International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.20, NO.2, SPRING 1989

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

ISEKI

ISEKI...Dedicated abundant harvests

As the means of producing life-sustaining food, agriculture surely rates as one of the most important industries in the world.

Since its founding 60 years ago, ISEKI has been doing its part to ensure that those engaged in the worldwide agricultural effort can meet modern challenges. Through the production of quality farm machinery and labor saving systems, ISEKI has become famous as the premier manufacturer of such machinery.

It is ISEKI's sincere hope that by continuing these efforts, world agriculture will further develop, thereby producing abundant harvests and world peace for people everywhere.

to producing and world peace

ISEKI & CO., LTD.

Foreign Affairs Division
3-6, Kioi-cho, Chiyoda-ku, Tokyo, 102 Japan
Cable Address: ISEKIRICE TOKYO
Telex: 232-2752, 232-2753
Phone: (03) 238-5245~5260

HINOMOTO® TRACTOR

Hinomoto Tractors — Technology Teaming with Nature for a Better Tomorrow

In complete harmony with nature, Hinomoto technology ensures a bountiful harvest for the benefit of mankind. Agriculture has long been the foundation of civilization. Our commitment to serving society has led us to develop the most advanced machinery and technology, thus creating a bright, promising tomorrow. By maximizing the benefits of Mother Nature, we help farmers everywhere achieve a rich, prosperous harvest whose bounty is shared with all.

The world's first power disc revolutionized agriculture by eliminating the defects of conventional rotary tillers. The power disc tills deep into the ground, increasing the amount of land that can be cultivated and producing the ideal soil consistency for growth.

TOYOSHA CO.,LTD.

55, Joshoji-16, Kadoma-city, Osaka, 571 Japan
Cable: TOYOSHA NEYAGAWA
Telex: 05347763 MBTRAC J

International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.20, NO.2, SPRING 1989

Edited by

YOSHISUKE KISHIDA

Published quarterly by

Farm Machinery Industrial Research Corp.

in cooperation with

The Shin-Norinsha Co., Ltd.

and

The International Farm Mechanization Research Service

TOKYO

Yoshisuke Kishida, Publisher & Chief Editor

Contributing Editors and Cooperators

- AFRICA -
Van Lancker, Julien G. (Brundi)
Baryeh, Edward A. (Cameroon)
El Hossay, A.M. (Egypt)
Kandiah, Arumugam (Ethiopia)
Ampratwum, David Boakye (Ghana)
Bani, Richard Jinks (Ghana)
Djokoto, Israel Kofi (Ghana)
Some, D. Kimutai arap (Kenya)
Choudhury, Md. Shahansha Uddin (Nigeria)
Igbeka, Joseph C. (Nigeria)
Odigboh, E.U. (Nigeria)
Oni, Kayode C. (Nigeria)
Kuyembeh, N.G. (Sierra Leone)
Abdoun, Abdien Hassan (Sudan)
Saeed, Amir Bakheit (Sudan)
Khatibu, Abdisalam I. (Tanzania)
Tembo, Solomon (Zimbabwe)

- AMERICAS -
Nääs, Irenilza de Alencar (Brazil)
Ghaly, Abdelkader E. (Canada)
Valenzuela, A.A. (Chile)
Mirdha, A.H. (Mexico)
Chancellor, William J. (U.S.A.)
Esmay, Merle L. (U.S.A.)
Goyal, Megh Raj (U.S.A.)
Philips, Allan L. (U.S.A.)

- ASIA and OCEANIA -
Farouk, Shah M. (Bangladesh)
Mazed, M.A. (Bangladesh)
Gurung, Manbahadur (Bhutan)
Wang, Wanjun (China)
Chandra, Satish (Fiji)
Michael, A.M. (India)
Mittal, J.P. (India)
Ojha, T.P. (India)
Verma, S.R. (India)
Soedjatmiko (Indonesia)
Behroozi-Lar, Mansoor (Iran)
Sakai, Jun (Japan)
Snobar, Bassan A. (Jordan)
Chung, Chang Joo (Korea)
Haffar, Imad (Lebanon)
Bardaie, Muhamad Zohadie (Malaysia)
Shrestha, Bala Krishna (Nepal)
Afzal, Mohammad (Pakistan)
Chaudhry, Allah Ditta (Pakistan)
Chaudhry, Md. Siddique (Pakistan)
Devrajani, Bherulal T. (Pakistan)
Mughal, A.Q. (Pakistan)
Nath, Surya (Papua New Guinea)
Lantin, Reynaldo M. (Philippines)
Venturina, Ricardo P. (Philippines)
Aziz, M.H. Abdel (Saudi Arabia)
Illangantileke, S. (Sri Lanka)
Kathirkamathamby, Suppiah (Sri Lanka)
Chang, Sen-Fuh (Taiwan)
Rojanasaroj, C. (Thailand)
Singh, Gajendra (Thailand)
Pinar, Yunus (Turkey)

- EUROPE -
Kaloyanov, Anastas P. (Bulgaria)
Pedersen, T. Touggaard (Denmark)
Pellizzi, Giuseppe (Italy)
Wanders, A. Anne (Netherlands)
Kilgour, John (U.K.)

EDITORIAL STAFF
(Tel. 03/291-5718)
Yoshisuke Kishida, Chief Editor
Kensuke Sakurai, Managing Editor
Yoshinori Sasaki, Assistant Editor
Noriyuki Muramatsu, Assistant Editor
D.A. Cruz, Editorial Consultant

ADVERTISING
(Tel. 03/291-3672)
Kuniharu Ikeda, Manager (Head Office)
Hiroshi Yamamoto, Manager (Branch Office)
Advertising Rate: 300 thousand yen per a page

CIRCULATION
(Tel. 03-291-5718)
Soichiro Fukutomi, Manager
Editorial, Advertising and Circulation Headquarters
7, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo, 101, Japan

Copyright © 1989 by
FARM MACHINERY INDUSTRIAL RESEARCH CORP.
SHIN-NORIN Building
7, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo 101 Japan
Printed in Japan

This is the 63rd issue since the issue, Spring of 1971

EDITORIAL

The Ecological Imbalance and More

There is certainly much more to the ecological imbalance: more than a political issue in many parts of the world; more than scores of thousands of square kilometers of forests disapperaring from the face of the earth annually; and much more than the alarming increase of carbonic acids in the atmosphere in the face of a dwindling oxygen supply. Also at stake is the future of the agricultural environment. For when agriculture is also threatended and endangered, so is mankind itself – for agriculture will always be equated with food for the inhabitants of the planet Earth.

It is quite an irony, but all too true, that indiscriminate deforestation goes unabated in most developing countries. For want of hard, foreign currency from developed countries, not a few governments of the Third World, at the manipulation of opportunist politicians, pawn their future by exporting their primary resources: lumber and other forest products, for example. And when the logging operations abandon the onceverdant mountainsides, an equally destructive slash-and-burn agriculture takes over. No sooner than water sheds disappear. Then drought or flood ensues and causes havoc and further devastation of the ecosystem.

Sooner than expected, the ecological imbalance will adversely affect also the agricultural environment unless everyone pitches in – governments, private sectors, aid-givers, farmers, politicians, students and just about everyone! The passage of laws protecting the ecosystem is good but only to the extent that they are properly implemented. Interested parties concerned with agricultural mechanization, like the AMA, should not be left out in the total effort to slow down, if not arrest, the advance of ecological imbalance. For one thing, the use of farm machines and other heavy equipment will hasten the recovery of denuded hillsides. Seen from another angle, agricultural machineries will enable farming operations to be performed more timely and increase the effective utilization of farmlands. To be sure, a widespread use of farm machineries and farm mechanization technology needs to be addressed – not only to ensure agricultural productivity but also to protect the precious natural environment from further destruction.

The AMA hereby commits itself to help promote any campaigns for solving the environmental problems before they become insurmountable. Specifically, the AMA calls for contributed articles, case reports, research results that relate to the ecological imbalance for sharing with many others through the pages of the AMA.

Yoshsuke Kishida
Chief Editor

Tokyo
May, 1989

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol. 20, No. 2, Spring 1989

Yoshisuke Kishida	7	Editorial
Brian G. Sims Adrian Aragon Ramirez	9	Draft Oxen Energy Expenditure: A Mexican Case Study
A. Tajuddin K.R. Swaminathan	15	Development of Tractor-operated Hoist for Fruit Harvesting
Sheruddin Bukhari Khalil Ahmed Ibupoto Ghulam Hyder Jamro Mohammad Zafrullah	17	Grain Losses of Various Wheat Varieties Harvested by Power Reaper
S. Sokhansanj D.S. Jayas J.D. Wasserman	19	Predicting Dryer Performance Using Similitude Analysis
K.S. Kim M.G. Shin B.C. Kim J.H. Rhim H.S. Cheigh W. Mühlbauer T.W. Kwon	23	An Ambient-air In-storage Paddy Drying System for Korean Farms
Megh R. Goyal Octavio Colberg William Vicenty	30	Separation of Asparagus Berries Using Stationary Plot Thresher
G.C. Misener C.D. McLeod	33	A Resource Efficient Approach to Potato-Stone-Clod Separation
M. Hassan R.C. Lazaro M.R. Hoque	37	Orifice Meter for Pump Discharge Measurement
S.D. Kulkarni	42	Pulse Processing Machinery in India
N.N. Sarker Shah M. Farouk	49	Some Factors Causing Rice Milling Loss in Bangladesh
Mustafa A. Hummeida Ahmed El Tayeb Ahmed	53	Resistance of Sorghum, Peanut and Seasame to Air Flow
Joginder Singh S.K. Sekhon Amarjeet Kaur	57	Requirements and Use of Tractor Power in Punjab Agriculture
Toshio Konaka Wan M. Zakludin	59	Design of Group Mechanization System Using "CAFARMS' Computer Model for Kada Area
Delmar Bandiera Marchetti Irenilza de Alencar Nääs	66	Status of the Agricultural Engineering National Program in Brazil
Surya Nath	71	Agricultural Mechanization Prospect in Papua New Guinea
Abdul Majid A.S. Khan S.I. Ahmad	74	Scope and Implications of Mechanizing Rice Production in Pakistan
News	79	
New Products	81	
Book Review	83	

* * *

Instructions to AMA Contributors 85

Co-operating Editors 86

Back Issues 88

Draft Oxen Energy Expenditure: A Mexican Case Study

by
Brian G. Sims
Agricultural Food and Research Council
Institute of Engineering Research
Wrest Park, Silsoe, Bedfordshire
MK45 4HS, U.K.

Adrian Aragon Ramirez
Agric. Engg. Unit (UIMA), Cotaxtle, Veracruz
Experimental Station of the Mexican Institute
of Forestry and Agricultural Research (INIFAP)
Apartado 429, Varacrus, Mexico

Abstract

Measurements were made of the draft force, forward speed, power output and energy use of a pair of draft bovines performing traditional agricultural tasks on a small farm in Veracruz State, Mexico. This instrumentation was developed for use in Costa Rica.

The instrumentation performed well in Mexico, the basic data obtained permitted preliminary observations to be made on improving draft bovine use and form part of an expanding pool of information necessary for identifying priority areas for research in draft animal power.

Energy demand through the year indicated marked peaks for soil preparation and weed control principally, and slack periods in the dry season. It is possible that, given good feeding, single animals could perform light draft tasks (such as cultivating and planting) and this would need the evaluation of single yokes.

Better use of the US$1 000 investment in draft animals during the dry season could be achieved by irrigation, and a reduction of excessive tillage would reduce energy use and allow greater areas to be sown.

Introduction

World-wide the use of animals as a farm power source is extremely important. For example, Smith (16), 1981 quoted by Lawrence and Pearson (6) in 1985 estimated that the 200 million draft cattle and buffalo in the world produce 85% of the power used in developing country agriculture. Other writers give higher estimates of the importance of animal traction. For example, Barwell and Ayre (2), 1982 estimated the total number of draft animals in the world to be approximately 400 million, of which 300 million are cattle and buffalo, 80 million are equines (horses, mules and donkeys) and the remainder includes camels, llamas and alpacas. Ramaswamy (10), 1981 estimated that there are 2.8 million draft bovines in Mexico (together with 6.5 million horses and 3.2 million donkeys and mules).

In the state of Veracruz, Mexico it has been estimated that aproximately 50% of the agricultural land is plowed with animal power as well as about 75% of the subsequent cultivation operations (Sims, Moreno and Albarrán (14), 1985).

Given the importance of animal traction in Mexico it is surprising that so little work has been done on measuring the basic data on work output which are needed for any development programme aiming to increase land and labour productivity by means of a more rational use of draft animals. Such data are needed in order to relate food requirements to work output, to improve the design of implements and harnesses, and to identify alternative crop production systems which reduce unnecessary power use without prejudicing crop yeild.

The main purpose of the study described in this paper was to measure the energy expended by a team of bovines on a typical small farm throughout an entire year, as a step towards producing recommendations for improving draft animal use in the tropical coastal lowlands of Veracruz State.

The study was made using instrumentation developed in Costa Rica, and a second objective was to evaluate this equipment under Mexican conditions.

Materials and Methods

The Animals

The two animals studied were bulls: Cardenal, a five year old brown swiss x zebu cross weighing 445 kg and Durazno, a four year old 451 kg criollo. The weights were estimated with the following equation developed for Veracruz

draft animals (Sims and Jácome (15), 1986):

Body weight

$= 82.47 (L x G^2) - 20.43$ kg

Where: L is the body length from the tail root to the front shoulder (m)

G is the heart girth (m)

The animals were yoked with the traditional Spanish wooden yoke (**Fig. 1**) which is placed on the back of the necks of the animals and tied to the horns with leather strips. Yokes of different lengths (from 800 mm to 1.8 m between the centre line of the animals) were used according to the field operation and the distance between crop rows.

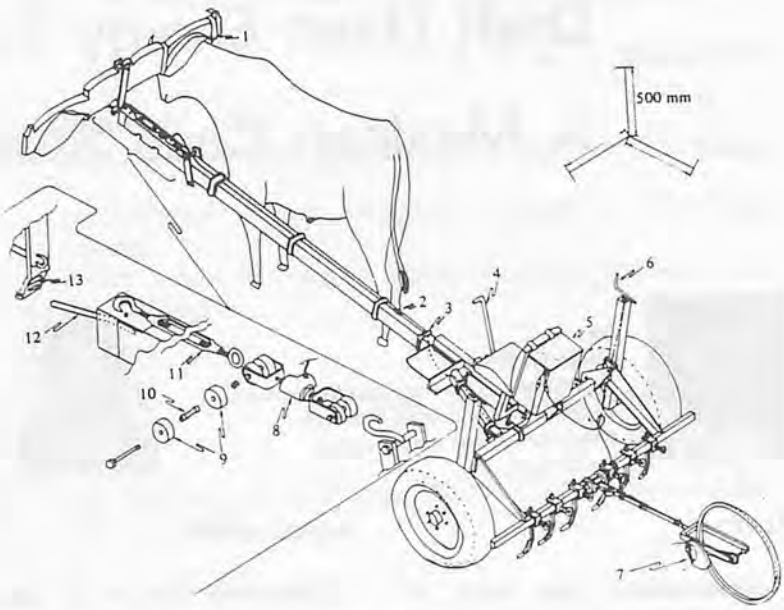


Fig. 1 The Yunticultor with instrumentation with inset showing load cell mounting details. Nomenclature: 1. Spanish yoke tied to horns. 2. five pin DIN connector. 3. cables tied to bar with rubber strips. 4. implement lift lever. 5. box housing IDD units. 6. implement levelling and depth control. 7. odometer. 8. load sell. 9. rubber buffers. 10. roller. 11. turnbuckle to adjust slack. 12. prong projects horizontally from front of drawpole. 13. roller supports prong and takes weight of drawpole.

