21	5	2	5	11.35
5	2	3	14.28	4	8	4	11.43
2	1	4	14.33	5	8	1	11.43
4	1	5	14.41	2	1	5	11.44
2	1	1	14.53	5	2	2	11.47
4	1	2	14.53	4	2	5	11.54
5	1	5	14.54	2	1	2	11.57
4	1	4	14.65	5	2	4	11.59
5	1	2	14.66	3	8	5	11.59
1	2	5	14.70	5	8	3	11.61

Table 3. Optimum and Near-Optimum Systems and their Respective Costs for 7.5 ha and 10.0 ha Farm Sizes

7.5-ha Farm Size				10.0-ha Farm Size			
Harvesting	Threshing	Drying	Cost $/T	Harvesting	Threshing	Drying	Cost $/T
2	8	5	8.40	2	8	5	7.49
2	8	2	8.52	2	8	2	7.61
2	8	4	8.64	2	8	4	7.73
2	8	1	8.84	2	8	1	7.93
2	8	3	9.02	2	8	3	8.11
5	8	5	9.25	3	8	5	8.21
3	8	5	9.34	3	8	2	8.33
5	8	2	9.37	5	8	5	9.38
3	8	2	9.46	2	7	5	8.42
5	8	4	9.50	3	8	4	8.46
4	8	5	9.52	5	8	2	8.51
3	8	4	9.58	2	7	2	8.54
4	8	2	9.64	5	8	4	8.63
5	8	1	9.69	3	8	1	8.65
4	8	4	9.77	2	7	4	8.66
3	8	1	9.78	4	8	5	8.69
2	7	5	9.84	4	8	2	8.81
5	8	3	9.88	5	8	1	8.82
3	8	3	9.96	3	8	3	8.84
2	7	2	9.96	2	7	1	8.86
4	8	1	9.96	4	8	4	8.93
2	2	5	9.97	5	8	3	9.00
2	7	4	10.08	2	7	3	9.04
2	2	2	10.09	4	8	1	7.91
4	8	3	10.15	3	7	5	7.92

Table 4. Optimum and Near-Optimum Systems and their Respective Costs for 12.5 ha and 15.0 ha Farm Sizes

12.5-ha Farm Size				15.0-ha Farm Size			
Harvesting	Threshing	Drying	Cost $/T	Harvesting	Threshing	Drying	Cost $/T
2	8	5	6.94	2	8	5	6.58
2	8	2	7.06	2	8	2	6.71
2	8	4	7.18	2	8	4	6.83
2	8	1	7.38	2	7	5	7.00
3	8	5	7.54	2	8	1	7.03
2	7	5	7.56	3	8	5	7.09
2	8	3	7.56	2	7	2	7.12
3	8	2	7.66	2	8	3	7.20
2	7	2	7.69	3	8	2	7.21
3	8	4	7.78	2	7	4	7.25
2	7	4	7.81	3	8	4	7.33
5	8	5	7.86	2	7	1	7.44
3	8	1	7.98	3	7	5	7.50
5	8	2	7.98	5	8	5	7.51
2	7	1	8.00	3	8	1	7.53
5	8	4	8.10	3	7	2	7.62
3	7	5	8.15	2	7	3	7.62
3	8	3	8.16	5	8	2	7.64
4	8	5	8.19	3	8	3	7.71
2	7	3	8.19	3	7	4	7.75
3	7	2	8.27	5	8	4	7.76
5	8	1	8.30	5	7	5	7.93
4	8	2	8.31	3	7	1	7.94
3	7	4	8.40	5	8	1	7.96
4	8	4	8.43	5	7	2	8.05

turn, gave the minimum cost of production per unit yield. All policies leading to the minimum cost of production were considered as optimal or first best; all policies leading to a cost of production greater than optimum but as small as all others as second best; and so on. The model on *k*th best policies developed by Bellman et al was used to determine the optimum and sub-optimum policies.

A computer programme was developed in FORTRAN II to evaluate the optimal and sub-optimal policies for the different farm sizes. The flow chart of the programme is shown in **Fig. 1**.

Results and Discussion

The combination of methods or machines that will give optimum (minimum) and near-optimum cost of production per unit yield was obtained. Only 25 preferred policies out of a very large number of combinations were obtained for each farm size. The results for different size of farms are presented in **Tables 2** to **6**. The number under each stage indicates the serial number of the method or machine shown in **Table 1**.

One system or combination (2, 8, 5) gave the optimum result in all these cases quoted except the smallest (2 ha) and the largest (25 ha) farm sizes. The costs of production ($ per t) 13.65 and 14.53 in 2 ha; 11.19, 11.43 and 11.59 in 5 ha; 7.56, 7.98 and 8.19 in 12.5 ha; 7.62 in 15.0 ha; and 7.38 and 7.65 in 17.5 ha; each were obtained by two alternative systems whereas the cost of production $9.96/t in 7.5 ha holding was obtained by three different systems. Twenty-five systems (optimum and near-optimum) for each holding size were given in order to enable the farmer or farm manager to decide a suitable system for his farm under the prevailing limitation.

Conclusion

The individual method or machine which appears in small scale enterprise as an element of optimum or near optimum combination has been eliminated in large-sized farms due to low capacity. The low capacity machines were kept out of the suitable combination for timeliness of operation which plays an important role in agricultural production. The use of some of the very high capacity machines do not appear to be feasible in small holdings. The combination of power tiller harvester, power tiller operated thresh-

Table 5. Optimum and Near-Optimum Systems and their Respective Costs for 17.5 ha and 20.0 ha Farm Size.

17.5-ha Farm Size				20.0-ha Farm Size			
Harvest-ing	Thresh-ing	Dry-ing	Cost $/T	Harvest-ing	Thresh-ing	Dry-ing	Cost $/T
2	8	5	6.33	2	8	5	6.13
2	8	2	6.45	2	8	2	6.25
2	8	4	6.57	2	7	5	6.29
2	7	5	6.60	2	8	4	6.38
2	7	2	6.72	2	7	2	6.41
3	8	5	6.76	3	8	5	6.52
2	8	1	6.77	2	7	4	6.54
2	7	4	6.84	2	8	1	6.57
3	8	2	6.88	3	8	2	6.65
2	8	3	6.95	3	7	5	6.68
3	8	4	7.00	2	7	1	6.73
3	7	5	7.02	2	8	3	6.76
2	7	1	7.03	3	8	4	6.77
3	7	2	7.15	3	7	2	6.80
3	8	1	7.20	2	7	3	6.91
2	7	3	7.22	3	7	4	6.93
5	8	5	7.26	3	8	1	6.96
3	7	4	7.27	5	8	5	7.07
3	8	3	7.38	3	7	1	7.12
5	8	2	7.38	3	8	3	7.15
3	7	1	7.47	5	8	2	7.20
5	8	4	7.50	5	7	5	7.23
5	7	5	7.53	3	7	3	7.31
5	7	2	7.65	5	8	4	7.32
3	7	3	7.65	5	7	2	7.36

Table 6. Optimum and Near-Optimum Systems and their Respective Costs for 22.5 ha and 25.0 ha Farm Sizes

22.5-ha Farm Size				25.0-ha Farm Size			
Harvest-ing	Thresh-ing	Dry-ing	Cost $/T	Harvest-ing	Thresh-ing	Dry-ing	Cost $/T
2	8	5	5.97	3	9	5	8.89
2	7	5	6.05	3	9	2	9.00
2	8	2	6.09	3	9	4	9.13
2	7	2	6.17	3	9	1	9.33
2	8	4	6.22	8	0	5	9.42
2	7	4	6.29	3	9	3	9.51
3	8	5	6.33	5	9	5	9.52
3	7	5	6.40	8	0	2	9.55
2	8	1	6.41	5	9	2	9.64
3	8	2	6.45	8	0	4	9.67
2	7	1	6.49	5	9	4	9.77
3	7	2	6.52	8	0	1	9.86
3	8	4	6.57	5	9	1	9.96
2	8	3	6.60	8	0	3	10.04
3	7	4	6.65	6	9	5	10.13
2	7	3	6.67	5	9	3	10.15
3	8	1	6.77	6	9	2	10.26
3	7	1	6.84	6	9	4	10.38
5	8	5	6.93	6	9	1	10.57
3	8	3	6.95	6	9	3	10.76
5	7	5	7.00	7	9	5	14.27
3	7	3	7.02	7	9	2	14.39
5	8	2	7.05	7	9	4	14.52
5	7	2	7.12	7	9	1	14.71
5	8	4	7.17	7	9	3	14.89

er with sundrying seems to be a very suitable combination for holdings in 5 to 14 ha range.

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Two New Principles of Weighing: Bicycle Wheel as Balance and Dynamometer

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Introduction

Up until now the wheel has not been used to measure weights and other forces. Balances and dynamometers based on the use of a bicycle wheel have many advantages. Thanks to industrial mass production of bicycles, good wheels are obtainable everywhere at low cost. Even used wheels can be quickly transformed into balances and dynamometers. They need not be taken apart nor the tyre be taken off. For these reasons the practical use of the wheel instruments is indicated in all cases where other instruments are too expensive or not available (delivery, customs, theft, breakdown), or not easily transportable. The use is also indicated where the variability of the quality to be measured exceeds 1%, e.g., soil strength, or where the range is so large that 1% error does not matter. The sturdiness of the bicycle wheel and the instruments based on it may well surpass that of all other balances.

The wheel balance may also serve educational purposes such as the demonstration of the theory of levers. Its low cost and ease of assembling makes it very practical for physics courses.

Balance by Automatic Adaptation of the Arm Length

Principle – In contrast to balances with fixed arm length and where equilibrium is obtained adding known weights to one arm, a wheel balance adjusts the length of the lever arms automatically by rotation until equilibrium is obtained (Fig. 1). The forces caused by the two objects apply at the circumference, their direction is parallel and they are acting in the same plane in which the wheel turns. The lines of action, therefore, also lies in the plane of the wheel, an extension of the lines on which the bodies are fastened. The apparatus is, therefore, an example of two dimensional rotation. The torque or moment caused by each force is the product of the gravity force and the perpendicular distance from the action line to the centre. If the sums of these moments is not zero a moment remains which will rotate the wheel and thus change the lengths of the arms till the two moments are numerically equal. If the weight of one of the objects is known, measurement of the lengths of the arms permits the calculation of the unknown weight. For each measurement the equation $X=a_K \cdot K/a_X$, where a stands for arm, X for the unknown and K for the known weight, has to be solved.

Wheel Balance with two Variable Arms, a Rideable Instrument – In order to transform a bicycle wheel into a balance, the latter is suspended vertically from a branch or beam and the front wheel is balanced by some pieces of wire, (Fig. 2). The centre is marked by a line running from nut to nut attached by loose loops and kept straight by some perforated object. A known weight is tied to the wheel so that its gravity force applies to the circumference, using a length of thin cord or fishing line a bit longer than the radius. Likewise a line for attachment of the unknown weight is tied at right angles to the cord carrying the known weight.

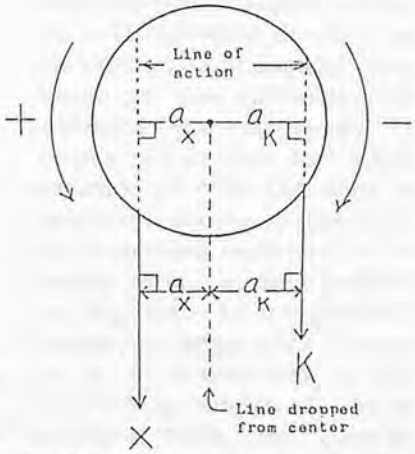

Fig. 1 Equilibrium attainment where X and K forces apply to bicycle wheel circumference; Length of arrows indicates relative magnitude.

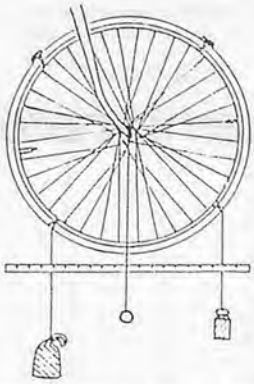

Fig. 2 Transforming a bicycle wheel into a balance.

To maintain balance equal lengths of cord are taped to the opposite sides. When the unknown object has been tied to its line the wheel will rotate till equilibrium is met. Then the length of the lever arms is measured as the distance from the crossing points of the cords with the ruler to the centre line. In case of need a ruler made of thin board and mm-paper may serve. All data needed to solve the equation have been obtained by now. Some systematic errors can be avoided by repeating the measuring procedure after reversal of the places of attachment. The accuracy of the measurement of the distance is about 1 mm.

The radius of a large bicycle wheel is 33 cm, the use of a single standard weight is, therefore, limited to objects weighing 0.33 to 3.3 times the standard (factor 10) if the error percentage may not exceed 1%. The weights tested successfully ranged from 100 g to 3 kg, a factor of about 300, $10^4/33$ g. If relative values such as moisture contents are to be determined the mass of the standard needs not to be known. This balance can be used again as a normal bicycle within one minute. For the determination of the unknown, the equation must be solved every time, which is quite a handicap when actually weighing. For this purpose, the following, more permanent set up is better fitted.

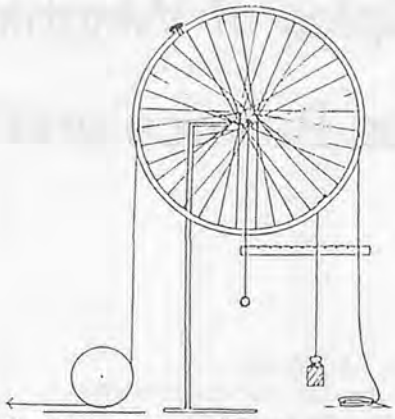

Fig. 3 Use of bicycle wheel as dynamometer.

Wheel Balance with one Variable Arm: Dynamometer and Automatic Balance – If the wheel is to be used as dynamometer, the point of application of the unknown force must not be displaced. If that place is fixed the displacement of the known weight in the horizontal direction indicates the magnitude of the unknown force. The constancy of one arm is achieved by applying the unknown force to a cord unwinding along the circumference (**Fig. 3**). The tire has to be taken off and the cord is wound once around the rim of the wheel, a sufficient length ($>\frac{1}{2}\pi r$) falling to the floor at either side. The drag of the cord is kept constant in this way. After balancing, the known weight is again attached to the circumference with a cord longer than r, making use of the hole of the air valve. The weight of this cord is compensated. Now the arm of the unknown is fixed at r, and the arm of the standard varies between O and r. It is convenient, therefore, to grade the ruler into centesimal fractions of r. Also, a rider can be fitted to the ruler to indicate the maximum force. When the set-up is to be used as dynamometer the force to be measured is applied in the horizontal direction and transferred via a pulley. The use as dynamometer is limited to those cases where the force increases, or is made to increase so

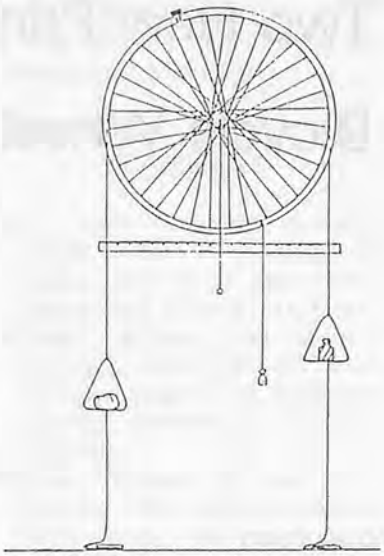

Fig. 4 Wheel balance with one variable arm: semiautomatic balance.

slowly that the inertia of the apparatus can be neglected. A second condition is that the object can be moved. The dynamometer has been used successfully in measuring soil strength in the range of 1 to 10^3 kN/m^2 with the shearing device of the author (1976). For the measurements of forces below 100 g.f., the grease of the ball bearings should be replaced by a light oil.

Wheel Balance with one Variable Arm, Semi-automatic Balance – As shown in **Fig. 4**, the reading accuracy of the second arrangement can be increased considerably by the use of counterweights attached to the loose end of the cord opposite to the unknown. The major part of the moment will then be compensated by the counterweight. The reading uncertainity of mm does not refer to the whole weight but only to the uncompensated fraction. In order to be able to use the whole range, twice the radius, the known weight with the variable arm will have to pass the centre line. The latter has, therefore, to be split into two single ones each with its own weight.

Wheel Balances with Equal Arms

Principle – Two forces acting in the same direction on either side of the centre in the turning plane of the wheel at equal distances from the centre are equal if the wheel does not rotate.

Automatic Balance with Equal Arms – After removal of the weight with the variable arm of **Fig. 4** one returns to a balance with equal arms (**Fig. 5**). The length of cord resting on the floor at either side should be equal to the distance of wheel centre to floor. As equilibrium is independent of the relative position of the scales, automation can be achieved easily. The length of chain lifted from the equilibrium position or from the floor is measured and multiplied by the weight of an unit length of the chain. In principle, there exists no limit to the length of the chain used. As the unit weight of the cord will be diminished by stress and as the length of cord exposed to stress at both sides of the centre will be unequal, the cord has to be stretched beforehand.

Semi-automatic Balance with Equal Arms – A semi-automatic balance for larger weights can be constructed as shown in **Fig. 6**. At the side opposite to the object a number of equal standard weights is attached to the cord with an interstice larger than the height of the weights. One end of a chain with the mass of one weight is attached to the same cord, while the other end can be moved up and down. When an object is put on the scales the wheel will start to rotate and a number of weights will be lifted equal to the mass of the object save the fraction of one weight. The chain is then lowered till the last section of the cord slackens. The mass of the object is then equal to that of the weights lifted plus that of the part of the chain supported by the cord on the weight side.

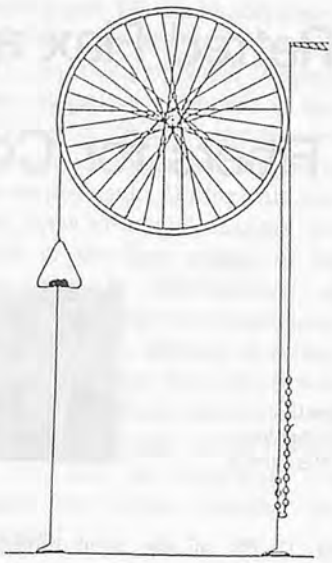

Fig. 5 Automatic balance with equal arms.