The Farm

The work was done on the land of Ciriaco Meza, Mozambique ejido, Medelí de Bravo municipality, Veracruz State. The land is flat with sandy loam soil and the climate is classified as sub-humid tropical with an annual average rainfall of 1115 mm and a mean annual temperature of 27° (García (3) 1973).

The farm size is 6.7 ha, the different crops and the areas sown to each are given in **Table 1**. In addition, the farmer planted 1.7 ha of tomatoes and 0.45 ha of beans in association with other farmers.

Agricultural Implements

The equipment used for each agricultural operation is listed in **Table 2** and briefly described as follows:

American plow – This is a conventional steel moldboard plow with a 250 mm cut. These plows are manufactured in several Mexican factories and are based on North American designs from the last century (Olmstead, Johnston and Sims (9) 1986).

Multibarra – The Multibarra is a multi-purpose tool bar developed by the Mexican Institute of Forestry and Agricultural Research (INIFAP). It consists of a tool bar with three spaces, one for a depth wheel, and two for implements,

Table 1 Crops Sown by Ciriaco Meza on 6.7 ha Farm (June 1985–July 1986)

Crop	Area sown (ha)	Total area (%)
Maize	3.85	57.5
Sweet potato	1.00	14.9
Beans	0.55	8.2
House and yard (fruit trees, pigs and chickens)	0.51	7.6
Pasture	0.45	6.7
Chile peppers	0.15	2.2
Tomato	0.14	2.1
Flowers	0.05	0.7

Table 2 Animal-drawn Agricultural Implements Used by Farmer Ciriaco Meza

Operation	Implement
Plowing	(i) "American" plow (ii) Multibarra multi-purpose tool bar fitted with moldboard plow
Disking	(i) 12 disk offset harrow (ii) Yunticultor wheeled tool carrier with 6 disk single acting harrow.
Levelling	Three trunk 190 mm diameter, 2.5 m long pulled by a rope.
Ridging	(i) "American" plow (ii) "Eguptian" plow (iii) Multibarra fitted with ridging body
Planting	Multibarra fitted with seeder and ridging body
Cultivating	(i) Two tined traditional cultivator (ii) Multibarra fitted with three cultivating tines
Earthing up (re-ridging)	(i) "American" plow (ii) Multibarra fitted with moldboard plow
Harvesting (only for lifting sweet potato)	(i) "American" plow (ii) Multibarra fitted with moldboard plow
Transport	Yunticultor with 500 kg capacity load carrying platform

which may be selected from moldboard plows, ridger, seeder, or cultivator (Moreno, Sims and Albarrán (8), 1982).

Offset disk harrow – This is another INIFAP-developed implement consisting of two gangs of six 400-mm diameter disks. The angle between the gangs is adjustable to vary the severity of soil disturbance, and the operator rides on a seat above (Moreno and Sims (7), 1984).

Yunticultor – The Yunticultor is a two-wheeled toolcarrier to which a range of tools (plows, disks, ridgers, seeders, cultivators) and a load carrying platform can be attached (Sims, Moreno and Albarrán (14) 1985). An early prototype, designed at the UK National Institute of Agricultural Engineering (Kemp (4), 1983), and used in Costa Rica is shown in **Fig. 1**.

Egyptian plow – The Egyptian, wooden, or Spanish plow was introduced by the Conquistadores some 500 years ago and has not changed since. It is made from a tree branch with a handle and draw pole fitted and a replaceable steel share on its leading edge.

Two/tined cultivator – This implement is also made in Mexico based on early North American designs. It has two 80-mm wide, curved tines, pointed at both ends for double working life (Sims, Moreno and Albarrán (13) 1984).

Instrumentation

The instrumentation used for this study was developed by Peter Lawrence while working in Costa Rica (Lawrence and Pearson (6), 1985. It consists of three basic elements: a force transducer, an odometer and two linked integrate, divide and display (IDD) units.

The force transducer is type F208 made by Novatech Ltd., Hastings, UK and has a range of 0-2500N. It is connected to the implement so that all the force exerted by the oxen passes through it. The attachment to the draw pole of the Yunticultor is shown in **Fig. 1**. A similar arrangement was used for the Egyptian plow and for all the other implements the transducer was connected to the draw chain or rope.

The draft force was not resolved into its vertical and horizontal components for two reasons: firstly, draft animals must work to move whilst bearing a vertical load and this could amount to about 10% of that needed to exert an equivalent horizontal force; secondly, the angle of the resultant force to the horizontal is approximately 10°. Thus the horizontal component is cosine 10° (0.985) times the resultant and the small difference is compensated for by the effect of the vertical component.

The odometer, mounted on a bicycle wheel, contains a slotted disk, an infrared emitter and detector cell. It emits one pulse for every 5.8 mm of forward travel and the signal can be divided (by IDD1) by a factor of up to 2^8 so that distances from a few meters to several kilometers can be measured.

For field measurements other than with the Yunticultor the IDD units were carried in a back pack and the odometer was held by hand by the researcher whilst the farmer carried on with his work in the normal way (**Fig. 2**).

Although this method may produce differences in the indicated distances harvested by the animals (when, for example, the researcher did not stop in unison with the animals), they were considered to be so small as to be negligible.

The output from the force transducer is fed into both IDD units. In IDD1 force measurements are recorded each time an odometer pulse is received thus a distance (rather than time) averaged draft force is measured. The IDD2 unit has an oscillator circuit producing square waves at 200 Hz. This is

Fig. 2 Measuring field performance with Egyptian plow.

used instead of odometer pulses during calibration of the instrumentation.

The instrument has three display panels to show distance travelled, work done and working time. Both the distance and work signals can be attenuated by dividing and by multiples of two up to 2^8.

Calibration

The instrument was calibrated at the end of each work day by suspending 1177.2 N (120 kg) from the force transducer and by injecting 1024 pulses from the oscillator.

As one pulse from the odometer is equivalent to a forward movement of 5.8 mm, the 1024 pulses from the oscillator are equivalent to 5.94 mm, and the apparent work done is 5.94 x 1177.2 Joules. If the number of counts displayed on the work counter is n, then the calibration factor F, for field reading is 5.94 x 1177.2 n.

The odometer was calibrated by pushing the wheel over a 100-m track and noting the distance display.

Field Measurements

Field readings of distance and work done and the attenuation of both displays were recorded with a portable tape recorder and later transferred to daily worksheets (**Table 3**). Also recorded were the air temperature, area worked, total work time and resting time: spot measurements (at least five) were made of the depth and width of work (RNAM (11) 1983) and the maximum soil shear strength was measured using a torsional shear

Table 3 Sample Daily Work Sheet Actually Used in Study

Date: 25 July 1985 Operation: Disking Effective work time: 3.83 h
Plot no: 5 Implement: 12 Disk harrow Moisture content: Low
Crop: Tomato Width of work: 1.01 m Max. shear strength: 9.68 9.68 kN/m²
Implement operator: Tello, Ciriaco's son Depth of work: 240 mm Work animals: Cardenal, Durazno

Field work started: 0700 h Finished: 1 140 h Rest time: 0.84 h* Effective work time: 3.83 h

Time (h)	Run time (s)	Temp. (°C)	Distance display				Work display			
			Start	Finish	Difference	Attenuation (2^X)	Start	Finish	Difference	Attenuation (2^X)
0700			0				0			
1050	72.0	34	141	164	23	8	112	135	19	8
1058	71.0		203	228	25	8	161	181	20	8
1102	71.7	35	265	288	23	8	205	228	23	8
1107	71.7	34	350	375	25	8	276	298	22	8
1116	71.7		377	402	25	8	298	315	17	8
1119	74.0		405	429	24	8	320	340	20	8
1123	71.7		461	489	28	8	364	387	23	8
1127	75.0			549	27	8	411	434	23	8
1132	70.0	33	582	607	25	8	456	480	24	8
1137	68.0	34	611	638	27	8	483	505	22	8

Area worked: 0.073 ha
Calibration factor (F): 15.9
Average power output during work = 1.21 kW
Average draft force during work = 2.32 kW
Average forward speed during work = 0.52 m/s
Work done from 0700 to 1140: $505 \times 2^8 \times F/10^6 = 2.06$ MJ
Distance covered from 0700 to 1140: $0.0058 \times 2^8 \times 638 = 947.3$ m/ms

*: Rest time of 0.84 h is the time when the farmer and the animals stopped in the shade. It does not include turning, field adjustments and stops during runs across the field.

box 245 mm in diameter and a torque wrench (the procedure is described by Ashburner and Sims (1), 1984). It was impractical to measure all the work done on every work day so that where necessary, results were estimated from previous (or subsequent) data.

Table 3 shows a 47-minute (1050 h – 1137 h) segment of the data recorded on this day. Both the distance and work displays were zero at the start of work at 0700 h. The data at the foot of the table refer to the complete work period (0700 h – 1140 h).

Calculation of Results

Work Done

If the work count reading after field work is N with attenuation r then:

Total work done = $F \times N \times 2^r$ J
(F: Calibration factor)

Distance Travelled

If the distance display is A with attenuation s, then:

Distance travelled
$= 0.0058 \times A \times 2^s$ m

Power

An average value of the power developed can be calculated from the data in **Table 3**. If the time of a run is t seconds then:

$$\text{Average power} = \frac{F \times N \times 2^r}{t} \text{ W}$$

Draft Force

After calculating the distance covered on each run (**Table 3**) then:

Distance average draft force

$$= \frac{F \times N \times 2^r}{0.058 \times A \times 2^s} \text{ N}$$

Forward Speed

Is given by:

Average forward speed

$$= \frac{0.058 \times A \times 2^s}{t} \text{ m/sec}$$

Results and Discussion

The field operations for each crop are listed in **Table 4** together with the energy requirements. The monthly variation in energy use through the year is shown in **Fig. 3**. **Table 5** gives values for draft animal performance in the different field operations. The data are averages for all the crops sown. The data for draft force, forward speed and power are for the animals at work, whereas the energy used, time/ha and distance/ha include all turning and rest times.

Fig. 3 shows the impact on the start of the rains at the end of June on the energy requirement. At this time the major crop, maize, is sown and the battle against weed infestation continues until August.

September and October are the months for planting beans, chile peppers, tomato, and sweet potato, with a further peak in December when a second tomato crop was sown.

As shown in **Table 4** tractors are used for disking and ploughing in three crops. This is in response to the need to sow by certain dates to take advantage of soil moisture. Severe yield penalties are incurred by delay. However, should time allow, or economic circumstances dictate the use of animals for these tasks, then the increase in energy use (**Table 4**) can be estimated from the data in **Table 5**.

The draft animal work period is from 0700 h to 1100 h with a second session in the afternoon from 1500 h to 1800 h, a daily total of 7 h. This time-table allows the animals (and the farmer) to rest during the mid-day and early

Table 4 Crops Grown, Field Operations, and Draft Animal Energy Used (Energy Demand for Tractor Powered Operations not Included)

Crop	Area sown (ha)*	Operation								Energy used (MJ)	
		Plow	Disk	Level	Ridge	Plant	Cultivate	Earth-up	Harvest	per ha	Total
Maize	4.85	Tractor	Tractor	–	once	manual	twice	once	manual	88.5	429.2
S. potato	1.00	Tractor	Tractor	once	twice	manual	–	once	once	107.9	107.9
Beans	0.77	Tractor	Tractor	once	combined	operation	twice	–	manual	69.5	53.5
Chile	0.15	once	twice	once	once	manual transplant.	twice	–	manual	182.6	27.4
Tomato	0.50	once	twice	once	once	manual transplant.	manual	manual	manual	140.4	70.2
Flowers	0.05	once	once	once	once	manual	once	–	manual	136.2	6.8
Transport	Approximately 30 km with the Yunticultor and platform										14.8
										Total	709.8

*: The area sown is that on Ciriaco Meza's own farm and the proportion of the maize, bean and tomato worked by Ciriaco's draft animals on other farmers' land.

Table 5 Draft Animal Performance in Different Field Operations

Operation	Width of work (mm)	Depth of work (mm)	Soil shear strength (kN/m²)		Draft force (kN)			Forward speed (M/s)	Power (kW)	Energy used (MJ/ha)	Output (h/ha)	Dist. walked (km/ha)
			min.	max.	min.	max.	average	av.	av.	av.		av.
Plowing	290	180	7.06	26.60	0.79	1.99	1.27	0.56	0.71	54.27	20.18	42.73
Disking	1 000	120	9.70	17.00	0.99	2.48	1.87	0.49	1.07	25.28	6.69	13.52
Levelling	2 300	–	7.06	7.06	0.85	1.45	1.15	0.63	0.72	13.00	2.26	11.30
Ridging (single body)	400	170	9.18	12.40	0.82	1.35	1.11	0.66	0.71	22.57	12.42	20.33
Ridging + planting	500	120	7.06	7.06	0.52	0.76	0.67	0.66	0.45	14.33	9.93	21.39
Cultivating	500	90	8.47	15.50	0.42	1.09	0.87	0.61	0.48	21.08	10.75	24.23
Earthing-up	470	170	8.00	14.00	0.83	1.09	0.95	0.63	0.60	23.75	11.07	25.00
Harvesting (estimated)	400	200	NR	NR	0.60	2.00	1.30	0.60	0.78	26.00	13.66	40.00
Transport	–	–	–	–	–	–	0.494	0.66	–	–	–	–

Note: i) The figures are averages taken over the whole year in all crops. ii) The implements used are given in Table 2.

afternoon intense sun. The rest periods during the 7 h work day amount to 18% leaving 5.74 h of effective work time. The air temperature during work periods averaged 31°C with a range from 23°C to 37°C.

The animals maintain a fairly constant forward speed (about 0.6 m/s) irrespective of draft force below a certain limit (speed is reduced significantly when the draft force reaches about 2.4 kN). It is possible that single animals could poerform the lighter draft operations (such as planting and cultivating) and this would be possible with the use of single yokes (Sims (12) 1985). Such an alternative would only be an advantage if the additional implements and operators were available to use both the animals at the same time.