Fig. 6 Semiautomatic balance with equal arms.

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INDEX TO ADVERTISERS

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Kobashi Kogyo Co., Ltd. 4
Kubota, Ltd. 6
Mametora Agric. Machinery Co., Ltd. 93
Matsuyama Plow Mfg. Co., Ltd. 90
Sukigara Agricultural Machinery Co., Ltd. 91
Toyosha Co., Ltd. 92
Yamamoto Mfg. Co., Ltd. 4

Qualities of Retted Flax and Degummed Fibers for Commercial Use

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Abstract

Bast fibers are extracted manually from the flax plant. Such fibers are coarse, less lustrous and remain in bundles because of the presence of pectinous material. Chemical method, as a subsidiary, is applied in order to improve the fiber quality and make it useful for commercial purpose. There is a large difference in the qualities of fibers extracted from retted straw manually and that obtained following the chemical treatment. Therefore, an attempt has been made to determine the effect of moisture content and plant diameter on each of the qualities like fiber content, tenacity and fineness. Further, for the purpose of predicting, each of the qualities of fibers obtained by either manual or chemical methods were determined.

Introduction

In India, the flax plant grows well in both the peninsular region of the South and the alluvial soils of the north. Its production is concentrated in the States of Bihar, Madhya Pradesh, Maharashtra, Punjab and Tripura. On the basis of production and area occupied by five major oil seeds, linseed accounts for 6.4% of total production and 12.7% of the total cropped area. This yields 1 345 000 t of deseeded straw containing about 323 000 t of useful fiber that is considered with only a little value at present. After the harvest the farmer normally rets the flax straw in standing water (32 ± 2°C) for 65-70 h and then they spread them on the roadside or on roof to dry in sun. Bast fibers are then extracted by manual beating followed by a hackling process. Sometimes, flax decorticators or mechanical breakers are used to extract fibers. The fibers thus obtained are rough and possess a colour between greenish-yellow to golden-yellow with fineness value of 22-60 "tex." It contains pith along with broken fibers. Flax fibers of such quality are not suitable for commercial use to manufacture linen, suiting, shirting, ropes, twines, cordages and artificial silk. In order to make these fibers useful, it is necessary to remove the pectinous material from the fibers by a suitable chemical method. This process helps not only in separating the individual fibers from fiber bundles but also improves the lustre. To obtain these qualities in the commercially used flax fibers, other qualities like tenacity and fiber content may be affected. Keeping this in view, the research work was undertaken with following objectives:

1. To evaluate the quantity and quality of fibers extracted manually and by the use of chemical treatment;
2. To correlate the qualities of fibers extracted manually and those obtained with the use of chemical treatment.

The Flax Plant: its Structure and Fiber

The flax plants grown in different parts of India show almost identical structure. They shoot straight up to between 45 and 116 cm without branching and possess greyish green colour during harvest. These stems are slender with approximate diameters of 1 to 3 mm. **Fig. 1** shows a typical transverse section of a flax plant at

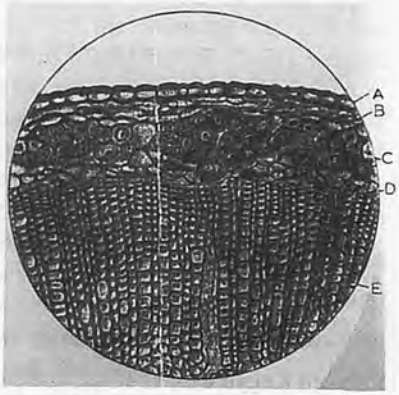

Fig. 1 Typical cross-section of a flax plant.

maturity. It will be noted that the useful fibers (bast fibers) are located somewhat away from cuticular cells and corticle parenchyma present in the single layer in pericycle of the flax straw. A large part of the flax plant contains woody tissue following the cambium layer. The fibers of these plants are long, narrow, thick and have lignified cells with pointed ends (4, 5, 6). They are called solerenchymatous fibers or phloem fibers or simply fibers whose length varies from 2 to 5 cm. They occur in bundles (4, 5, 6) of 10 to 40 individual fibers. One stem at maturity may contain about 30 fiber bundles arranged inside the cortex forming a ring around the hard hollow pith or stick. Unlike the other vegetable fibers, the bundles of these fibers are never separated from individual filament but are left more or less cemented together in groups due to gummy substance (3, 4, 5). In case the stems are not sufficiently loosened by biochemical process or water retted for 65-70 h, it is difficult to separate the tissues into individual fiber filaments.

Flax Retting

Retting of flax plants is primarily a process of fermentation and is brought about by the action of bacteria that enter into the flax plant through epidermis and cuticle and more so when the plant body is under swollen condition. During the retting period, bacteria help in decomposing the adhesive substances (pectinous matter) that bind the fiber to the stem and the woody pith which facilitates free and easy separation of the fiber in subsequent processes.

Water Retting

Prior to fiber extraction, the flax plants are usually submerged in a retting tank filled with soft water, preferably for about 2.5 to 3.5 days, depending on water temperature, biological activities of bacteria, age of crop and initial quantum of micro-organisms present in the retting tank. During this process, some structural changes also occur in the fiber wedges of the bark due to disintegration of tissues. Breakdown of tissues, however, follows a definite sequence, the cambium layer being the first to be attacked. Then thin-walled ray cells and soft tissues of the phloem are the next to disintegrate and finally the cortex become disorganised.

Dew Retting

In dew retting (ground retting), the straws are spread evenly and very thinly on the grassy land so that the dew can spread on it uniformly. This facilitates the development of an action of aerobic bacteria, always present in the soil, which break down and make soluble the pectinous walls, plant gum, etc, leaving the straw in a condition in which separation of the fiber can easily be carried out. To ensure uniformity, the straw is sometimes turned during the processing which involves greater labour and expense. Dew retting is comparatively an inexpensive process and it entirely depends on the weather and, therefore, is uncertain. If continued, wet weather prevents the lifting of the straw in the field at the proper time, it becomes over-retted and the fiber depreciates greatly in value because of nonuniformity in colour and quality. When good weather prevails dew retting is completed in 1-3 weeks.

Chemical Treatment

Commercial flax fibers are superior in quality with respect to color and luster, and their average fineness and tenacity values range between 0.18 to 0.25 tex and 18 to 27 g/tex, respectively. The flax fibers obtained manually or by mechanical means are coarse and their fineness value varies from 22 to 60 tex. Such a large variation is due to the presence of epidermis and corticle in fibers and that the fineness is due to the presence of adhesives, i.e., pectin substance or pectose. To make these fibers useful for commerce, chemical treatment as a subsidiary processing is resorted to. In such treatment, fibers are soaked in dilute solution of alkali, e.g., caustic soda and then boiled for a sufficiently long time. They are then washed thoroughly and sun-dried giving degummed fibers. There are two approved standard techniques followed: open heating and pressure heating.

Open Heating

Fiber ribbons are heated with 0.5% solution of ammonium oxalate at 80-85°C for about 30 min and then with a mixture of 0.5% "teepol" and 1.0% sodium sulphite at 75-80°C for 30 min. The fibers are then washed in clean water. The whole process is repeated thrice.

Pressure Heating

The fibers extracted manually are soaked in 0.5% ammonium oxalate solution and then heated to about 85°C in an autoclave for 0.5 h. The pressure is maintained to about 0.5-0.8 kg/cm^2. The fiber strands are then washed in warm water containing "teepol" and then finally washed in tap water.

Experimental Materials and Methods

The diameters of a group of retted flax plants selected random-

ly were measured at the middle and then their moisture content was determined. The fibers from these plants were carefully extracted manually. The fiber content (FC), the tenacity (T) and the fineness (FF) of retted fibers were measured following the standard and approved instruments as suggested by the Jute Technological Research Laboratory (JTRL), Calcutta. Again the extracted flax fibers were treated chemically following the open heating method described above. After drying them in atmosphere, the fibre content (FCC), the tenacity (TC), the fineness (FFC) and the moisture content (M) were measured. The procedure was repeated thrice for the entire range of plant diameters (1.23-2.68 mm) and moisture content (1.97-5.11%). The average values of the qualities are presented in **Tables 1** and **2**.

Results and Discussion

The fibers extracted manually were coarse and were golden-yellow in color. The individual fibers remain intact with other fibers in bundles due mainly to the incomplete removal of gum. But the fibers obtained following the chemical method were fine, lustrous and possessing cream-white to light-grey color. The fibers are fully separated into individual filaments and are suitable for commercial use.

Table 1 indicates that the fiber content obtained by chemical method is less than that obtained from retted plants. The difference of these two values (i.e., FC−FCC) represents the percentage of pectinous matter lost due to chemical treatment and its value is about 0.7-0.9%, on the whole plant weight basis. However, statistical analysis indicates that there is no significant difference in fiber content values observed between the methods of fiber extraction, i.e., manually extracted and that obtained following the chemical treatment. The fiber content and the tenacity values of the degummed fibers at each moisture content level decreased linearly with plant diameter while the fineness values were increased in the exponential form. The regression coefficients and the F-values of each of the qualities of degummed fibers at different moisture content levels are presented in **Table 3**.

The tenacity of degummed fibers was significantly lower than that obtained manually from the retted straw due to the loss of pectinous matter from the fibers. The tenacity values of degummed fibers obtained from the small diameter plants were significantly higher than those obtained from large diameter plants. On the other hand, fibers of better quality are obtained in respect of lustre and fiber separation (fineness). The fineness values of degummed fibers were in the range of 0.88 to 4.29 tex. This value of fiber fineness was significantly lower (1%) than that obtained from the retted straw manually. On the other hand, each of the fiber qualities of degummed fibers like the fiber content, the tenacity and the fineness values were not affected significantly by the moisture content variable.

Fig. 2 shows the plot of fiber content (FCC) obtained following

Table 1 Average Values of Fiber Contents Obtained manually from Retted Straw after Chemical Treatment

Moisture content	Average plant diameter range	Fiber content	
		Manually extracted	Chemically treated
M %	d ± 0.03 mm	(FC) %	(FCC) %
	Average moisture content, M = 1.97%		
1.89	1.35	30.25	29.91
1.76	1.68	28.35	28.01
2.06	1.97	26.83	26.52
2.11	2.24	25.40	25.09
1.82	2.40	24.62	24.27
2.18	2.62	23.57	23.06
	Average moisture content, M = 2.16%		
2.07	1.35	30.00	29.78
1.98	1.68	28.31	27.92
2.29	1.97	26.96	26.67
2.20	2.24	25.68	25.33
2.12	2.40	24.97	24.55
2.30	2.62	24.03	23.59
	Average moisture content, M = 3.13%		
2.96	1.35	29.36	29.12
3.03	1.68	28.04	27.58
3.22	1.97	26.98	26.61
3.19	2.24	25.95	25.60
2.90	2.40	25.38	24.91
3.48	2.62	24.62	24.22
	Average moisture content, M = 4.23%		
4.09	1.35	29.82	29.48
3.92	1.68	27.99	27.60
4.26	1.97	26.53	26.10
4.33	2.24	25.14	24.82
4.37	2.40	24.38	23.93
4.41	2.62	23.57	22.89
	Average moisture content, M = 5.11%		
5.21	1.35	29.98	29.58
4.92	1.68	27.69	27.34
5.06	1.97	25.80	25.41
5.34	2.24	24.08	23.68
4.80	2.40	23.15	22.84
5.33	2.62	21.94	21.47

Table 2 Average Values of Tenacity and Fineness Obtained manually from Retted Straw after Chemical Treatment.

Moisture content M %	Average plant diameter range, d ± 0.03 mm	Tenacity: Manually extracted g/"tex"	Tenacity: Chemically treated g/"tex"	Fineness: Manually extracted "tex"	Fineness: Chemically treated "tex"
Average moisture content, M = 1.97%					
1.78	1.26	30.91	29.80	23.82	1.07
2.36	1.57	27.53	26.31	34.22	1.53
2.10	1.82	24.79	23.22	43.63	1.79
1.83	2.28	19.77	18.09	63.23	2.64
1.56	2.50	17.37	15.57	73.57	2.98
Average moisture content, M = 2.68%					
2.32	1.26	31.06	30.01	29.90	1.22
2.79	1.56	27.69	26.40	33.59	1.49
2.48	1.82	24.97	23.54	46.20	1.90
2.86	2.28	19.96	18.46	75.12	3.04
3.02	2.50	17.57	15.80	91.63	3.48
2.61	2.65	15.93	14.20	103.91	4.09
Average moisture content, M = 3.36%					
3.42	1.26	30.90	29.69	19.27	1.04
3.56	1.57	27.67	26.60	32.56	1.39
3.16	1.82	25.07	23.40	46.33	1.92
3.20	2.28	20.29	18.70	79.31	3.07
3.79	2.50	18.00	16.45	98.81	3.87
3.03	2.65	16.44	14.79	113.55	4.26
Average moisture content, M = 4.34%					
3.98	1.26	30.39	29.59	19.46	0.88
4.62	1.57	27.51	26.24	32.86	1.54
4.55	1.82	25.18	23.71	46.72	2.06
4.27	2.28	20.90	19.45	79.92	3.15
4.15	2.50	18.85	17.35	99.55	3.89
4.47	2.65	17.46	15.73	114.38	4.29
Average moisture content, M = 5.11%					
4.86	1.26	30.00	28.74	21.07	1.06
5.19	1.57	27.39	26.01	34.21	1.56
5.38	1.82	25.29	23.88	47.37	1.95
5.03	2.28	21.42	19.91	77.82	3.07
4.94	2.50	19.56	17.96	95.34	3.77
5.26	2.65	18.30	16.60	108.40	4.09

Table 3 Single Parametric Relationships of Qualities of Chemically-Treated Fibers at Different Moisture Levels

Average moisture content, M, %	Regression Coefficients a_0	Regression Coefficients a_1	Correlation Coefficient	Cumulative error, %	F-Value **
Fiber content, $FCC = a_0 + a_1 d$					
1.97	37.07	−5.35	0.999	0.113	21798.6
2.16	36.20	−4.84	0.999	0.247	2798.6
3.13	34.17	−3.83	0.998	0.282	1401.9
4.23	36.36	−5.16	0.999	0.245	4444.3
5.11	38.09	−6.38	0.999	0.353	3595.1
Tenacity, $TC = a_0 + a_1 d$					
1.97	44.19	−11.44	0.999	0.273	24272.0
2.68	44.28	−11.36	0.999	0.286	39068.9
3.36	43.24	−10.75	0.999	0.485	4958.2
4.34	41.77	−9.81	0.999	0.515	5405.9
5.11	39.70	−8.70	0.999	0.124	76110.4
Fineness, $FFC = a_0 + a_1 d$					
1.97	0.40	0.82	0.997	2.883	546.2
2.68	0.38	0.89	0.998	2.736	890.1
3.36	0.28	1.04	0.998	2.383	1535.4
4.34	0.25	1.10	0.990	7.147	173.8
5.11	0.33	0.97	0.996	3.213	798.4

** Significant at 1%.

chemical treatment (degummed) with those obtained by manual method (FC) from retted straw. Similar plots of tenacity (between TC and T) and fineness (between FFC and FF) of fibers are shown in **Fig. 3**. The constants of the regression and correlation coefficients are presented in **Table 4**. They show that the qualities of degummed fibers, such as its content, tenacity and fineness values are less than those of the retted fibers obtained manually. These relationships might be of help in obtaining an expected average value of the quality of degummed fibers for any known value of manually extracted retted fibers.

Conclusions

1. Each of the values of fiber quality like the fiber content, tenacity and fineness of the degummed fibers are lower than those obtained from retted straw manually. But the variation in moisture content between 1.97-5.11% does not show any significant effect on each of the fiber qualities.
2. Flax straw of 1.23-2.68 mm diameter contains 0.7-0.9% pectinous matter which when removed by suitable chemical treatment, gives better quality fiber in respect of tenacity, fiber fineness, colour and lustre values.
3. With the increase in plant diameter, the fiber content and the tenacity values of degummed fibers decreased linearly while the fineness values increased exponentialy.
4. All the quality characteristics, i.e., fiber content, tenacity and fineness of degummed fibers were linearly correlated with those obtained from manually retted straw.

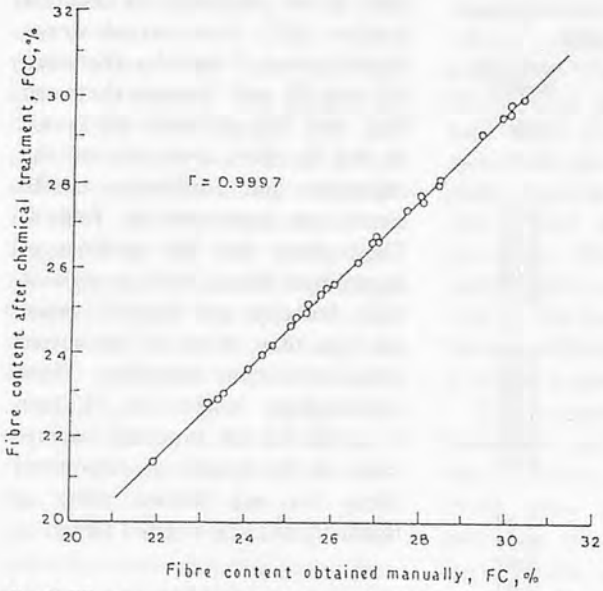

Fig. 2 Fiber contents obtained manually and after chemical treatment.

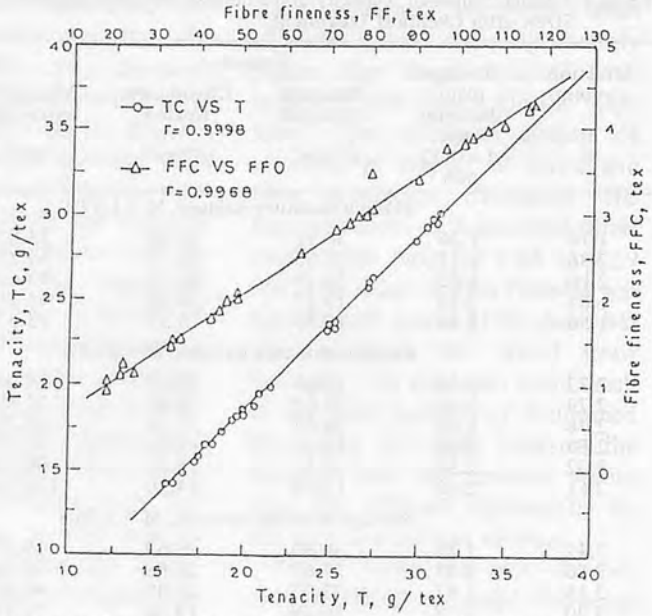

Fig. 3 A. Fiber tenacity of retted (T) and degummed (TC) fibres. B. Fibre fineness of retted (FF) and degummed (FFC) fibres.