The animals are allowed to graze at night and during the midday rest period and for this, a piece of rough pasture 0.45 ha in size is reserved on the farm. At times the animals are tethered by the road side to eat whatever grass they can find. Lawrence (5), 1985 suggests that the optimum level of energy expenditure for draft oxen is 1.7 x maintenance and that good quality grass will allow this without body weight loss. However, if the grass is of poor quality, as is the case in Veracruz State during the dry season from November to June, then it is probably better to use both animals together rather than unduly fatigue them by working individually.

What is clear from **Fig. 3** is the scarce use made of the animals from January to May. Without irrigation it is difficult to sow and sustain a crop and, consequently, use the animal power resource (about US$ 1 000 for the pair) which instead of producing is consuming during this period.

A final discussion point arises from the data in **Table 4**. It is arguable that there is a considerable over-use of soil cultivation, especially at the disking stage. A more rational selection of tillage techniques (perhaps with the adoption of no-till corn production and

herbicide use or conservation tillage in other crops) has the potential to reduce energy consumption without reducing yield per hectare, and may allow greater areas to be sown.

Conclusions and Recommendations

The instrument (force transducer, odometer and IDD units) developed in Costa Rica, allowed on-farm measurements of draft bovine speed, draft force, rate of work and energy output to be made in Mexico. These basic data permit preliminary observations to be made on improving draft oxen use and form part of an expanding pool of information, necessary for identifying priority areas for research in draft animal power.

Many low draft force operations (such as planting and cultivating) could probably be performed by single animals rather than the yoked pairs used at present. Work should continue on evaluating harnesses, collars and yokes for single animals for use in these and other tasks.

Soil cultivation practices may often be excessive and the design, modification and evaluation of animal-drawn tillage equipment for reduced, and/or more efficient, soil cultivation is called for.

The use of the instrumentation package evaluated in Mexico is indicated in both these recommended areas of investigation.

REFERENCES

1. Asburner, J.E. and Sims, B.G. 1984. Elementos de diseño del tractor y herramientas de labranza. San José, Costa Rica. IICA p.28-30.
2. Barwell, I and Ayre, M 1982. The harnessing of draught animals. London, Intermediate Technology Development Group. 92p.
3. García, E. 1973. Modificationes al sistema de clasificación de Köppen. México, Universidad Nacional Autónoma de México, p.196-199.
4. Kemp, D.C. 1983. The Nikart: a new animal-drawn implement for cultivation and transport. Appropriate Technology 10(1): 11-13.
5. Lawrence, P.R. 1985. A review of the nutrient requirements of draught oxen. In: J.W. Copland, ed. Draught animal power for production. Proceedings of an international workshop held at James Cook University, Townsville, Qld, Australia 10-16 July, 1985.
6. Lawrence, P.R. and Pearson, R.A. 1985. Factors affecting the measurements of draught force, work output and power of oxen. J. agric. Sci., Camb. 105: 703-714.
7. Moreno Rico, D., and Sims, B.G. 1984. Una rastra de tracción animal. Veracruz, México, Secretaría de Agricultura y Recursos Hidráulicos, Instituto Nacional de Investigaciones Agricolas, Campo Agrícola Experimental Cotaxla. Desplegable informativo núm. 2, 6p.
8. Moreno Rico, D, Sims, B.G., Albarrán Simón, J. 1982. La Multi-barra. Veracruz, México, Secretaría de Agricultura y Recursos Hidráulicos, Instituto Nacional de Investigaciones Agricolas, Campo Agricola Experimental Cotaxtla. Desplegable informativo 1, 6p.
9. Olmstead, A.L. Johnston, B.F., Sims, B.G. 1986. Forward to the past: the diffusion of animal powered tillage equipment on small farmers in Mexico. Agricultural History (University of California) 60(1): 62-72.
10. Ramaswamy, N.S. 1981. Report on draught animal power as a source of renewable energy. Rome, FAO, 164p.
11. RNAM (Regional Network for Agricultural Machinery) 1983. RNAM test codes and procedures for farm machinery. Philippines, RNAM, Technical series 12p.23.
12. Sims, B.G. 1985. Recherche et developpement en traction animale dans l'etat de Veracruz (Mexique). Machinisme Agricole Tropical (France) No.91 September 1985. p.36-41.
13. Sims, B.G., Moreno Rico, D., Albarrán Simón, J. 1984. Conceptos y prácticas de cero labranza con maiz para el pequeño agricultor. Veracruz, México. Secretaría de Agricultura y Recursos Hidráulicos, Instituto Nacional de Investigaciones Agrícolas, Campo Agrícola Experimental Cotaxtla. Folleto técnico 1, p.4.
14. Sims, B.G., Moreno Rico, D., Albarrán Simon, J. 1985. El Yunticultor, equipo y uso. Veracruz, Mexico, Secretaria de Agricultura y Recursos Hidraulicos, Instituto Nacional de Investigaciones Agricolas, Campo Agricola Experimental Cotaxtla. Folleto miscelaneo 1, April 1985, p.3.
15. Sims, B.G. et Jácome Maldonado, S. 1987. Estimation du poids des bovins de trait au Mexique. Machinisme Agricole Tropical (France) No.98 April-June 1987. p.71-74.
16. Smith, A.J. 1981. The role of draught animals in agricultural systems in developing countries. In: vegetable productivity (ed. C.R.W. Spedding), pp.247-262. London, Macmillan. ■■

Development of Tractor-operated Hoist for Fruit Harvesting

by
A. Tajuddin
Asst. Prof
Dept. of Farm Machinery
College of Agric. Engg.
Tamil Nadu Agric. Univ.
Coimbatore-641003, India

K.R. Swaminathan
Prof and Head
Dept. of Farm Machinery
College of Agric. Engg.
Tamil Nadu Agric. Univ.
Coimbatore-641003, India

Abstract

A tractor-operated hoist for fruit harvesting by means of which one can easily reach a height of 7 m from ground level has been developed. The platform was first rigidly fitted to the main beam. Later the platform was hinged to the main beam incorporating four-bar linkage mechanism in order to keep the platform horizontal during both lifting and lowering operations. The hoist can be effectively used for both fruit harvesting and allied operations. The tractor attachment costs only U.S. $200.

Introduction

Pole-and hand-harvesting of fruits is still in practice in most of the developing countries. Fruits get damaged when plucked by this method, making almost half of the harvested fruits unmarketable (Sahu et al, 1985). Fifty per cent of the labour engaged in fruit production is used in pole-and hand-harvesting of fruits (Brown et al, 1983). The cost of mechanical fruit harvesting machine is usually high. Therefore, a low-cost hoist has been developed as a tractor attachment.

Materials and Methods

The tractor-operated hoist consists of a main beam (A) hinged to the tractor upper hitch point (Fig. 1). The main beam is supported by the lower links of the tractor through a drawbar and strut assembly (B). The length of the main beam was determined by taking into account the self-weight of the tractor, location of centre of gravity of the tractor and the gross load of the hoist attachment.

The cross sections of the main beam and other components of the hoist were determined for structural safety considering the axial loads acting on the individual members (Rajkumar et al, 1986). A 900 x 900 mm size platform (C) was rigidly fitted to the free end of main beam at a graphically determined angle of 60° with the main beam in order to keep the platform horizontal at the raised position. To facilitate the use of platform during operation, a staircase with two steps having different inclinations (D) was rigidly fitted to the platform. The operator has to stand on the first step which is parallel to the ground at the lowered position of the hoist. Half-way during lifting he moves to the second step and when the platform reaches the top, he will move to the platform which will become

Fig. 1 Tractor-operated hoist with fixed platform in lowered position.

Fig. 2 Tractor-operated hoist with fixed platform in raised position.

Fig. 3 Tractor-operated hoist with hinged platform in four-bar linkage mechanism.

horizontal (Fig. 2). However, this arrangement requires more skill on the part of the operator and it is highly susceptible to fatal accidents.

Therefore, a four-bar linkage mechanism was incorporated in the unit (Fig. 3). The tractor chassis acts as the fixed link. The main beam, platform and an additional beam (E) act as the other three hinged linkage, the opposite links being equal in length. The platform will move approximately in a vertical line due to a higher ratio of lengths of the adjacent links. The additional beam is hinged between a rectangular frame (F) which is rigidly fitted to the tractor chassis and the vertical support of the platform. The platform was made to 1300 x 500 mm rectangular size so that the operator can reach maximum offset distances on either side of the tractor. The platform was provided with suitable enclosures for ensuring convenience and safety of the operator during operation (Fig. 4). Additional reinforcements were given to the main beam to avoid bending.

Fig. 4 Tractor-operated hoist in harvesting sapota fruits.

Resutls and Discussion

The tractor-operated hoist was tested for harvesting sapota, mango and breadfruit tree crops and it was found suitable for harvesting such fruits. The maximum height of reach by the operator standing on the platform was 7 m from ground level. The extreme branches of fruit trees, especially those with thorns, could be easily reached by the hoist, which is practically not possible in the pole-and hand-harvesting process. At the same time, there was no damage to the plucked fruits. The hoist was also tested for harvesting coconut (tall x dwarf varieties) and found to be equally suitable.

Apart from harvesting fruits and coconut, the hoist could be used for the following operations within the operating height of the unit: a) operation like lopping, pruning and spraying around the canopy of tree crops which are not performed due to lack of suitable machinery; b) repair and maintenance works of buildings such as plastering, ceiling works, and electrical works; and c) maintenance works of telegraphic lines. The hoist weighs 155 kg and costs US $200.

Conclusions

The tractor-operated hoist will be a useful attachment for tractors due to its many uses in and around the farm. The operational height of the hoist may be increased by suitably increasing the length of beams. Front wheel weight may be added for balancing if necessary. Telescopic arrangement may be incorporated in the unit so that the overall length of the hoist can be shortened for better mobility during transit. There is scope for using the hoist in maintenance work of electrical over-head lines also.

REFERENCES

1. Sahu, S.D., M.D. Singh, and Manjit Singh. 1985. Fruit harvesting in Hilly Region. Agricultural Engineering Today, 9(1):9.
2. Brown, G.K. et al. 1983. Status of harvest mechanisation of horticultural crops. American Society of Agricultural Engineers Special Publication, 3:78.
3. Barger, E.L., Carleton, W.M., McKibben, E.G. and Roy Bainer. 1958. Tractors and their Power Units. John Willey and Sons, New York.
4. Rajkumar, D., Ramasubramanian, T. and Renuga Devi, S. 1986. Design Development and Testing Unpublished B.E. (Ag.) Project Work, Department of Farm Machinery, College of Agricultural Engineering, Tamil Nadu Agricultural University, Coimbatore.
5. Guide for Estimating Cost of Farm Machinery Operations. IS: 9164-1979. Indian Standards Institution, New Delhi. ■■

Grain Losses of Various Wheat Varieties Harvested by Power Reaper

by
Sheruddin Bukhari
Assoc. Prof.
Farm Power and Machinery
Sind Agric. Univ.
Tandojam, Pakistan

Khalil Ahmed Ibupoto
Lecturer
Farm Buildings and Structures
Sind Agric. University
Tandojam, Pakistan

Ghulam Hyder Jamro
Asst. Prof.
Dept. of Agronomy
Sind Agric. Univ.
Tandojam, Pakistan

Mohammad Zafrullah
Asst. Agric. Engineer
FMI Testing Sub-Station
Sind Agric. Univ.
Tandojam, Pakistan

Abstract

Grain losses of various wheat varieties harvested by Kubota power reaper AR-120 was investigated at Latif Experimental Farm, Sind Agriculture University, Tandojam in 1986.

Many of the varieties did not show any significant responses on plant height, tillers/plant, spikes/plant and spikes/square meter. On the contrary, the genotypes showed highly significant (P 0.01) response for grain yield and straw yield. However, the varieties Pavan and Sarsabz gave better yield relative to other varieties.

Grain losses differed greatly in shattering loss, cutter bar loss and conveying loss. The cutter bar loss was maximum in all varieties and loss was minimum for Pavon and Sarsabz (among the early and late varieties).

Introduction

Wheat (*Triticum aestivum* L.) is an important food crop and is the staple for the majority of the world's population. The crop is cultivated in all four provinces of Pakistan but its production on commercial scale is largely carried out in the provinces of Sind and Punjab.

Pakistani farmers find it difficult to get adequate labour for harvesting the crop. Late harvesting of crop results in considerable grain losses. Iqbal (1980) concluded that the grain losses increased as the harvesting was delayed after the ripening of the crop and losses increased linearly with time after ripening of crop, i.e., from 3% in first week, to 7% in third week. Further, he reported that the cost of mechanical harvesting was half that of the conventional harvesting using manual labour. Brown and Vasey (1967) observed that the average total machine loss, excluding shatter loss, was 3.4% of the yield of standing wheat crop. The average shatter, comb and rear losses were 2, 1.5, 4%, respectively. The total average machine loss was 1.5 bushels per acre. The average shatter, comb and rear grain losses in bushels per acre were 0.5, 0.4 and 0.4 to 1, respectively. Zafarullah (1985) found that the total machine grain losses were 1.1% and for manual harvesting with sickle the losses were 2.1%. He also found that machine harvesting needed only 6.7 ha man hours per ha compared with 98.5 man hours per ha for manual harvesting.

The traditional method of harvesting wheat crop by the use of sickle is uneconomical, time consuming and labourious. Keeping in view the introduction and development of mechanical harvesting machines, the reaper is one of the most efficient machines to harvest and windrow the crop, save cost, time and to minimize grain losses.

The object of the study was to identify losses in harvesting and of various wheat varieties with the use of the reaper.

Materials and Methods

The experiment was carried out to evaluate wheat grain losses at Latif Experimental Farm, Sind

Table 1 Mean Squares for Various Quantitative Characteristics of Various Wheat Varieties Harvested by Reaper

Source of variation	D.F.	Plant height	Tillings per plant	Spikes per plant	Spikes m^2	Grain yield kg/ha	Straw yield kg/ha
Replications	3	18.89^{NS}	2.70^{NS}	2.70^{NS}	$18\,212.83^{NS}$	$2\,309\,280^{**}$	$879\,500^{**}$
Varieties	4	–	–	–	–	–	–
Error	12	–	–	–	–	–	–
Total	19	–	–	–	–	–	–

NS = Non-significant. ** = Significant at 1% level.