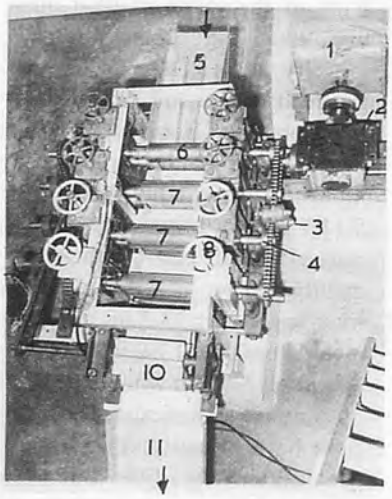

Fig. 4 Flax decorticator assembly showing details. 1– 5hp motor, 2– Gear reduction unit. 3– Chain tightener, 4– Sprocket, 5– Inlet tray, 6– Primary plain roller, 7– Secondary fluted roller, 8– Loading mechanism, 9– Cam and micro-switch, 10– Flemish mill, 11– Outlet tray.

Table 4 Regression Coefficients of each Quality of Retted and Degummed Fibers

Particulars and nature of equation	Regression coefficients		Correlation coefficient, r	Cumulative error, %	F-Value *
	A_1	B_1			
Fiber content, $FCC = A_1 + B_1.FC$	−0.7877	1.0156	0.9997	0.190	42336.0
Tenacity, $TC = A_1 + B_1.T$	−2.4556	1.0431	0.9998	0.404	58909.3
Fineness, $FFC = A_1 + B_1.FF$	0.3141	0.0356	0.9968	3.411	4375.2

* Significant at 1% level

F-values at 5 and 1% levels from statistical tables are 4.15 and 7.52, respectively.

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"Landbouw RAI"
International Agricultural Machinery Exhibition
Jan. 20-25, 1986
at The RAI Exhibition and Congress Centre, Amsterdam, The Netherlands

It is held every two years, and on the last occasion, in 1984, it attracted a record number of visitors, namely 132,362. That year there were over 250 exhibitors, and the exhibition occupied combined area of 69,000 square metres.

Reputation – The international reputation of the Landbouw RAI is obviously connected with the reputation of Dutch agriculture, which is renowned for its high yield and excellent quality. This is the result of efficient farm management achieved through large-scale mechanisation.

Dutch industry has a great deal to offer – Clearly, there is direct interaction between the progressive Dutch farmers on the one hand and Dutch manufacturers of machines and implements for agriculture and horticulture on the other. The latter industry comprises a hundred small and medium-sized firms, which together employ some 5,000 people and have a combined turnover of almost three quarters of a billion guilders.

Representative range of products – The exhibition programme at the "Landbouw RAI" comprises implements and machinery for farming, horticulture and forestry. On display will be tractors, machines and other mechanical implements used in arable farming, dairy farming, livestock farming, fruit farming and horticulture.

In addition there will be cattle fodders, seeds, fertilisers, pesticides, tools, engines and fuels for use in agriculture and horticulture. For dairy farmers there will also be milking machines, bulk milk coolers and milking sheds.

International Congress – During the "Landbouw RAI 86" an international conference will be held at the RAI Congress Centre in Amsterdam on the theme of "New Land", i.e., Polder construction, Reclamation, Land division, Land utilization for agriculture and forestry.

The international congress "New Land" is being organised by the initiative of the Ministry of Economic Affairs and the Ministry of Traffic and Waterways. The organisation of the congress has been entrusted to the Rijksdienst voor, de IJsselmeerpolders, IMAG Wageningen, in cooperation with RAI Gebouw bv.

Holland Export Centre – In order to boost still further the exports of the agricultural machinery industry, the Ministry of Economic Affairs will organise a Holland Export Centre at Landbouw RAI 86 in close cooperation with the relevant industrial organisations.

Foreign visitors can also obtain expert help in connection with agricultural methods and international trade at the Holland Export Centre. The Centre will also provide visitors with a special catalogue containing extensive information on the products of all exporters of agricultural machinery in the Netherlands.

This catalogue can also be obtained from:
The Ministry of Economic Affairs
Netherlands Foreign Trade Agency
Metalworking and Machine-Building Industry Division
Bezuidenhoutseweg 151
2594 AG The Hague.

88th International Agricultural and Animal Farming Fair/ 39th Agricultural Machinery Show
March 19-16, 1986,
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The Trade Sections
- Farming foodstuff products;
- Seeds, nursery, flower growing and greenhouse goods;
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- Machines and tools for working terrain, including fertilization, seeding, plant cultivation and protection, harvesting, primary processing, grading and preserving farm products, machinery for lifting and transporting loads;
- Machinery and systems for the agrarian industry;
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Figures of the latest event (1985)
Exhibiting area: 300,000 sqm
Exhibitors: 2,446 (including 363 from 23 countries except Italy)
Visitors: 508,736 (including 5,784 from 91 countries except Italy)

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May 7-13, 1986,
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At the DLG Exhibition '86, the farmer can inform himself on

developments in all branches of agriculture: Advanced design of agricultural machines, a special show and demonstrations of "DLG approved machinery", informational shows of the Ministries of Agriculture, national and international breeding stock competitions and demonstrations, machines and equipment for the farmyard, joint national exhibition stands, banks and insurance companies, agricultural construction, seed materials, fertilizers and crop protection, development aid, advice on marketing and sales problems, forestry, expert consulting by neutral institutions and many more.

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Exhibition Program – Agricultural machines, agricultural tractors, miscellaneous other machines and equipment; Livestock production (competition of all breeds and types, international livestock show, machines and equipment for farmyard operations); Agricultural operating materials, such as seed and plant materials, commercial fertilizers, crop protection equipment, mixed feedstuffs; Agricultural construction; Electronic data processing; Energy and environment technologies; Vegetable, grove and horticultural technologies; Forest technology, landscaping; Informational and special shows.

For further information contact; Deutsche Landwirtschafts-Gesellschaft
Fachbereich Ausstellungen
Zimmerweg 16
D-6000 Frankfurt-am-Main

The 3rd Indonesian Agricultural and Food Production Exhibition
October 21-25, 1986, Jakarta, Indonesia

Indonesia's current Five Year Development Plan (Repelita IV, 1984-89) emphasises self-sufficiency in rice production and food crops. Major investment sectors: primary processing of food, plantation crops, fish and shellfish. 1985-86 budget allocates US$1.4 billion to agriculture.

Agriculture & Food Indonesia has been endorsed as Indonesia's agricultural meeting place by all sectors of the industry including the Ministry of Agriculture's extension and education service, the co-operatives (KUD), plantation managers, national regional dealers, research and food processing stations.

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Sugar	1,778,000
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Rubber	1,125,000
Tea	119,000
Coffee	315,000
Cloves	44,000
Pepper	46,000
Livestock 1983:	
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Production in tons	2,100,000

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Mechanization of Japanese Agriculture

(Japan)

By Koichi Maeda

This book deals with the history and present status of the agricultural mechnization in Japan and describes the backgrounds of the mechanization which are peculiar to the Japanese agriculture. While policies on mechanization may vary from country to country depending upon agricultural, technological and social conditions of the individual country, it is hoped that this book will be of interest to those who are concerned with development of agricultural mechanization in their respective countries.

The author is former director of the Institute of Agricultural Machinery, Ministry of Agriculture who has experience for many years in the research and administration of agricultural mechanization.

Size: 21 x 15 cm, 108p, paper cover.

Published by Japan FAO Association, Baji-Chikusan Kaikan, 1-2 Kanda Surugadai, Chiyoda-ku, Tokyo, Japan

Development of the agricultural machinery industry in developing countries – Proceedings of the 2nd International Conference

(The Netherlands)

By A. Moens and A.H.J. Siepman (compilers)

The Second International Conference on Agricultural Mechanization in Developing Countries was held at the RAI Congress Centre in Amsterdam, the Netherlands, 23-26 January 1984. The Conference was held in association with the 13th International Fair on Agricultural Machinery.

Specific themes of the conference were:

– the actual status and the future development of agricultural mechanization;

– the actual status and the future development of the agricultural machinery industry.

These proceedings of the conference include the final recommendations and conclusions, general reports, papers of the key note speakers, country reports, some reports on miscellaneous subjects and a list of participants.

Some 167 experts from 49 countries, mainly from Latin America, Africa and Asia, took part in the conference.

The large amount of up-to-date information from countries worldwide and the conclusions drawn during the conference will provide the readers with that information that they need for business, education, research or any other activity.

Size: 24.5 x 18 cm, 400p, hard cover

Published by Pudoc, P.O. Box 4, 6700 AA Wageningen, the Netherlands.

Agricultural Credit – A Global Enigma

(U.S.A.)

By Jack D. Hartman

This new book relates to the pros and cons of agriculture credit systems in the United States and foreign countries. It is supported by the results, analyses, and surveys garnered from farm lending systems of approximately sixty nations and suggests ways in which an agricultural credit system can best be operated so that farmers financially helped can be most successful.

Agricultural credit will be useful and interesting for the agricultural student, farmer or rancher, as well as the agricultural lender and those administering the lending system. The book provides a broad prospective of agriculture credit systems and gives special attention to the small farmers of America as well as abroad, and critiques and offers ways to improve the lending system.

Size: 28 x 21.5 cm, 156p, soft cover

Published by The Interstate Printers and Publishers, Inc. Jackson at Van Buren, Danville, Illinois 61832-0594, U.S.A.

Erosion and Sediment Pollution Control, Second Edition

(U.S.A.)

By R.P. Beasley, James M. Gregory and Thomas R. McCarty

This book builds on over 30 years of the experience of R. P. Beasley, a noted leader in soil conservation; this experience was recorded in the previous edition. Revisions have been made to keep up with technologies such as improvements in weed and insect control with chemicals, which allows for less tillage; better machines for tilling and planting crops in residue; and development of small computers and calculators to evaluate equations for decision making. While computer programs are not included, equations for tables and figures are provided where possible to facilitate calculations.

Major changes have been made in Chapters 2, 4, 5, 6, and 7. Chapter 2 now includes a section on pollution from agricultural chemicals. Chapter 4 includes new procedures for predicting the effects of tillage and cover on water erosion. Chapter 5 includes runoff prediction with the rational method as well as the Beasley method for predictions outside the United States. Chapter 6 includes a procedure for exact solution for trapezoidal waterways and an update on underground outlet design. Chapter 7 now includes more on economics of alternative systems as well as a simple detailed example. Other chapters have received minor changes.

Size: 23.5 x 16 cm, 364pp, hard cover.

Price: US$27.95

Published by Publicity Dept., Iowa State University Press, 2121 South State Avenue, Ames, Iowa 50010, U.S.A.

Agricultural Electronics — 1983 and beyond (Proceedings of the National Conference on Agricultural Electronics Applications Dec. 11-13, 1983, Chicago)

(U.S.A.)

This two-volume set contains the 98 papers presented at the National Conference on Agricultural Electronics Applications. This proceedings, devoted to the application of electronics to agricultural systems and equipment, provides with the latest information on a variety of these applications. The scope of the proceedings includes five categories of electronics applications: Volume I contains papers on Field Equipment and Irrigation and Drainage.

Volume II contains those on Controlled Environments, Livestock Production Systems, and Materials Handling and Processing.

Size: 23 x 15 cm, Vol. I–353pp, Vol. II–809pp, soft cover, Price – Member $39.50 List $47.50.

Published by American Society of Agricultural Engineers, 2950 Niles Rd., St. Joseph, MI 49085-9659, U.S.A.

Robotics and Intelligent Machines in Agriculture

(U.S.A.)

This proceedings results from the first International Conference on Robotics and Intelligent Machines in Agriculture, organized by members of the Agricultural Engineering Department of the University of Florida, and held as one track of Robotech '83 in Tampa, Florida, October 2-4.

The objectives of this conference were to review current research related to intelligent machines and robotics in agriculture, to project future applications of robotics in agriculture, and to stimulate new research in these areas. The papers by Anson, Gerrish and Surbrook, Key, Kawamura, Ito, McClure, Grand d'Esnon, Johnson et al., Mancaster, Sullivan, and Krutz and Mailander give a fascinating insight into recent and current research.

Papers by Tesar, Anson, Krutz, Tutle, Siegel, and Orrock and Fisher present diverse glimpses of the future. Of particular interest to Florida was the emphasis on robotic citrus harvesting in the papers by Tutle, Orrock and Fisher, and Coppock. If attendance and interest exhibited by the audience is any indication, it seems assured that research and new applications of robotics and intelligent machines to agriculture have been stimulated by this conference.

Size: 23 x 15 cm, 160pp, soft cover

Price: Member $19.00
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Published by American Society of Agricultural Engineers, 2950 Niles Rd., St. Joseph, MI 49085-9659, U.S.A.

Future Agricultural Technology and Resource Conservation — Proceedings of the RCA Symposium held Dec. 5-9 1982/ Washington, D.C.

By Burton C. English, James A. Maetzold, Brian R. Holding, and Earl O. Heady

The RCA Symposium: Future Agricultural Technology and Resource Conservation was held to determine the direction that American agriculture is headed and the impacts of modern farming practices on land use, soil, and the environment. These were among Congress' concerns when it passed the Soil and Water Resources Conservation Act (RCA) in 1977. The act instructs the U.S. Department of Agriculture (USDA) to make periodic appraisals of the country's agricultural resources and to develop a national soil and water conservation program.

To conduct these appraisals, models of the U.S. agricultural economy analyze the potential impacts of different conservation programs and conditions on productivity, resource use, crop and tillage patterns, food supplies and prices, export levels, and other related vaiables. The analysis, a portion of which is being carried

out at the Center for Agricultural and Rural Development at Iowa State University, extends into the future to evaluate long-term impacts of these variables.

Symposium participants were asked to provide projections for these variables. Among their objectives were:

Identifying current production and conservation technology and assessing future prospects for improving agricultural food and fiber production;

Determining how scientific agricultural technology can be blended with farm management practices;

Identifying factors limiting the adoption of conservation practices;

Determining the current status and assessing the future of adoption of conservation practices into existing farm systems;

Assessing the status and use of the soil and water resources available for agricultural production; and

Evaluating other soil and water conservation issues identified by the USDA and by symposium participants.

Symposium organizers from the Soil Conservation Service of the USDA and the Center for Agricultural and Rural Development at Iowa State University focused the program on nine areas: soil management technology, tillage, and crop rotation practices; land use; water resource technology and management; adoption and diffusion of soil and water conservation practices; crop technology; crop nutrition technology; pest management technology; machinery technology; and red meat, dairy, poultry, and fish technology. Participants for each of these areas were identified largely through a national inventory of their peers.

The symposium extended over three and a half days. The first two days were devoted to papers presented by the major speakers. The third day was devoted to presentations by the discussants and deliberations by work groups, each composed of 15 to 23 specialists.

Each work group had a moderator to facilitate discussion and summarize the group's findings. The final half day was devoted to presentations of the work groups' findings and conclusions.

This proceedings contains all the papers and work group summaries. An Executive Summary of the symposium was published in October 1983 by the Center for Agricultural and Rural Development at Iowa State University.

Size: 23.5 x 16 cm, 617pp, hard cover

Price: US$24.65

Publishers: Publicity Department, Iowa State University Press
2121 South State Avenue
Ames, Iowa 50010, U.S.A.

Farming Systems in Africa
The Great Lakes Highlands of Zaire, Rwanda, and Burundi – World Bank Technical Paper No. 27
(U.S.A.)

By William I. Jones and Roberto Egli

This agroclimatic zone – equatorial, yet temperate and well-watered – has a population of 12 million people and covers an area of 93,000 km^2 in three countries: Burundi, Rwanda, and Zaire. At 130/km^2, population density is high for Africa. The population is almost entirely rural; agriculture and livestock raising are virtually the only economic activities. As a consequence, farms are small. Farming is, for Africa, quite intensive. This population density and this intensivity of land use are recent developments resulting from rapid population growth. They are coupled with extreme economic isolation.

This study, based largely on field interviews but also on a review of the zone's exceptionally poor data sources, makes a first attempt to describe farming systems in the region, which is broken into 11 models for this purpose. Evolution of farming practices and adaptation to changing conditions are analysed. Then the study reviews and assesses a large number of farm-level system changes, most of them proposed by governments and development projects, but some which the mission observed farmers undertaking on their own initiative. The study's assessments lead to recommendations on soil conservation and enrichment measures likely to be interesting to all parties under different circumstances, including the appropriate role of forestry and for using fertilizers on food crops. There are also suggestions on possible diversification in export crops, and on attractive changes in existing cropping patterns and in the present livestock system.

Size: 27 x 21 cm, 118pp, paper cover.

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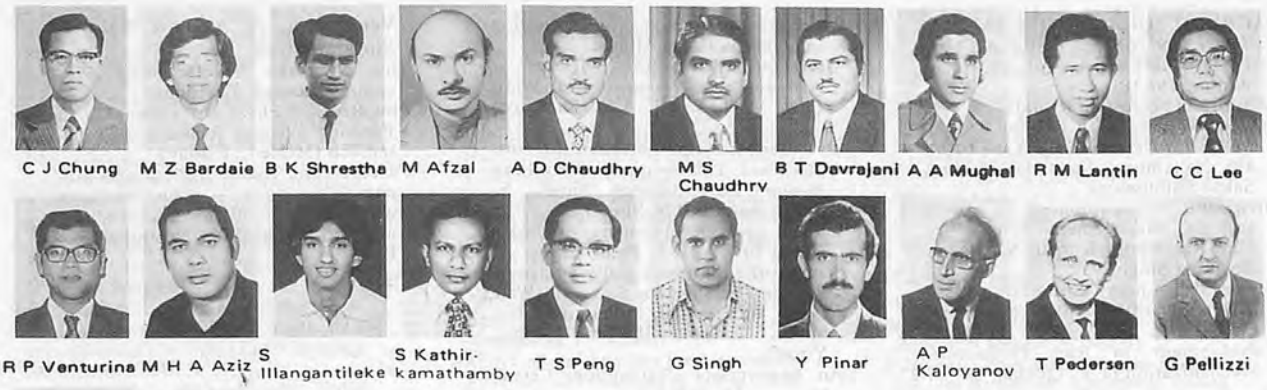

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OBITUARY

Siswadhi Soepardjo, who has been a co-editor AMA in Indonesia since the maiden issue in 1971, died on August 25th, 1985 on his business trip in Saudi Arabia for heat stroke.