Table 2 Mean Squares for Various Grain Losses of Various Wheat Varieties Harvested by Reper

Source of variation	D.F.	Shattering loss (kg/ha)	Cutter bar loss (kg/ha)	Conveying loss (kg/ha)
Replications	3	4.028^{**}	$1\,870.19^{**}$	7.785^{**}
Varieties	4	–	–	–
Error	12	–	–	–
Total	19	–	–	–

** = Significant at 1% level.

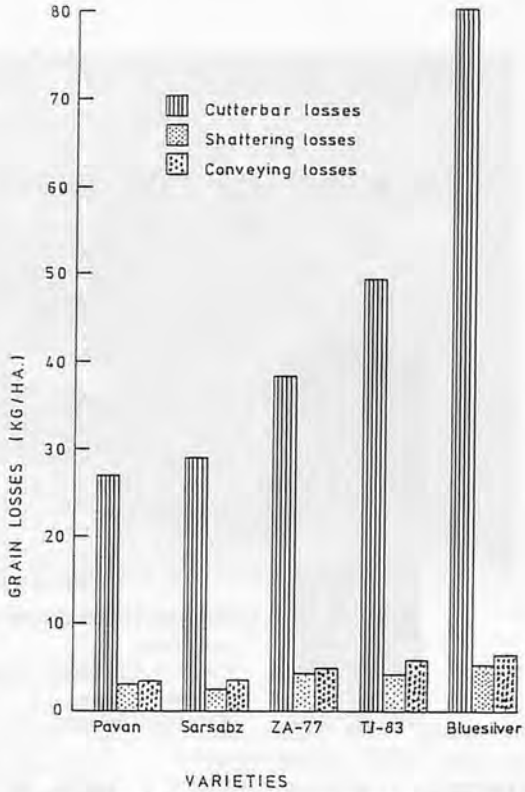


Fig. 1 Grain losses for different wheat varieties.

Agriculture University, Tandojam on March 12, 1986 using a randomized block design with four replications and five treatments (wheat varieties), i.e., Pavon, Sarsabz, ZA-77, TJ-83 and Blue Silver. Each plot size was 12 m x 6 m. Drilling was done using the single coulter rabi drill with 12 cm row to row distance. Full dose of phosphatic fertilizer was applied before drilling. Nitrogenous fertilizer was applied in two split doses, one at first irrigation and second at third irrigation.

Agronomical observations such as plant height, tillers, spikes were recorded on five plant basis from each treatment at random. For grain yield and straw yield, crop samples were taken from three randomly selected spots of 1 m^2 each. Shattering losses were observed by counting grains and earheads fallen on the ground after reaping. Cutter bar loss was determined after reaping by placing 1 m^2 frame at three randomly selected locations for each variety. The conveying loss was found by placing a polythene sheet (15 m long) along the side of the wheat to be harvested. After reaping the crop, the windrowed grains on the sheet were taken away and the fallen grains were collected/weighed from 1 m^2 area from three randomly selected places for each wheat variety.

Results and Discussion

Table 1 indicates that plant height, tillers/plant and spikes/plant did not show any significant difference among themselves within different genotypes. The highly significant (P 0.01) response for grain and straw yield among the wheat varieties could be due to the total grain losses and varietal traits.

Table 2 and **Fig. 1** indicate the various grain loss diffrences. Maximum grain losses were recorded in late variety Blue Silver followed by late variety TJ-83. The minimum grain losses were observed for the early variety Pavon and Sarsabz followed by early variety ZA-77. The cutter bar loss was observed highest (**Fig. 1**) followed by conveying loss and shattering loss for all varieties which was also observed by Hunt (1979) while reviewing the work of Huber and White.

REFERENCES

1. Brown, W.T. and G.H. Vassy (1967). Wheat harvest survey. Univ. of Melbourne, Dept. of Agri. Enging. 1-103.
2. Iqbal, M., G.S. Shaikh and J.K. Sial (1980). Harvesting and threshing losses of wheat with mechanical and conventional methods. AMA. Japan 11(3): 66-70.
3. Mohammed Zafarullah (1985). Feasibility report of Kubota power reaper AR-120. Test report FMI/TSQ-2/85 Agricultural Farm Machinery Institute Testing Sub-Station, Agricultural Engineering Department, Quetta, Baluchistan, Pakistan.
4. Hunt, D. (1977). Farm Power and Machinery Management Laboratory Manual and Work Book. 7th Ed. Iowa State Univ. Press, Ames, Iowa. 1-365. ■■

Predicting Dryer Performance Using Similitude Analysis

by
S. Sokhansanj
Assoc. Prof.
Dept. of Agric. Engg.
University of Saskatchewan
Saskatoon, Saskachewan
Canada S7N OWO

D.S. Jayas
Asst. Prof.
Dept. of Agric. Engg.
University of Manitoba
Winnipeg, Manitoba
Canada R3T 2N2

J.D. Wasserman
Project Engineer
Agric. Machinery Inst.
Humboldt, Saskachewan
Canada SOK 2AO

Abstract

A simple relationship based on the principles of dimensional analysis was developed to predict fuel consumption per unit capacity of a dryer. The relationship was developed from data obtained during full scale drying tests for three types of grain (wheat, barley and corn) and rapeseed (one type of oilseed, canola) in two different makes of grain dryers (mixed air flow type and cross flow air recirculating type). Grain's ability to lose moisture was taken as a partinent variable to incorporate different grains. Humidity ratio of drying air was used to incorporate two types of dryers. An excellent correlation coefficient showed that with one empirical model the performance of a dryer can be predicted under varying drying conditions.

Introduction

In field testing of commercial grain dryers only a few variables can be adjusted and maintained constant. Initial moisture content of the grain, the drying air temperature, and the grain flow rate are among the variables that can be controlled. Ambient and grain temperatures, airflow rates, and drying characteristics of a particular grain are variables that often cannot be adjusted. However, these variables have a significant effect on drying and the dryer performance. Tests with scale models under laboratory controlled conditions are required in order to account for these variables when the results of the in-field tests are being presented in the form of generalized dryer performance. For example, a thin layer drying test reveals the differences between the drying characteristics of individual types or hybrids within a type of grain. A test on a thick layer of grain could be used to determine the pressure drop/airflow characteristics, or the effects of foreign materials on the airflow distribution. Yet there are so many peculiarities to each commercial dryer that a full performance cannot be predicted by analytical models or laboratory simulations alone. A functional relationship must be devised to relate the performance of a dryer to the controllable variables. The parameters of these relationships can then be found from the experimental data. The estimated parameters represent the variables that have not been included directly in the development of the model.

The purpose of this study was to formulate an empirical model based on similitude analysis and on full scale drying tests to predict dryer performance (fuel consumption per unit throughput) in general terms.

Dimensional Analysis

Similitude Analysis

Similitude or dimensional analysis can be used to perform the selection, combination, and analysis of variables of a drying test. Similitude analysis has been applied to grain drying by Nelson (1960), and Chien and Mathes (1971). These researchers applied the principles of similitude to study fixed bed dryers under laboratory conditions.

The similitude analysis is performed by formation of a functional or mathematical model which describes the relationship among the physical variables of the system. The physical variables are grouped such that each group becomes dimensionless. These groups are formed on the basis of dimensional homogeneity of any general prediction/functional relationship. Each one of these groups is called a "pi" term. The minimum number of independent "pi" terms is equal to the difference between the number of variables and the number of

Acknowledgements: The financial assistance from the Prairie Agricultural Machinery Institute, Humbolt, and Agriculture Canada is gratefully acknowledged.

fundamental dimensions (i.e., Length(L), Mass(M), Temperature (T), and Time(t)) required to dimensionally define the variables.

The following steps are followed to complete the dimensional analysis:

1. Selection of pertinent variables affecting the phenomenon under consideration, based on knowledge and understanding of the system;
2. Combination of the pertinent variables into an appropriate set of dimensionless parameters, the "pi" terms; and
3. Determination of the functional relationship among the "pi" terms by analysis of the results of the experiments.

Table 1 List of Variables that Control Throughput of a Grain Dryer

Variables	Symbol	Unit	Dimension*
Variables that can be controlled in the field:			
Final moisture	Mf	kg/kg	–
Grain flow rate	Gp	kg/h	$M\ t^{-1}$
Fuel consumption	Fc	kg/h	$M\ t^{-1}$
Drying temperature	Td	K	T
Humidity ratio**	Hr	kg/kg	–
Additional variables that may be controlled in the laboratory experiment:			
Ambient air temperature (abs)	Ta	K	T
Airflow rate	Ga	kg/h	$M\ t^{-1}$
Static pressure	Sp	Pa	$M\ L^{-1}\ t^{-2}$
Atmospheric pressure	Ap	Pa	$M\ L^{-1}\ t^{-2}$
Grain parameter	k1	–	–
Dryer parameter	k2	–	–
Foreign materials	FM	kg/kg	–
Humidity ratio	Hr	kg/kg	–
Grain mass	Gm	kg	M
Initial moisture	Mi	kg/kg	–

*M is the dimension of mass, L is the dimension of length, T is the dimension of temperature, and t is the dimension of time.
**In recirculating grain dryers the humidity ratio of the drying air can be controlled by adjusting the recirculation rate.

Selection of Pertinent Variables

Bakker-Arkema et al (1973) proposed 14 controllable variables as inputs to a simulation program in order to evaluate the performance of a dryer. Nelson (1960) listed 26 variables for a fixed bed dryer which included the physical and thermal properties of grain and air, and the characteristics of the dryer such as bed thickness. However, he used only 13 variables in the formation of the "pi" terms.

A list of the pertinent variables used in this study for the analysis of grain dryers is given in **Table 1**. The variables are listed in two groups; those that can normally be controlled or adjusted in the field, and those that can be adjusted under laboratory controlled conditions. Some variables may be varied both in the field and in the laboratory. Humidity ratio of the drying air in recirculating air dryers and the foreign materials in the grain are two such examples.

Two variables, the grain factor (k1), and the dryer factor (k2), represent parameters related to the grain and to the dryer, respectively. The grain parameter k1 may represent a relative drying rate of a grain type compared to other types. Some other variables such as airflow pressure drop characteristic could also be used to characterize different grains. The dryer parameter k2 represents a specific identifiable characteristic of the dryer that can be presented by a measured quantity. The humidity ratio of drying air has been used to characterize the different dryers. This represents the recirculation of the exhaust air in percent.

Dimensionless Groups

The dimensionless terms selected as being pertinent to the present study were developed according to the method outlined by Murphy (1950) and are given in **Table 2**. The performance of the dryer is represented by the ratio of units of fuel consumed per unit of throughput capacity in terms of kg/h of dried grain at the final moisture content. The final moisture content has been chosen as an independent variable because its control and uniformity is the major goal of the drying process.

Functional Relationship

To study the performance of two full-sized continuous grain dryers (mixed flow type and recirculating air type) used to dry wheat, barley, corn and canola, the following functional relationships were fitted to the test data:

a. Drying a particular grain type in a certain dryer the fuel consumption per unit throughput of which is described by:

$$Fc/Gp = c1\,(dM/Mf)^{a1}\,(dT/Ta)^{a2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Table 2 Dimensionless Groups Formed from List of Variable in Table 1

Group	Description
Fc/Gp	Fuel consumption per unit of throughput*.
dM/Mf	Points moisture removed per final moisture content.
dT/Ta	Temperature rise over the ambient air temperature.
k1	Grain drying characteristics of a particular grain.
k2 (Hr)	Dryer characteristics (humidity ratio).
Sp/Ap	Pressure ratio of the pressure in the dryer and of the atmosphere.

$dM = M_i - M_f$ and $dT = T_d - T_a$; *Throughput is grain flow rate at Mf, kg/h.

b. Drying all four types of grains in a certain dryer the fuel consumption per unit throughput of which is described by:

$$Fc/Gp = c1(dM/Mf)^{a1}(dT/Ta)^{a2}(k1)^{a3} \quad \ldots\ldots\ldots (2)$$

c. Drying all four types of grains in two commercial dryers the fuel consumption per unit throughput of which is described by:

$$Fc/Gp = c1(dM/Mf)^{a1}(dT/Ta)^{a2}(k1)^{a3}(Hr)^{a4} \quad \ldots (3)$$

The dimensionless group (Sp/Ap) of **Table 2** can be introduced into equation (2). However, due to difficulty in obtaining data on airflow and/or static pressure, on the farm, this was not used.

The values of coefficients c and a with their respective subscripts can be different in each equation and are estimated using experimental data.

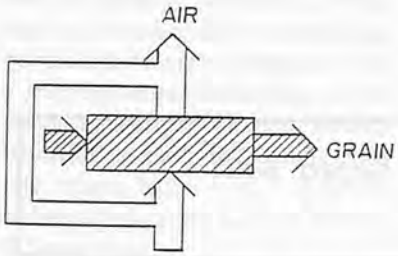


Fig. 1 Recirculating air cross-flow dryer.

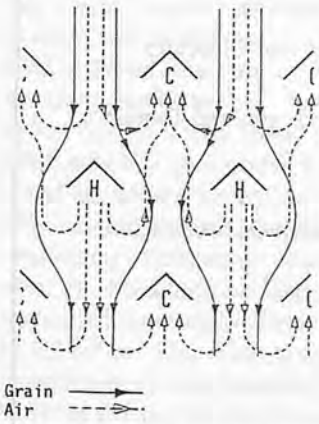


Fig. 2 Mixed-flow dryer.

Drying Tests

During the summer and fall of 1981 two continuous flow commercial grain dryers were tested. One of the grain dryers was a cross-flow recirculating air type and the other was a mixed-flow type. The pattern of airflow for both dryers is shown schematically in **Figs. 1** and 2. Three grains (wheat, barley and corn) and one oilseed (canola) were dried. Several initial moisture contents were obtained by adding water to the dry grain. The wetted grain was conditioned in large steel bins equipped with stirrers. The dryers were operated according to the manufacturer's recommendations. The details of dryers, testing methods, conditions and test results have been published elsewhere (PAMI, 1982a and 1982b).

Results and Discussions

A multiple regression analysis program (MULTG, Hewlett-Packard Co., Cupertino, CA 95014) was used for the statistical analysis. **Table 4** contains a list of values of the parameters estimated by fitting equations (1)-(3) to the data. The dryer types S (cross-flow recirculating air type) and V (mixed-flow type), the grain types and the total number of the sample size are also shown in **Table 4**. The zero value of a constant means that the pertinent "pi" term was not included in the parameter estimation. The "pi" terms were introduced in the equation step-by-step to evaluate any improvement or change in the multiple regression coefficient (R). For example, k1 data from **Table 3** was included in run numbers 6 and 12; and k2 (humidity ratio in this work) was included in run number 15. The term "run number" means the regression analysis run.

The "fit" for a particular grain and for a certain dryer was generally good (runs 1 to 4 and 7 to 10). Except for run number 4, the remaining regression coefficients (R)

Table 3 Factors Indicating Average Ability to Release Moisture in Drying, Relative to Wheat under Similar Conditions

Grain	k1
Wheat	1.0
Barley	0.9
Corn	0.6 – 1.0
Rapessed (canola)	11.0

Source: Kreyger 1972.