He was a chairman of Dept. of agricultural engineering, Bogor Agricultural University and a chairman of Indonesian Society of Agricultural Engineers.

He was the first man who obtained Ph. D. Degree of agricultural engineering in Indonesia.

We are very grateful to him in recognition of his service for AMA during his life time.

BACK ISSUES

(Vol. 15 No. 1, Winter 1984~)

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 15, No. 1, Winter, 1984)

Editorial (Yoshisuke Kishida) 9
Direct Seeding with Coated Rice in Submerged Paddy Field (3) (Yoshiaki Nakamura, Haruhiko Murase, Sakae Shibusawa) 11
Irrigation Well Equipment as Affected by Management Unit Size (Jaw-Kai Wang, Kumar Nagarajan, Devindar Singh) 14
Renewable Energy Sources: A Case Study in Kenyan Village (Giuseppe Pellizi) 21
Development in Rice Production Mechanization (J. C. Igbeka) 27
Development of a Sugarcane Planter for Developing Countries (L. N. Shukla, S. K. Tandon, S. R. Verma) 33
Status of Farm Mechanization Facilities in Khairpur, Pakistan (Sheruddin B. Bukhari, Mohammed Saleh Soomro, Ali Gohar Rajper, Jakhro Ghulam Sarwar) 37
Process of Technology Generation (Irenilza de Alencar Nãas) 43
Harvest and Post-Harvest Management of Crops in Semi-Arid Tropics (O. P. Singhal, S. S. Tomar) 47
Agricultural Mechanization Technology Transfer in Developing Countries (Fallak S. Sial) 51
Agriculture and Agricultural Mechanization in Nigeria (M. S. U. Choudhury, H. L. Musa) 57
Agricultural Mechanization in Fiji (S. Chandra) 65
Effect of Inflation in Depreciation Analysis of Farm Equipment (J. P. Mittal, R. N. Kaul) 73
Development of Low-Cost Indigenous Technology to Minimize Water Losses due to Seepage in Irrigation Canals (Abul Khair, Sunil Ch. Dutta, Mesbauddin Ahmed) . . 77
Abstracts 82
News 84
New Products 85
Book Review 86

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 15, No. 2, Spring, 1984)

Editorial (Yoshisuke Kishida) 9
Reorientation of Agricultural Mechanization for Developing Countries (G.W. Giles, M.L. Taneja) 11
Suitability of Small Tractors in Pakistan: Technical Considerations (Zia ur Rahman, Abdul Shakoor Khan) 24
Rational Use of a General-Purpose Farm Tractor in India (A.C. Srivastava) 27
Conversion of Spark-Ignition Engine for Alcohol Usage—Comparative Performance (M. Zohadie Bardaie, Rimfiel Janius) 31
Some Thoughts on Agricultural Mechanization (Fallak S. Sial) 35
Mechanized Cultivation of Taro (Colocasia Esculenta) in Fiji (S. Chandra, A.P. Sharma) 41
Mechanization of Peanut Harvesting in Malaysia (Desa Ahmad) 44
Sprinkler Distribution Patterns as Affected by Pressure and Wind (S.M. Arshad Ali, A.D. Barefoot) 49
Cylinder Concave Mechanism and Chemical Treatment for Dehulling Pigeon Peas (Digvir Singh, S. Sokhansanj, B.P.N. Singh) 53
Design and Development of Solar Copra Dryers (R.T. Patil) 59
Studies of a Simple, Locally Designed Pepper Thresher for Sarawak (Wan Ishak Wan Ismail, Mohammad bin Mohd. Lassim, Ibrahim Mohd. Yusof) 63
An Appropriate - Technology Cereal Cleaner (J.C. Igbeka) 67
Quantitative and Qualitative Losses in Paddy and Wheat in Bangladesh (Jatindra Nath Samajpati, Md. Shawkat Ali Sheikh, Md. Abdur Rashid) 71
Effects of Pineapple Waste Storage Conditions on the Chemical Composition of Bran (Kushal Pal, G.S. Mittal, V.K. Jindal) 76
Development of Ostwald Chart for Paddy-Straw Combustion (Krishna Kumar, S. Bal, T.P. Ojha) 79
News 82
New Products 83
Book Review 86

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 15, No. 3, Summer, 1984)

Editorial (Yoshisuke Kishida) 9
A Computer Program for Agricultural Machinery Management: Selection of a Particular Tractor Size (Shaukat Khan, Muhammad S. Chaudhry, Sharafeddin M. Sherif) 11
Evaluation of No-Tillage and Conventional Tillage Systems (D.N. Sharma, M.L. Jain, Suresh Sharma) 14
Development and Field Evaluation of Coulter Attachment for Direct Drilling (L.N. Shukla, S.K. Tandon, S.R. Verma) 19
Performance Evaluation of an Automatic Potato Planter-cum-Intercultivator (A.K. Sharma, B.C. Srivastava) 22
Deep Placement Fertilizer Applicators for Improved Fertilizer Use Efficiency (Amir U. Khan) 25
Agricultural Mechanization in Selected Southeast Asian Countries (Gajendra Singh) 33
A Power Tiller-Mounted Vertical Conveyor Reaper-Windrower (I.K. Garg, V.K. Sharma, Santokh Singh) 40
Grain Drying with Solid Heat Transfer Media (G.S. Mittal, H.M. Lapp) 45
Tractor Operation Training Safety Seat (W.S. Barnes, H.D. Henderson) 51
Conventional Farm Tools and Evolution of Farming Systems in Sarawak, Malaysia (Makoto Hoki, Merle L. Esmay) 63
Evaluation of Container Sacks for Effective Rice Bran Storage (V. Venkatesan, S. Anthoni Rai, K. Singaravadivel) 68
The Nebraska Tractor Test Procedure (Louis I. Leviticus) 71
The Role of Physical Technology in Farming Systems Research and Extension (Merle L. Esmay) 77
Feature: The Latest Agricultural Machine in Japan — The products which will be highly accepted by users in 1984 (Shin-Norinsha Co., Ltd.) 78
News 86

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 15, No. 4, Autumn, 1984)

Editorial (Yoshisuke Kishida) 9
Soil-Bin Investigations of Blade Tools (R.N.S. Yadav, K.P. Pandey) 11
Evaluation of Low-Horsepower Equipment for No-Till Farming (C. Garman, D.S. Ngambeki, N. Navasero) 15
Design and Development of a Ground-Metered Shrouded Disc VLV Sprayer (M.S.U. Chaudhury) 19
Design, Development and Evaluation of a Tractor-Operated Multicrop Thresher (V.K. Sharma, S.S. Ahuja, N.S. Sandhar, I.K. Garg, P.K. Gupta, J.S. Sandha) 26
Water Transmission Characteristics and Growth of Maize as Affected by Depth of Tillage (Ahmad Ali Hassan, S.M. Rahman, S.S. Prihar) 31
Effect of Water Management Practices on Penetration Resistance of Paddy Soil (S.V. Subbaiah, K.G. Pillai, R.P. Singh, K.R. Dhandapani) . . . 35
Agricultural Mechanization and Labor Employment: A Case of Punjab, Pakistan (M.A. Chaudhry) 38
Farm Power in Bangladesh and its Prospects of Improvement (A.K.M. Moniruzzaman) 43
Vibration Control in Agricultural Machinery (A.P. Sharma, M.L. Jain) 47
Studies on Grain Storage Structures in Mymensingh District (Gurudas Mandal, Jatindra Nath Samajpati, Md. Abdur Rashid) 50
Parboiling of Paddy with Heated Sand (B.D. Shukla, A.U. Khan) 55
Fuel Chracteristics of Agricultural Residues (K.Kumar, S. Bal, T.P. Ojha) 61
Design of an Environmental Control System for Broiler Research (Rajinder P. Kachru, M.H. Raoufat) 65
Microprocessors and Microcomputers: An Appropriate Technology for Developing Countries? (M. Stephen Kaminaka) 70
A Critical Review of the Indian Tractor Industry (B.K.S. Jain) . . . 75
Abstracts 78
News 80
New Products 82
Book Review 84