Table 4 Estimated Values of Constants of Equations 1-3

Run No.*	Description of the run	Estimated constants					R**	Sample size
		c1	a1	a2	a3	a4		
1	V wheat	1 056.80	0.915	2.606	0	0	0.99	5
2	V barley	47.66	0.743	0.802	0	0	0.97	10
3	V corn	6.68	0.611	−0.989	0	0	0.99	5
4	V canola	36.23	0.798	0.821	0	0	0.92	10
5	V all crops	61.93	0.776	1.044	0	0	0.92	30
6	V all crops	54.98	0.797	0.856	−0.155	0	0.98	30
7	S wheat	1.71	0.807	−0.159	0	0	0.98	8
8	S barley	5.07	0.729	−0.414	0	0	0.99	7
9	S corn	0.21	0.563	−4.385	0	0	0.99	6
10	S canola	20.31	0.739	0.623	0	0	0.99	8
11	S all crops	37.26	0.806	0.893	0	0	0.91	29
12	S all crops	33.21	0.823	0.785	−0.043	0	0.97	29
13	All crops and dryers S & V	53.68	0.780	1.048	0	0	0.92	59
14	All crops and dryers S & V	42.06	0.804	0.823	−0.085	0	0.91	59
15	All crops and dryers S & V	10.75	0.842	0.502	−0.187	−0.235	0.97	59

V – Mixed flow dryer. S – Cross flow air recirculating dryer. *Run No. means regression analysis run. **Correlation coefficient.

were more than 0.97. The regression analysis was extended to include all samples of four crops that were dried in a particular dryer. For the mixed-flow dryer, R was 0.92 (run 5), and for the cross flow air recirculating dryer it was 0.91 (run 11). The R values in both cases were improved when k1 was included in the estimation (runs 6 and 12). The data for k1 were the relative ability to each grain type to release moisture with respect to wheat's ability. Kreyger (1972) listed these relative values for several grains. His data are reproduced in **Table 3**. Kreyger cautioned against any generalizations based on these data. Nevertheless his data was used by the authors as a result of which the prediction equations were improved substantially. Comparing run 5 with run 6 and run 11 with run 12, it is observed that the R values have improved from 0.92 to 0.98 and from 0.91 to 0.97, respectively.

The last three regression analyses of **Table 4** (runs 13, 14 and 15) show that despite substantial differences between two dryers, the regression equation (3) can be used to estimate the dryer performance. The value of R was consistently improved as a result of the inclusion of the relative drying factor k1, and the humidity ratio (Hr) in the equation. We close humidity ratio (Hr) of drying air as it entered into the dryer as a main operational difference between the two dryers. As mentioned earlier, other factors that identify a dryer more specifically may be considered as well.

Figures 1 and 2 represent schematic diagrams of the pattern of grain and air flow in dryers.

Conclusions

The simple model developed can be used to predict dryer performance for several grains and dryers if parameters differentiating grains and dryers are included in the model.

REFERENCES

Bakker-Arkema, F.W., S.F. DeBoer, L.E. Lerew and M.G. Roth. 1973. Energy conservation in grain dryers: I. Performance evaluations. Paper No. 73-324. Am. Soc. Agric. Eng., St. Joseph, MI.

Chien, K.S. and R.K. Mathes. 1971. Dimensional analysis of seed moisture movement in deep bed drying. Trans ASAE, 14(2): 277-281.

Kreyger, J. 1972. Drying and storing grains, seeds and pulses in temperature climates. Inst. Stor. Proc. Agric. Prod. Wageningen, The Netherlands.

Murphy, G. 1950. Similitude in engineering. Ronald Press Co., NY.

Nelson, G.L. 1960. A new analysis of batch grain dryer performance. Trans ASAE, 3(2): 81-85, 88.

PAMI. 1982a. SUPERB S500C Grain Dryer. Evaluation Report 290. Prairie Agricultural Machinery Institute, Humboldt, Saskatchewan, Canada.

PAMI. 1982b. VERTEC VT 5600 R Grain Dryer. Evaluation Report 289. Prairie Agricultural Machinery Institute, Humboldt, Saskatchewan, Canada. ■■

Is your Agricultural Machinery Industry faced with problems of development and growth?

We can provide you with know-how to help your company and industry develop and grow.

Specific Information Service.

Statistics, Product Information, Patents, Test & Research Data, References and Directory.

Survey & Research.

Marketing Research, Forecasting on Economic, Technical, Supply, Demand, etc. and Dealer Search.

Consultation.

Policy Making, Management Improvement, New Development of Organizations, Motivation.

Publication Activities.

Basic, Production and Sales Statistics for Agricultural Machinery, etc.

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

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

An Ambient-air In-storage Paddy Drying System for Korean Farms

by
K.S. Kim
Korea Advanced Institute
for Scienced and Technology (KAIST)
P.O.Box 131, Cheongryang
Seoul, Korea

M.G. Shin
KAIST
P.O.Box 131, Cheongryang
Seoul, Korea

B.C. Kim
Pusan National Univ.
30 Jang Jung-Dong, Dong Lae-Ku,
Pusan, Korea

J.H. Rhim
KAIST
P.O.Box 131, Cheongryang
Seoul, Korea

H.S. Cheigh
Professor.
Pusan National Univ.
30 Jang Jung-Dong, Dong Lae-Ku,
Pusan, Korea

W. Mühlbauer
Professor
Institute for Agric. Engg.
Hohenheim University
Stuttgart, West Germany

T.W. Kwon
KAIST
P.O.Box 131, Cheongryang
Seoul, Korea

Abstract

An ambient-air in-storage paddy drying system for small scale Korean farms was developed and tested. This dryer consists of a rectangular container, an air distribution system and a centrifugal fan. The system can be incorporated into either new or existing structures. When drying is finished the container can be used for storage purposes or as a machine shed. Depending on the dimensions of the container and the depth of the bulk, the loading capacity ranges from 3 to 5 t, which allowes application to farm sizes of 0.5 to 1.0 ha.

The dryer can be constructed by the farmers themselves or by craftsmen using locally available materials. Tests carried out in 1981 to 1985 showed that under Korean weather conditions, a layer of paddy 0.9 to 1.2 m thick can be dried within 7 to 15 days from an initial moisture content of up to 25% to safe storage conditions by continuous ventilation with ambient air. No additional heat source is required. Low airflow rates of 3.1 to 6.0 m^3/m^3-min result in a power requirement of approximately 400 Watt for driving the fan. In relation to the savings in labour and the reduced mass losses, the energy costs are negligible. Compared with traditional sun-drying methods the product quality is significantly better.

Introduction

The shortage of farm labour has become a serious problem for Korean agriculture in the last few decades. Especially during transplanting, harvesting and post-harvest operations there is a great lack of farm labour which gives mechanization a high priority.

Despite of the introduction of a number of reaper binders and combine harvesters the greater part of the paddy is still harvested manually using sickles. Traditionally, the cut plants are spread out evenly in the field or bundled and stocked for natural drying. This method, however requires high labour input, causes mass losses and also lowers the quality of the paddy.

After heavy rainfalls many fields are flooded and any plants or bundles which cannot be hung on trees or ridges or which cannot be transported to drained areas may be spoiled. Furthermore, drying and rewetting cycles can cause breakage during milling. In addition, the introduction of high yielding varieties confronted farmers with shattering losses due to the non-uniform ripening of the kernels.

In order to prevent mass losses which occur during harvesting and post-harvesting operations and to improve the quality of the paddy, the farmers were forced to thresh the paddy with moisture content of 22 to 25%. Because of the lack of adequate drying methods the farmers still spread out the threshed paddy on straw mats or on paved areas. But this natural sun drying method also requires high labour inputs and leads to additional mass losses.

In order to overcome the existing shortage of farm labour during the harvesting period, the introduction of drying systems which can be economically adopted on Korean farms is an urgent necessity. Studies have shown that high-temperature dryers cannot be applied economically due to their high capital cost and the need for imported fossil fuels for heating the drying air (1). Investigations carried out at the Korea Advanced Institute for Science and Tech-

nology (KAIST), Seoul (2, 3) indicated that low-temperature in-storage drying seems to be the most promising on-farm drying method under Korean conditions. Low investment cost, independence of imported fuels, low labour requirements and better product quality are in favour of this method (3). However, round metal bins with perforated false floors which are the commonly used system for low-temperature drying in industrialized agricultural production (4) are not suitable for use on small-scale Korean farms. The capacity of even the smallest units available on the market is far too great. Furthermore, loading and unloading requires expensive conveyor systems.

As part of the technical cooperation between the Federal Republic of Germany and the Republic of Korea, an in-storage drying system for paddy has been developed and tested. The newly developed system is described below.

Objectives

The general objective of the investigation is the development and testing of an ambient-air in-storage drying system for paddy which can be used on small-scale Korean farms. The specific objectives are:

- Design of a simple dryer for paddy which can be constructed by the farmers themselves, craftsmen or small scale industries using low cost materials which are locally available.
- Protection of the crop during drying and storage from insects, rodents and birds, as well as from water penetration through floor and walls.
- Determination of the influence of weather conditions and drying parameters on drying time, energy consumption, uniformity of moisture content and product quality.
- Economic evaluation of the drying systems with respect to investment and operation costs, labour requirements, losses, and quality of the dried product.

Equipment

The major components of the newly-developed drying system are the rectangular container, air distribution system and the centrifugal fan as shown in **Fig. 1**. The dryer can be incorporated into either new or existing structures and can be used not only for drying, but also for storage purposes. The standard version of the container is 2.4 m in length, 1.8 m in width and can be loaded up to a depth of 1.2 m. Depending on the bulk depth, the loading capacity ranges from 1.5 to 3 t.

The air distribution system consists of a rectangular main duct and V-shaped lateral ducts as shown in **Fig. 2**. The ducts can be constructed either from plywood or from galvanized metal sheet. To achieve the desired uniform air distribution, the distances between the lateral ducts should not exceed 0.4 m and the openings between the lateral ducts and the floor should be a minimum of 0.02 m. The air duct system can easily be removed. The container can then be used for storing equipment once the crop has been sold.

A 0.4-kW motor is required to drive the fan in order to force 3.1 to 6.0 m^3 air per m^3 grain per min through the bulk. To make optimum use of the solar radiation it is

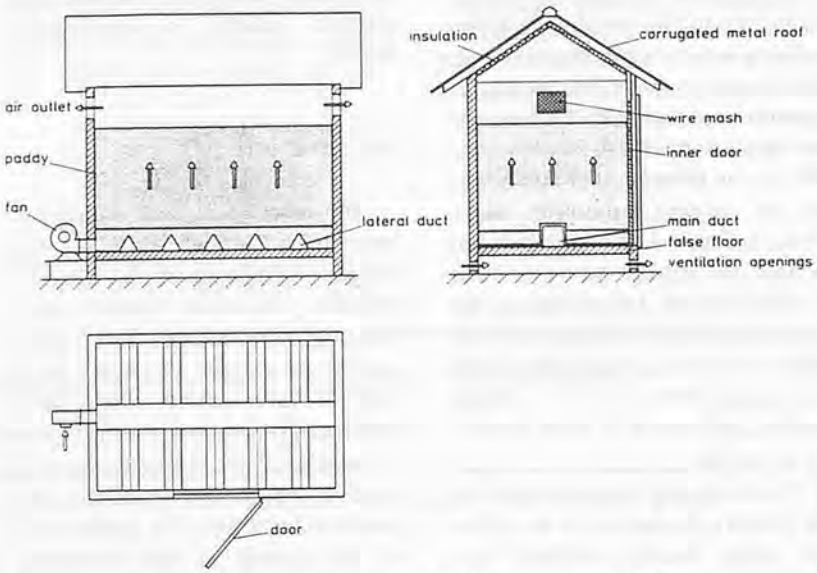


Fig. 1 Ambient-air in-storage drying system for paddy.

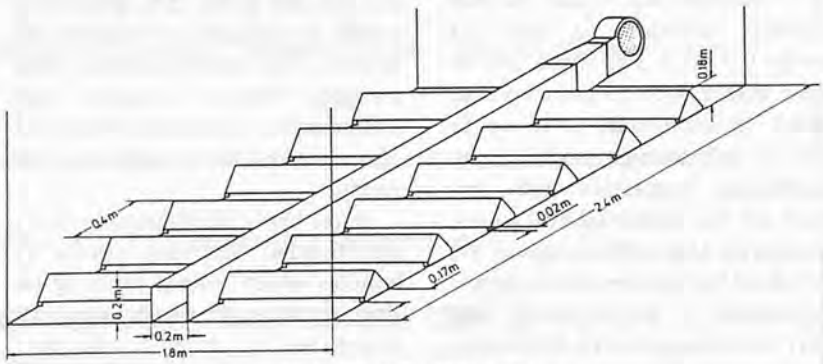


Fig. 2 Air distribution system.

recommended that the fan be installed at the south side of the structure. To prevent recirculation of the almost saturated exhaust air, the air outlets should be located on the opposite side of the structure.

A housing protects the fan from rain and allows the waste heat from the electric motor to be used to pre-heat the drying air slightly.

The walls of the rectangular structure and the false floor can be built of concrete or cement blocks. To prevent water penetration the insides of the walls and of the false floor have to be coated with waterproof material. The V-shaped roof consists of corrugated steel which is insulated with styrofoam. This prevents the condensation of water when the temperature drops below the dewpoint.

Openings in the walls allow natural ventilation of the space below the false floor and above the grain surface. To prevent insects, birds and rodents from getting into the structure, all openings are covered with wire mesh.

For loading and unloading purposes, a double door is installed. The inner door consists of several boards which can be added or removed one at a time. This makes loading and unloading easier. The outer door protects the crop from rain and theft.

Instrumentation

The water removed during the drying process was determined by weighing the wet and dried paddy. The average initial and final moisture contents of the paddy before and after drying were determined by means of samples taken daily by a double concentric tube sampling device from a total of six positions at the bottom, in the middle and on top of the bulk. The changes in moisture content and quality of the paddy in relation to bulk depth and drying time were determined. The moisture content of the kernels was ascertained by the oven method. Temperature and relative humidity of the ambient and the exhaust air were measured and recorded continuously by hygrothermographs.

The air distribution over the cross section of the dryer was measured by an integrating airflow meter, the pressure drop in the bulk by a manometer. For the determination of the airflow rate a nozzle was installed at the air inlet of the fan. The airflow rate can be calculated from the pressure drop in the nozzle and the density of the air.

In order to investigate the influence of the drying process on the quality characteristics of the paddy, a control sample was taken of the wet paddy and dried at a temperature of approximately 20°C which ensures that no change in quality can occur.

The milling properties such as dehulling and milling rate and the cracking ratio, were ascertained by the methods outlined in the Agricultural Product Inspection Manual (5). Paddy acid value was determined by the AACC method (6). The quality of the dried paddy was evaluated in accordance with the Korean quality standards (5).

Materials and Drying Procedure

Drying experiments were carried out in 1981 and 1982 with the high yielding variety 'Milyang 30', and in 1983 and 1985 with the traditional variety 'Akibare'. The paddy was harvested by combine harvesters, had moisture contents ranging from 17.2 to 24.0%. After pre-cleaning the paddy was transported in bags to the experimental site and loaded manually into the dryer. Before starting ventilation the surface of the bulk was levelled. The crop was continuously ventilated except on rainy days until the moisture content of the top layer reached 15% w.b.