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 16, No. 1, Winter 1985)
Editorial (Yoshisuke Kishida) 9
Boat-Tractor Hull Design to Minimize Drag Forces (N.C. Thai, W.J. Chancellor) 11
Energy Conservation in Mechanized Agriculture in Chile (Edmundo J. Hetz) 18
Cocoa Drying and Storage Using Charcoal and Solar Heated Rocks (Edward Baryeh) 23
Comparative Use of Moldboard and Chisel Plows on Wheat Yield and Weed Density in Iraq (Lufti Hussain Mohammed Ali) 29
Improved Disc Harrow with Solid Shaft and Casehardened Bush Bearings (Deepak Choudhri, Hem Chandra Joshi) 31
Animal-Drawn Wheeled Tool Carrier: An Appropriate Mechanization for Improved Farming Systems (Harbans Lal) 38
The Use of Fluid Drilling and Soil Conditioning Techniques for Spring-Sown Onions (S.M. Ward, F. O'Driscoll) 45
Design Parameters of Mole Drainage System in Bangkok Soil (Ahmad Ali Hassan, Apichart Anukularmphai) 49
Storage Practices for Yam in Nigeria (J.C. Igbeka) 55
Power Tiller Industry in India (S.S. Tomar) 59
Status of Dung Utilization in India and its Prospects (H.C. Joshi, R.C. Jakhmola, D.N. Kamra) 63
Mechanization of Sugarcane Farming in India (R.N.S. Yadav) 67
Measurement of Properties of Rice Husk Boards: Part I Physical and Mechanical (B.D. Shukla, T.P. Ojha, C.P. Gupta) 72
News 83
Book Review 85

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 16, No.2, Spring 1985)
Editorial (Yoshisuke Kishida) 9
Dynamic Behaviour of Wet Soil and Tillage and Traction in Wet Land (N.K. Awadhwal, C.P. Singh) . . . . C.P. Singh) 11
Appropriate Technology-Animal-Drawn Equipment for Small Farmers in Nūble, Chile (Mario Ibanez C., Edmundo J. Hetz) 21
Improved Animal-Drawn Moldboard Plough Utilizing Available Draft power (A.A. Mainul Hussain, S.M. Farouk, N.N. Sarker) 25
Design Characteristics and Performance of Wind Mills for Pumping Irrigation Water (B.V. Ramana Rao, S.C. Chowdhry, P. Sharma) 27
Simple Attachments to Indian Country Plough (Ghanshyam Das, Avinash Agarwal) 30
Windpump for Irrigation in Hararghe Region of Ethiopia (Peter Burudi, K.P. Srivastava) 33
A Tractor-Mounted Digger for Potatoes (G.C. Misener) 39
Design, Development and Field Evaluation of Vertical Conveyor Reaper Windrower (R.S. Devani, M.M. Pandey) 41
Measurement of Properties of Rice Husk Boards: Part II (B.D. Shukla, T.P. Ojha, C.P. Gupta) 53
Suitability of Flexible Packaging Films for Rice, Dal and Wheat Flour (Mridula Bhattacharjee, Surya Nath) 61
Combustion Process of Rice Husk for Amorphous Silica Production (H.D. Banerjee, A. Chakraverty, A.K. Mahapatra, P. Nishra) 67
Results of an Opinion Poll on Safety Features of Tractors in India (N.S. Sandhar, J.P.S. Malhotra) 72
Status of Agricultural Machinery Manufacturing in Sind, Pakistan (Muhammad Saleh Soomro, Sheruddin B. Bukhari) 75
Need for Smallholding Mechanization in Pakistan (A.Q.A. Mughal) 79
Abstract 82
News 83
New Products 85

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 16 No. 3, Summer, 1985)
Editorial (Yoshisuke Kishida) 9
Notes on Agricultural Machinery Manufacture in the Developing Countries of Asia (Adrian G. Rijk) . . . 11
A Stationary Threshing Machine: Design, Construction and Performance Evaluation (A.E. Ghaly) 19
Modification and Testing of Bullock-Drawn, Single-Row Corn Planter (Jan Muhammed Baloch, A.Q.A. Mughal) 31
Weed Control through Inter-Row Cultivation in Upland Rice (C.M. Singh, K. Moody, S.C. Cho) 35
Electrostatic Spraying with a Knapsack Sprayer (E. Moser, Md. Daulat Hussain) 41
Partial Mechanization of Sugarcane Harvesting (M.P. Sharma, Kishan Singh) 47
A Study of Traditional and Mechanized Systems for Maize Production (U.G.N. Anazodo) 51
Need for National Cooperative Tillage Research in Pakistan (M.A. Choudhary) 57
Sunflower Oil: An Anticipated Diesel Fuel Alternative (Abdul Rehman Tahir) 59
Auditing Appropriate Technology Appropriately (Sushila Saxena, Naresh Chandra Saxena) 65
Mechanization of Sugarcane Farming in India (B.K.S. Jain) 67
Importance of Agriculture in the Oil-Rich Kingdom of Saudi Arabia (Fallak S. Sial) 70
The Nebraska Test Procedure—Using the Results (Louis I. Leviticus) . . . 77
Abstracts 84
News 85

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 16, No. 4, Autumn, 1985)
Editorial (Yoshisuke Kishida) 9
Economics of Tractor Operation in Swaziland (Harry D. Henderson, Wolfgang Guericke) 11
Animal-Drawn Wheeled Tool Carrier in India under On-Farm Conditions (V.M. Mayande, R. Sarin, G.E. Thierstein) 17
Evaluation of Manual Planters for Selected Crops in West African Savanna (M.S.U. Choudhury) 25
Spray Characteristics of a Rotary Atomizer (Shane M. Ward) 30
A Kinetic Analysis of Large Rounding Jet-Irrigation Apparatus (Zong Sheng-Yu) 33
Comparison of Axial-Flow and Centrifugal Pumps for Low-Lift Irrigation (Edwin J. Calilung, Gódofredo C. Salazar, Celerina L. Maranan, Robert E. Stickney) 35
Efficiency of Resource Use in a Tube Well Irrigation Scheme in Sri Lanka (H.M.G. Herath) 39
Effect of Irrigation on Cotton Yield in Southern USSR (Tashkent) (Md. Motiur Rahman Khan) 43
Performance of Indigenous Hand Weeders in Bangladesh (Md. Syedul Islam, Khondaker Azharul Haq). . . 47
Mechanical Harvesting of Cotton in the Sudan (Mahmoud Hassan Ahmed) 51
Study of a Segmented Paraboloid Type Solar Heat Collector (M.H. Pahoja, C.N. Gangde) 54
Impact of Farm Technology and Energy on Developing Agriculture (M.A. Choudhary) 59
Status of Mechanization on Hilly Farmlands of Puerto Rico (Megh R. Goyal, Felix R. Rivera-Negron, Eliodoro J. Ravalo, Rene Otero-Davila, William F. Allison) 65
Machinery Selection Concerning Farm Sizes (S. Swain, T.P. Ojha). 69
Two New Principles of Weighing: Bicycle Wheel as Balance and Dynamometer (F.F.R. Koenigs). 73
Qualities of Retted Flax and Degummed Fibers for Commercial Use (A.C. Datta, N.G. Bhole) 76
News 81
Book Review 83

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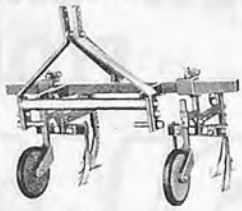

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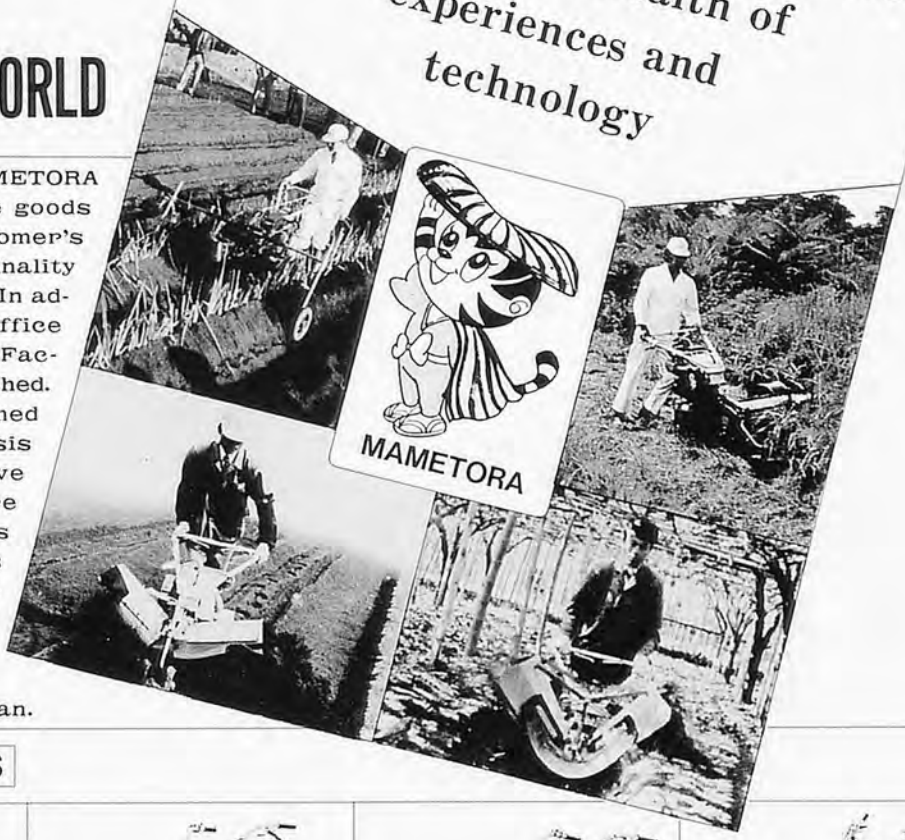

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