In order to determine the optimum operating condition in terms of capacity and energy consumption the loading capacity was increased from 2.5 t to 3.0 t and simultaneously the airflow rate was reduced from 6.0 to 3.1 m^3 air per m^3 grain per min.

Results and Discussion

The results of the drying tests conducted in 1981 to 1985 with the ambient-air in-storage drying system are described and discussed below. The most important data are summarized in **Table 1**.

Weather Conditions

The quantity of water which can be theoretically absorbed by the air is a measure of the drying potential of low-temperature drying systems (4). The drying potential of the ambient air should be sufficient to dry the crop to a moisture content which allows safe storage. Besides the drying potential, the temperature of the ambient air also has a considerable impact on drying behaviour. Low drying air temperatures lead to slow drying. This, however, also prevents undesired mould growth and enzymatic reactions. An analysis of the weather data for the paddy drying periods in the years of 1981 to 1985 shows that the average ambient air temperature ranged from 12.6 to 18.6°C. The distinctly low air temperatures in combination with a drying potential of the ambient air ranging from 0.0011 to 0.0018 kg H_2O per kg air indicate the high potential for ambient-air drying under Korean weather conditions. The probability distribution curves for the drying potential of the ambient air show that it was only during 20% of the drying period that this potential was not suffi-

Table 1 Summary of Results of 1981 to 1985 Ambient-air In-storage Drying Tests

Item		1981	1982	1983	1985
Initial moisture content	% w.b.	21.9	21.6	24.0	17.2
Final moisture content					
average	% w.b.	14.6	13.2	13.6	14.3
minimum	% w.b.	13.8	12.6	12.5	13.6
maximum	% w.b.	15.1	13.9	15.2	14.3
Variety		Milyang	Milyang	Akibare	Akibare
Drying period		Oct. 3–12	Sept. 27–Oct. 9	Oct. 13–28	Oct. 21–28
Ambient air temperature					
average	°C	15.8	18.6	12.6	12.8
minimum	°C	8.5	12.4	4.5	4.9
maximum	°C	22.1	26.5	20.8	23.4
Relative humidity					
average	%	69.9	63.3	64.0	72.0
minimum	%	32.2	29.2	27.5	28.4
maximum	%	94.3	95.5	93.2	98.5
Drying potential	kg H_2O/kg air	0.0013	0.0018	0.0014	0.0011
Air flow rate	m^3/m^3 min	6.0	5.0	3.9	3.1
Air velocity	m/s	0.090	0.092	0.078	0.062
Grain depth	m	0.9	1.1	1.2	1.2
Static pressure drop	Pa	–	–	161.7	209.7
Mass of wet grain	kg	2 500	3 000	2 900	3 000
Mass of dried grain	kg	2 286	2 710	2 551	2 898
Water removed	kg	214	290	349	102
Fan operation time	h	186	211	352	156
Drying time	h	216	288	360	168
Drying rate	kg H_2O/h	0.99	1.01	0.97	0.61
Electric energy consumption	kWh	74.2	84.4	140.6	62.4
Specific energy costs on the basis of on farm use	US $/kWh	0.044	0.044	0.044	0.044
Total energy cost	US $/t	1.298	1.231	2.121	0.910

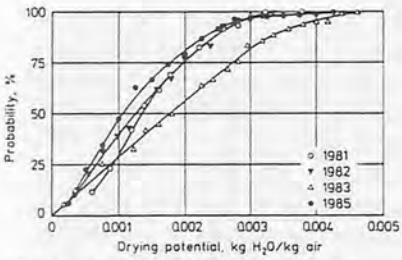


Fig. 3 Probability distribution of the drying potential of the drying air during the drying periods 1981 and 1985.

cient to dry the paddy to less than 15%, as shown in Fig. 3.

Drying Time

The drying time of low-temperature grain drying systems mainly depends on the weather conditions, airflow rate, bulk depth and initial moisture content of the kernels (4). The drying tests carried out between 1981 and 1985 showed that the drying potential of the ambient air is sufficient to dry a layer of 0.9 to 1.2 m of paddy to safe storage conditions without supplementary heat using airflow rate of 5.0 and 6.0 m^3/m^3-min, respectively. Drying takes 7 to 9 days to reduce the moisture content from about 21 to an average of 14%. Even high moisture paddy with a moisture content of 24% was dried with an extermely low airflow rate of 3.1 m^3/m^3-min in almost 15 days. However, when drying late-harvested paddy with a high initial moisture contents using such low airflow rates, drying cannot be guaranteed to be finished before the bad weather starts (7). This makes it necessary to store the paddy at a relatively high moisture content and to finish drying in early spring. In order to reduce the weather-related risk of the ambient air drying system it is recommended that the dryer be operated at an airflow rate of about 6 m^3/m^3-min instead of minimizing the energy consumption.

Uniformity of Drying

The drying tests have shown that compared with high-temperature drying or natural sun drying, ambient air drying leads to a more uniform drying. As indicated in Fig. 4, the differences in moisture content between top and bottom layer range from 0.7 to 2.7%. The slight overdrying of the bottom layer, which is typical of all batch drying processes, can be compensated by continuing the ventilation with cold air.

Energy Cost

Depending on acreage and yields and on the quantity threshed daily, the in-storage dryer has to be operated either partly loaded, loaded layer by layer, or fully loaded. In all cases the air distribution in

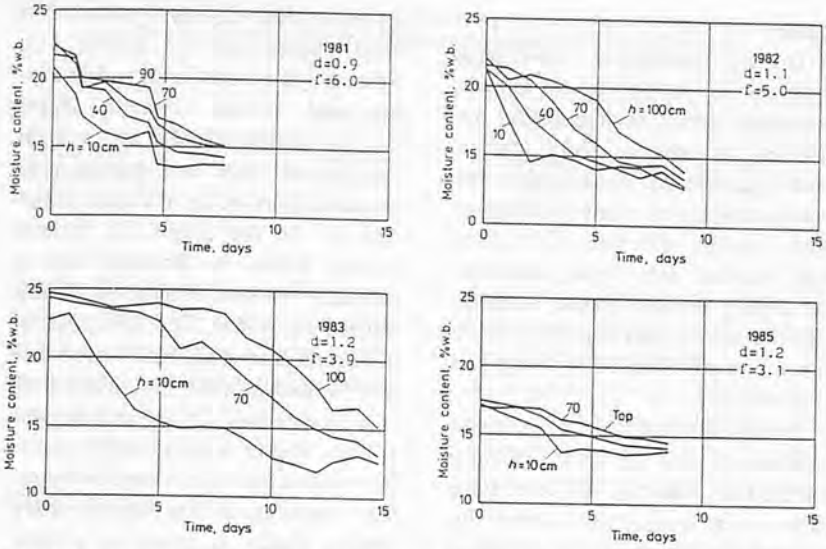


Fig. 4 Influence of drying time and bulk depth on the drying behavior of paddy during ambient-air in-storage drying. (d: bulk depth (m), f: air flow rate (m^3/m^3 min)).

Table 2 Influence of Bulk Depth on Power Requirement and Efficiency of Fan

Bulk depth m	Airflow rate m^3/m^3 min	Static pressure Pa	Power requirement kW	Efficiency %
0.7	6.02	128	0.416	9.1
0.9	4.55	184	0.417	12.7
1.2	3.08	214	0.400	14.0

the bulk should be uniform to yield the desired uniform moisture content by the time drying is finished. **Fig. 5** shows examples of the air distribution when the dryer is loaded to a height of 0.7, 0.9 and 1.2 m. The air distribution system as shown in **Fig. 2** guarantees an almost uniform air distribution even when the dryer is only partially loaded. Besides the air distribution the bulk depth also influences airflow rate, air resistance, electricity consumption and efficiency of the fan as indicated in **Table 2**.

The relatively low efficiency of the fan used for the drying tests can be traced back to the low efficiency of only 40% of the electric motor and to the use of a cheap fan with forward curved blades. By optimizing the use of the electric motor, as well as switching over to a more efficient fan with backward curved blades, the total efficiency could be increased to between 60 and 70%, but this also leads to significantly higher costs.

From the farmers' point of view it seems that, at present, it is more economical to use a low cost and less sufficient fan as the energy cost of running the fan is only 0.910 to 2.12 U.S.$ per t of paddy. Compared with the savings in labour costs and the reduction in mass losses, these operating costs are relatively low. However, from a macroeconomic point of view, increasing the efficiency of the fan and motor is of great importance. If a large number of ambient-air in-storage drying systems are to be introduced successfully the electric power companies will have to increase power supply for the rural areas significantly.

Besides optimizing the use of the fan and motor efficiencies, reducing of the airflow rate is another promising strategy for cutting power requirements. As shown in **Fig. 6** the airflow rate greatly affects the pressure drop which occurs when forcing the air through the bulk. To prevent mould growth and ensure the desired uniform air distribution, it seems impossible to reduce the airflow rate below 5 to 6 m^3/m^3-min.

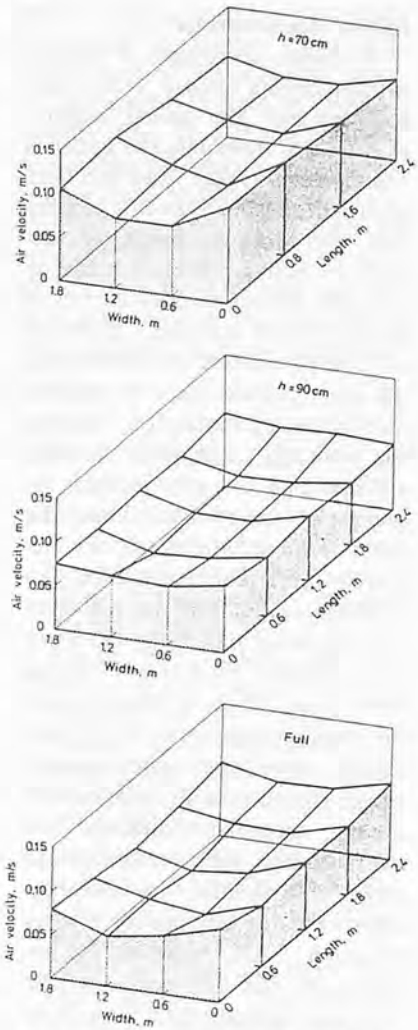


Fig. 5 Air distribution at different bulk depths.

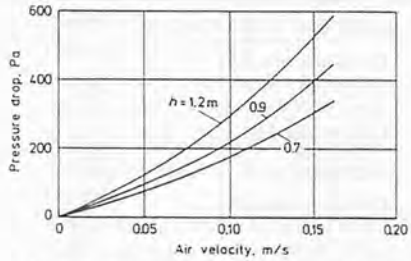


Fig. 6 Influence of air velocity and bulk depth on pressure drop.

Labour Requirements

A major advantage of the in-storage drying system is its easy handling and low labour requirement. After threshing, the paddy is transported in bags from the field to the drying shed. During loading the inner door is closed by successively adding the next board as the grain surface reaches the top of the last board installed. To obtain the desired uniform air distribution, the grain surface has to be levelled before starting ventilation. Loading the instorage dryer with 3 000 kg and levelling the grain surface requires 7.5 man-hours. When the dryer is loaded, labour is only required for a daily check on the moisture content of the top layer and for switching off the fan when it is raining. Natural sun drying takes 5 to 10 days depending on the weather conditions (8, 9). During this period one person is required for almost 60 h for distribution, mixing, guarding, collecting and transportation back to the storage facilities. Unloading the in-storage dryer takes approximately 8 man-hours. It must, however, be remembered that this work could be done in a period when there is no shortage of labour on the farm.

Quality

During ambient-air in-storage drying the paddy is completely protected from environmental influences as well as from insects, birds and rodents. Furthermore, the paddy does not come in contact with foreign materials. Compared with natural sun drying ambient-air drying is much more hygienic and the mass losses can be reduced from between 3 and 4% (1, 8, 9) to almost zero.

The quality characteristics of the ambient-air dried paddy are summarized in **Table 3**. All tests have shown that ambient-air drying the no negative effects on the dehulling rate, milling yield and cracking ratio. According to the Korean paddy quality standards (5) the ambient-air dried paddy can be classified as grade 1. Additional tests showed that neither the germination rate nor the number of invaded kernels or the total viable mould count was affected by this drying method **(Table 4)**. The slight increase in the acid values does not justify the conclusion that the paddy is deteriorated.

Economics

A comparative economic analysis of three drying systems has been carried out by KAIST (1). System I is a traditional paddy drying and storage system. After cutting, paddy is dried in the field for several days and bound into bundles, then set up in stocks in the field or on the ridges for further drying. Paddy is threshed with a moisture content of about 17% and redried on a mat. The dried paddy is packed into sacks and stored in a mud-walled storage bin. System II is a mechanized drying and storage system. Paddy is harvested by combine and dried with a high-temperature continuous-flow dryer. After drying, paddy is stored in a conventional flat store. System III is the ambient-air in-storage drying system described above. In order to allow comparative calculations of economic data, a number of assumed parameters, such as initial cost, shelf-life, depreciation, interest, maintenance, tax and labour cost have been chosen on the basis of available literature. Real experiments yielded further parameters such as drying capacity, drying and storage losses, labour and energy requirements.

Comparative cost analysis for 3.6 t of paddy to be dried and stored, respectively, resulted in the figures shown in **Table 5**. System III, the lowest in total cost, is the most capital intensive with fixed costs accounting for 85.6% of total cost, while System I is the most expensive and labour intensive, with fixed costs on only 38.7% of total cost. Based on these results, the break-even unit of utilization is 29.3 t for System I; 4.4 t for System II; and 2.3 t for

Table 3 Influence of Ambient-air In-storage Drying on the Miling Properties of Paddy

Item	1981	1982	1983	1985
Dehulling rate (%)				
Control	78.3	–	78.8	80.5
LT drying	78.3	–	78.7	80.3
Miling field (%)				
Control	71.9	69.8	70.7	74.4
LT drying	69.9	69.7	68.7	74.7
Cracking ratio (%)				
Control	11.0	–	–	–
LT drying	5.0	–	–	–

Control : single layer drying under shade

Table 4 Influence of Ambient-air In-storage Drying on Quality Characteristics of Paddy

Location	Germination rate %		Invaded kernels %		Total viable mold count 10^6 CFU/g		Acid value (mg KOM/g crude oil)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Bottom layer	96.5	96.4	93	98	1.35	1.21	–	–
Middle layer	96.5	99.0	97	90	1.62	1.44	8.9	9.3
Top layer	96.5	98.0	94	92	1.33	1.12	–	–

Table 5 Cost Composition of Traditional Sundrying Method, High Temperature Continuous Flow Drying and Ambient-air In-storage Drying System

(Unit: Won)

Item	System 1	System 2	System 3
Fixed cost	43 875	127 669	74 825
Variable cost	69 400	36 488	12 492
Total cost	113 275	164 157	87 137

System III. These figures show only System III to be economical, since it is the only one to achieve break-even utilization below the reference quantity of 3.6 t.

Conclusions

Based on the results of several drying tests with the newly-developed ambient-air in-storage drying system the following conclusions can be drawn:

- In the Korean climate paddy can be dried without supplementary heat to safe storage conditions by utilizing the drying potential of the ambient air.
- The in-storage drying system with a loading capacity of 3.0 to 5.0 t can be economically applied to paddy producing farms possessing an acreage of 0.5 to 1.0 ha.
- The simple dryer can be constructed by farmers, local craftsmen or small scale industries.
- All materials required, including fan and motor are available on the Korean market.
- Incorporating the dryer into existing farm structures substantially reduces the investment required.
- When drying is finished the dryer can be used for storage of paddy or other crops, or alternatively, as a machine shed.
- During drying the crop is completely protected from rain, water penetration through floor and walls, birds, rodents and insects.
- In contrast to natural sun drying, in-storage drying is more hygienic as the paddy does not come into contact with foreign material during drying.
- In-storage drying reduces the labour input considerably and eliminates the existing bottleneck during the harvesting period.
- Early harvesting and threshing not only reduces field losses, but also permits earlier soil preparation when growing a winter crop.
- Ambient-air dried paddy fulfills the Korean quality standards with respect to milling and polishing rate, moisture content and percentage of broken kernels.
- The need for a fan to force the air through the bulk does not limit the distribution of the in-storage drying-system because most Korean farms are serviced by electricity.
- In relation to the benefits of the system with respect to reduced mass losses, improved product quality and savings in labour input, the energy costs are negligible.
- Introducing ambient air dryers instead of high-temperature drying systems avoids the need to import crude oil.
- A simplified cost-benefit analysis has shown that the ambient-air in-storage drying system has certain advantages from an economic point of view in comparison with high-temperature continuous-flow dryers and traditional non-drying methods.

From 1984 to 1987 approximately 50 000 ambient-air in-storage drying systems have been introduced on Korean farms with the support of National Agricultural Cooperative Federation (NACF) credits. This is the first step in converting the existing post-harvest system from bag to bulk handling. Further improvements can be achieved by optimizing fan efficiency and by replacing the air duct system by air sweeping floors, which allow mechanical unloading.

REFERENCES

1. Cheigh, H.S.: Techno-economic evaluation of paddy drying and storage process at farm level in Korea. Unpublished Report, KAIST (1982).
2. Cheigh, H.S., Rhim, J.W. and Kim, S.K.: Korean J. Food Sci. Technol., **14**, 271 (1982).
3. Cheigh, H.S., Mühlbauer, W., Rhim, J.W. and Shin, M.G.: Korean J. Food Sci. Technol. 17 (1), 25 (1985).
4. Mühlbauer, W., Stahl, T., Hofacker, W. and Reisinger, G.: Am. Soc. of Agr. Eng., Paper No. 82-3006 (1982).
5. Office of National Agri. Products Inspection (Korea): Agr. Product Inspection Manual, Seoul (1981).
6. A.A.C.C.: Cereal Laboratory Methods, 7th ed., Am. Assoc. of Cereal Chemists. St. Paul, Minn. (1962).
7. Cheigh, H.S., et al. A system for small-scale farm drying and storage of Paddy in Korea. GASCA-Seminar, Kuala-Lumpur (1986).
8. Lee, C.H. and Chung, C.J.: An evaluation of Rice Post-Harvest Systems in terms of Grain Losses and Maximum Recoveries (Final Report), Seoul National Univ., Suweon (1978).
9. Pyun, Y.R.: Prevention of Post-Harvest Losses of Grains at the Village Level (Final), KAIST Report 78-2001-2-1-1 (1981). ■■

Separation of Asparagus Berries Using Stationary Plot Thresher

by
Megh R. Goyal
Assoc. Agric. Engineer
Fortuna Res. and Devel. Center
HC 02 Box 7115, Juana Diaz
PR 00665-9601, U.S.A.

Octavio Colberg
Res. Asst.
Fortuna Res. and Devel. Center
Juana Diaz, Puerto Rico
U.S.A.

William Vicenty
Res. Asst.
Fortuna Res. and Devel. Center
Juana Diaz, Puerto Rico
U.S.A.

Abstract

A stationary plot thresher was evaluated in terms of efficiency in separating asparagus berries from the plant. The use of this unit reduced labor input by 70% compared to manual operation. A cylinder speed of 650 rpm (throttle lever setting #9) resulted in the best machine performance. At 650 rpm, feed rate was 34.3 kg/h compared to fuel consumption of 0.76 *l*/h (or 0.022 *l*/kg). Cylinder speed had no effect on the percentage of material collected in the threshing units except in the sieve unit. Separation loss was high at low cylinder speeds.

Introduction

In 1981, the first asparagus (*Asparagus officinalis*) reseach was initiated at the Fortuna Substation, Juana Díaz, located in the semiarid zone of Puerto Rico, in collaboration with Rutgers University, New Brunswick, New Jersey, USA. The purpose was to produce good quality seed for sale in the northern United States. Separation of asparagus berries from the plant has been a tedius and costly operation since 1983. The separation process involved hand harvesting of whole plants and then passing them through a set of three sieves placed on concrete blocks. The process is not only time consuming, but the sieved material contained berries and trash. The berries were then separated by washing the sieved material in a bucket. Asparagus seed from berries were then obtained with a blender. In 1984, a machine was developed consisting of a set of metalic sieves on an iron frame and a 40-cm fan to separate the trash (**Fig. 1**). The plant was allowed to pass across a set of hooks mounted on a bar where the pushing action removed the berries from the harvested plant. Although this machine increased the efficiency of removing the berries from the plant, it lacked portability to the field and it was not gasoline operated. In early 1985, the Swanson* plot thresher – was made available by Rutgers University to separate berries from the plant in the field.

Fig. 1 Stationary separator to remove berries from asparagus plant. Berries are removed by a pushing action against a set of bars welded on a rod.

No studies have been reported on the use of a thresher to separete asparagus berries.

The objective of this study was to evaluate the performance of a multicrop plot thresher for separating asparagus berries from the standing crop; and the labor input in the manual and machine operations. The study was conducted at the Fortuna Substation, Juana Diaz, P.R..

Note: Approved for publication as journal article No. 86-87 by the Agricultural Experiment Station, UPR-RUM.

This study was conducted under Project SP-90, "Asparagus Seed Production" and technical problem for the course Hort 6995, Department of Horticulture, University of Puerto Rico, Mayaguez. The authors are grateful to Mrs. Carmela Chao de Báez for providing stastical analysis and for her valuable suggestions; and to Department of Horticulture and Forestry, Rutgers University, New Brunswick, NJ for financial and professional support.

*Trade names in this publication are used only to provide specific information. Mention of a trade name does not constitute a warranty of equipment of materials by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

Materials and Methods

Figure 2 shows the experimental equipment used in the present study. This stationary plot thresher (length = 3.3 m, width = 1.8 m and height = 1.2 m) consists of a power unit, G78 x 15 tires, standard trailer chassis width, levelling jack, rear grain hopper, shaker screen, rasp type cylinder and a concave air supply fan, adjustable speed drive, and safety chains. A Wisconsin gasoline 7 hp engine with twin disc clutch operates the threshing-chopping cylinder. A clutch box assembly engages or disengages power from the engine to the threshing unit and determines the required cylinder speed.

The operation of the machine* involves three distinct functions: threshing, separating and cleaning. The rotating rasp bar cylinder (33 cm diameter x 45.7 cm long) threshes the plants by rubbing them against the stationary concave to remove the berries from the plants. The degree of threshing is determined by the cylinder speed and cylinder/concave clearance. In the separating operation, the main grain pan collects all the grain, chaff and unthreshed grain. The main grain pan has a shaking action and moves the material rearward with the berries settling at the bottom of the pan, and the lighter chaff settling on top of the berries. The berries and chaff come off the end of the main grain pan and are met by a continuous flow of air from the fan (blower unit). The air from the fan blows the chaff over the top of the sieve and out of the rear of the thresher while the berries pass through the openings of the sieve and to the clean seed pan. The clearance between the cylinder and concave was set at 0.64 cm.

*Swanson Plot Thresher: Operator's Instruction Manual – Sir. No. 228 Model B1. Swanson Machine Co., Champaign, Illinois. page 5.

Fig. 2 Swanson stationary plot thresher powered by 7 hp Wisconsin gasoline engine.

Cylinder Speed Calibration

After the engine was started, a throttle lever was set at 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and a corresponding cylinder speed was recorded with a rpm counter. No cylinder motion was observed at lever settings of 0, 1, 2, 3, 4, 5. Therefore, the thresher performance was evaluated with lever settings at 6, 7, 8, 9 and 10 which were equivalent to cylinder speeds of 550, 600, 625, 650 and 675 rpm, respectively.

Machine Performance

At the time of harvest, the asparagus field was free of weeds and had perfectly standing plants with berries that had ripened evenly. In June 1985 the crop was harvested manually and transported in bundles to the working area. During this period the weather was hot and uniform from one day to another. The gasoline tank was filled, and the cylinder speed was set at the desired speed. The machine was started and a warm up time of 2 min was allowed. Out of 55 kg of asparagus sample, 5 kg was fed into the receiving pan of the machine. With a stop watch, time was recorded to thresh 5 kg of the sample and a feeding rate was calculated. Gasoline consumption (l/h and l/kg) was determined by measuring the quantity of gasoline needed to fill the tank again using a cylinder. For each test run, the material in the sieve, blower, seed tank and ground was collected carefully and weighed separately. Twenty grams of the collected sample was used to evaluate grain loss on each unit. For each test run, 100 g of the sample was oven-dried at 70°C for 72 h for determination of sample moisture content (dry basis) and a 50-g sample was used to determine straw/seed ratio in the unthreshed sample. A germination test was conducted with a moist towel, and germination was counted on the 10th, 20th and 30th days. At each speed or lever setting, nine tests were run. **Table 1** shows the analyzed data.

Labor input to obtain 100 kg of asparagus seed both with this machine and manual labor was also recorded.

Results and Discussion

Table 1 shows the effects of cylinder speed on the characteristics of unthreshed sample (mois-

Table 1 Effect of Cylinder Speed on Performance of Engine-operated Stationary Thresher to Separate Asparagus Barries from Plant

Cylinder speed	Unthreshed sample 1)					Feed rate	Gasoline consumption		Output (material collected) 2)								Berry loss 3)			
	Moisture content	Germination %		Straw	Seed				Sieve		Blower		Seed tank		Ground		Sieve	Blower	Ground	Total
(rpm)	% db	max.	min.	%	%	kg/h	1/h	1/kg	kg/h	%	kg/h	%	kg/h	%	kg/h	%	%	%	%	%
550	39.6	90	80	78.6	21.4	30.5	0.56	0.018	24.1	79.1	0.3	1.0	5.8	19.0	0.3	0.9	4.0	1.2	4.6	9.8
600	38.8	90	80	78.4	21.6	31.5	0.61	0.019	25.0	79.4	0.2	0.7	5.8	18.4	0.5	1.5	3.9	1.1	4.2	9.2
625	39.2	92	84	78.8	21.2	33.0	0.69	0.021	25.5	77.2	0.5	1.4	6.4	19.7	0.6	1.7	4.5	1.5	3.2	9.2
650	40.4	95	80	78.8	22.0	34.3	0.76	0.022	26.9	78.5	0.3	1.0	6.8	19.6	0.3	0.9	1.9	1.5	2.2	5.6
675	39.0	90	80	78.7	21.3	32.3	0.76	0.023	25.6	79.4	0.4	1.3	5.9	18.0	0.4	1.3	3.8	1.4	2.2	7.4

1) Moisture content is based upon samples dried for 72 h at 70°C. Germination tests were conducted using moist towels and germination was counted on 30th day.

2) Percent material collected = (material collected on the unit per h/feed rate) × 100

3) Percent berry loss = (berry loss on the unit/material collected on the unit) × 100

Note: Each observation is a mean of 9 test runs.

ture content, germination, straw /seed ratio) and machine performance parameters (feed rate, fuel consumption, material collected on each threshing unit and berry loss in each unit). The unthreshed sample versus cylinder speed exhibited no relationship. It was, therefore, assumed that the samples in all test runs were uniform.

The relationship between the feed rate (kg/h) into the machine versus cylinder speed (rpm) was quadratic and the regression coefficients were significant at 5% level of significance. The feed rate was increased as the cylinder speed was changed from 550 to 650 rpm and it was reduced with further increases in cylinder speed to 675 rpm. Specific fuel consumption (1/kg) and fuel consumption (1/h) increased linearly with cylinder speed within 550 to 675 rpm; the regression coefficients were significant at the 5% level of significance. The coefficient of determination (R^2) was 0.98.

No relationship was observed among the material collected (kg/h, %) on the blower, seed tank, ground and cylinder speed. Within 550 to 675 rpm, the material collected on the sieve varied from 77.2 to 79.4 % compared to 18.0 to 19.7% in the seed tank. Less than 1.7% material was lost on the ground compared to 1.4% in the blower unit. A quadratic relationship was observed between the percentage of berry loss on the ground and cylinder speed; and between the total berry loss and cylinder speed. Total berry loss varied from 6.6 to 9.9% within 550 to 675 rpm. Comparison of machine performance characteristics at 550 to 675 rpm suggested an optimum cylinder speed of 650 rpm. Values of feed rate (kg/h), material collected (kg/h) on the sieve and seed tank were highest with a minimum percentage of berry loss at 650 rpm.

It takes 40.9 man-h to obtain 100 kg of asparagus seed with the use of this thresher; 136.4 man-h in the manual operation. The use of the thresher, therefore, reduced labor input by 70%. ■■

A Resource Efficient Approach to Potato-Stone-Clod Separation

by
G.C. Misener
Res. Engineer
Res. Station
Agriculture Canada
Fredericton, N.B.
Canada

C.D. McLeod
Agric. Engineer
Res. Station
Agriculture Canada
Fredericton, N.B.
Canada

Abstract

Efforts were directed towards the development and evaluation of a simplified approach for the separation of loose soil, clods and stones from potatoes on a potato harvester. A mechanism was developed which consists of a combination of disc-shaped clod rollers and cylindrical brushes. The prototype separator effectively sieved all of the loose soil from the potatoes, 60% of the stones and 47% of the clods while reducing power consumption. Driven interface rollers, bridging the flow of material between different components, also proved successful.

Introduction

To improve labour utilization for harvesting crops, small compact harvesters need to be developed. This can be achieved by examining each event in the harvesting sequence to determine if an equivalent simplified component can be used. For harvesting potatoes grown in soil with stones, several complex potato-stone separators have been developed and mounted on the harvester. European harvesters rely on an x-ray sorting mechanism while their North American counterparts use an air flow system requiring more than 100 kW of power. However, in order to develop a compact harvester, this component needs to be simplified.

Sides and Smith (1970) describe several available methods of potato-stone separation. They indicate that from 1000 to 1500 t/ha of soil are lifted by a potato harvester. Mixed with this soil, there are 150 000 to 250 000 tubers combined with an equivalent number of stones. A common stone separation device on harvesters in Canada is the transverse tilted belt which used differences in rolling resistance as the means of separation. Interference between objects on the belt reduces the effectiveness of this method. Another commercial method is the x-ray separator which is presently used in Europe. Where stones are present in Canada, a large percentage of the harvesters are equipped with air flow separators where the potato-stone mixture is carried through an upward moving airstream and the potatoes are lifted from among the stones. This operation has both high capital and high operating costs due to the large air flow required.

Eaton and Hansen (1969) evaluated a method of separating stones from potatoes using cylindrical brushes. A theoretical study indicates that separation of cylindrical objects with a specific gravity ratio of 2.5 to 1, within a size range of 35 to 100 mm in diameter, is possible using this method. Laboratory tests with their prototype separator show that the separating efficiency did not depend on brush speed, loading rate or separation slope. Brush spacing was found to be the only significant parameter for this type of separation although bristle size and length were not examined.

The objective of the present study was to develop a stone separating mechanism for small potato digger-harvesters.

Design of Separation

A prototype potato harvester was built in 1983 in order that the brush separator could be evaluated. The harvester is described by Misener et al (1984). The prototype harvester initially used three cylindrical brushes located immediately behind the digger chain. The brushes were mounted so that the material flowed across their axes. The spacing between the 160 mm diameter brushes was adjustable. Each brush consisted of 20 rows of 5 mm diameter tufts made from 50 mm long nylon bristles 0.25 mm in diameter mounted at 13 mm centers on a 60 mm diameter core. The brushes were hydraulically driven using tractor-supplied power

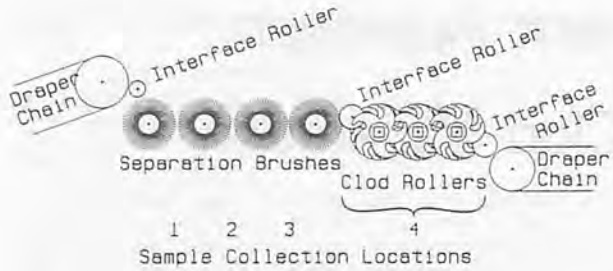


Fig. 1 Brush and clod roller assembly.

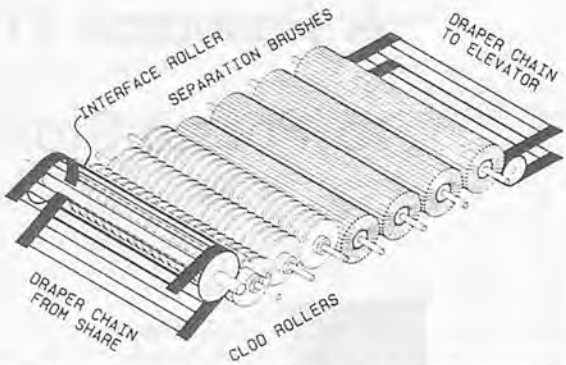


Fig. 2 Modified arrangement of brushand clod roller assembly.

which allowed simple speed changes.

In 1984, one additional brush and three rolls of clod rollers were installed to improve the separation of soil-stone-potatoes (**Fig. 1**). This combination of brushes and clod rollers was selected because the brushes seemed effective in reducing soil clods and it was thought that if the brushes could reduce the clod size first then the clod rollers would effectively sieve the smaller clods. In practice, when the brushes became loaded with soil, their effectiveness for stone separation was reduced and to avoid this, it appeared that the clod rollers should precede the brushes. This arrangement was evaluated during the 1985 season.

The final arrangement included a change in the shape of the clod rollers. The original clod rollers were star-shaped as shown in **Fig. 1**. In operation, stones would jam between the fingers of the clod rollers which varied the torque requirements, changed the rotational speeds and, on occasion, even stalled the rollers. The clod rollers were changed by eliminating the finger model and adding solid rubber discs as depicted in **Fig. 2**. This configuration was evaluated in 1986.

All of the preceding designs implemented hydraulically driven interfacing rollers which are small diameter rollers used between adjacent or sequential components such as the brushes and clod rollers. These rollers prevent small potatoes from falling through gaps by compensating for shape differences while acting as moving transition zone for the product to pass over. They also reduce the drop from one component to the next such as from the clod rollers to a conveyer.

Sampling Procedure

In the four-year study, each arrangement of brushes and clod rollers was evaluated under field conditions. As the test harvester was operated, data were collected over 7.6 m intervals. The weight of material passing through each of the gaps between the brushes was measured after being collected by trays installed underneath the brushes. The amount of material passing through the clod rollers was also determined in 1984.

In 1985, detailed data were collected under laboratory conditions as described by Misener and Mcleod (1987). The laboratory arrangement included a feeding conveyor on which mixtures of stones, clods and potatoes were placed and fed at controlled rates onto a 1.3 m wide brush separator. Potatoes were distributed evenly at a known weight on the conveyor and then either stones or clods were uniformly mixed with the potatoes. The conveyor speed was constant during the tests while the weight of material per unit length on the conveyor was varied to deliver various loading rates to the separator. Tests consisting of three replications were randomly conducted with an average ratio of stones/potatoes of 0.05 over a range of feed rates of 9.0, 18.0, 27.0 and 36.0 t/h. The tests included brush gap settings of 7.0, 10.0, 13.0 and 16.0 mm. One set of tests was also undertaken with soil clods mixed with potatoes. The ratio of clods/potatoes was 0.05 with a feed rate of 9.0, 18.0, 27.0 and 36.0 t/h at a fixed brush gap setting of 13.0 mm.

Results and Discussion

With the initial arrangement, which had been evaluated in 1983, brushes rotating at 70 rpm were able to separate a large portion of the stones from the tubers without causing a significant loss of tubers (**Fig. 3**). Brush spacing affected the separation efficiency with the wider gap allowing a larger percentage of stones to be separated from the tubers, in agreement with Eaton and Hansen, (1969). However, tuber loss is considerably higher with the brushes set at the larger gap. An object will not fall through the brushes unless its density and cantilevered position on the bristles causes sufficient deflection of the bristles to allow the object to pass through. This action tends to provide the selection between materials with different densities such as potatoes and stones. In the field harvesting situation there are many

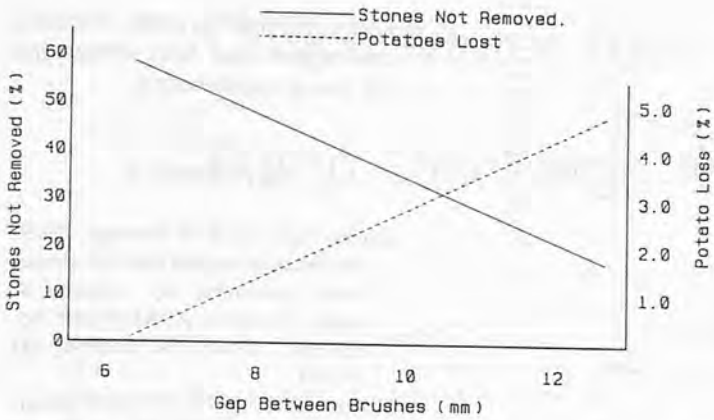


Fig. 3 Effectiveness of stone removal by brush separator and potato loss from separator. Percentages are expressed in terms of weight.

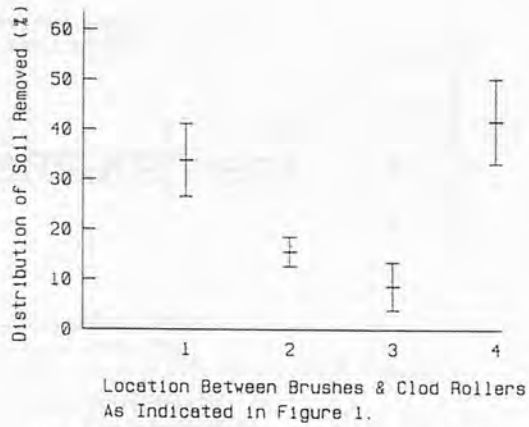


Fig. 4 Distribution of soil removed by brushes and clod rollers.

dynamic and geometric factors as well as interferences between potatoes and stones preventing density from being the only separating criteria. For instance a stone landing on top of a potato, in a brush gap could force the potato through into the rock discharge area while leaving the stone in the potato area. It is not uncommon to have a small potato forced through the brush by a larger potato while a large flat rock remains on top of the brushes. As a result of these factors there may be potatoes mixed with the stones in the stone discharge and stones mixed with the potatoes after the brushes.

During the initial year of the study the amount of soil mixed with the potatoes being transferred to the bulk truck was considered too high when compared to the level achieved by commercial harvesters. Soil that was mixed with the potatoes in the bulk truck consisted of loose soil and small clods. The surfaces of the tubers were essentially free of soil due to the cleaning action of the brushes.

With the installation of one additional brush and three rolls of clod rollers, there was a significant reduction in the amount of loose soil transferred to the bulk truck. **Figure 4** shows the effect of the combination of brush and clod roller on soil-potato separation. Forty percent of the soil separated from the potatoes in this combination was sieved through the clod rollers located after the brushes.

All of the loose soil was removed from the potatoes being loaded into the bulk truck during the evaluation in 1985 when the clod rollers were positioned in front of the brushes. Similar results were obtained in 1986 with the brushes separating 59.4% by number or 37.9% by weight of the stones from the potatoes. Forty-seven percent of the clods (31.0% by weight) introduced to the brush separator were removed along with all of the loose soil.

The disc-shaped clod rollers were as effective as the star-shaped rollers in removing loose soil. The disc-shaped rollers required little power to drive them compared to the star-shaped rollers. Small stones would jam in the fingers of the star shaped rollers and cause high torque requirements. One kW of power was required to operate the

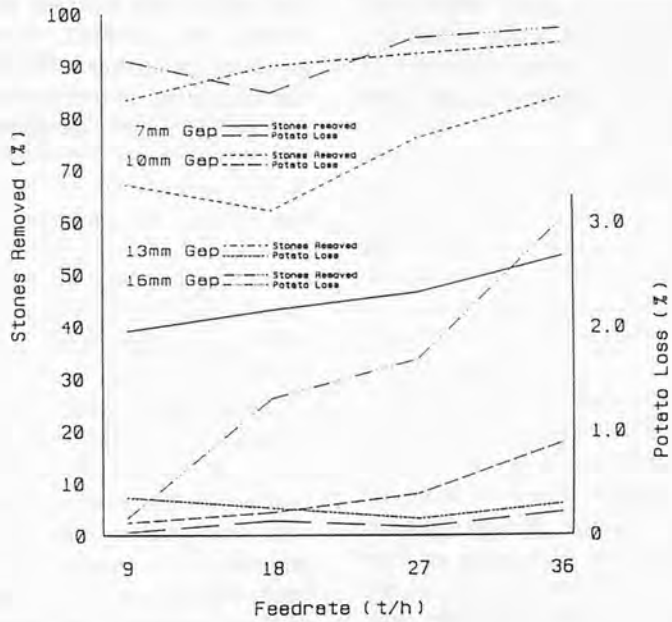


Fig. 5 Effectiveness of brush separator in removing stones from potatoes under laboratory conditions. Percentages are expressed in terms of weight of the products.

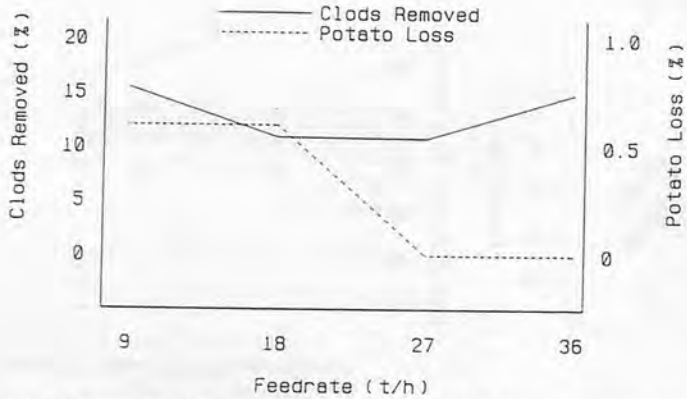


Fig. 6 Effectiveness of brush separator in removing clods from potatoes under laboratory conditions. Percentages are expressed in terms of weight of the products.

disc clod roller-brush asembly.

Results describing the performance of the brushes achieved under laboratory conditions are shown in **Figs. 5** and **6**. The brushes set at a gap of 13 mm effectively separated 89.9% by weight of the stones and 10.9% by weight of the clods from the potatoes at a feed rate of 18 t/h. Due to the lower specific gravity of the clods, the brushes are less effective when separating the clods as compared to stones. During the laboratory tests, there were no clod rollers, which may account for the lower separation of the clods when compared to the results obtained under field conditions.

Conclusions

In order to significantly downsize conventional potato harvesters, the separation of stones, soil and clods from potatoes could be achieved by a disc roller-brush assembly. The mechanism essentially eliminated the loose soil and, on the average, 59.4% of the stones and 47.0% of the clods. The power required to drive the mechanism was determined to be one kW for a two-row machine. Driven interface rollers were effective in transferring the products from one harvester component to another. The separating performance verifies the potential for developing resource efficient systems featuring low capital cost, light weight and low energy requirements.

REFERENCES

Eaton, F.E. and R.W. Hansen. 1969. Mechanical separation of stones from potatoes by means of rotary brushes. ASAE Paper No. 69-108, ASAE, St. Joseph, MI 49085.

McRae, D.C. 1978. Potato harvesting and transport. Survey Paper. 7th Triennial Conference. EAPR, Warsaw, Poland pp. 79-84.

Misener, G.C., C.D. Mcleod and L.P. McMillan. 1984. Evaluation of a prototype potato harvester. Transactions of the ASAE 27(1): 24-28.

Misener, G.C. and C.D. Mcleod. 1987. Evaluation of potato-stone-clod separation mechanisms. Can. Agric. Eng. (In press).

Sides, S.E. and N. Smith. 1970. Analysis and design of potato-stone separation mechanisms. ASAE Paper No. 70-673, ASAE, St. Joseph, MI 49805. ■■

Orifice Meter for Pump Discharge Measurement

by
M. Hassan
Scientific Officer
Agric. Engg. Div.
Bangladesh Agric. Res. Inst.
Dacca, Bangladesh

R.C. Lazaro
Formerly Water Management Specialist
Winrock International

M.R. Hoque
Assoc. Prof.
Dept. of Irrigation and Water Management
Bangladesh Agric. Univ.
Dacca, Bangladesh

Abstract

Two approaches in developing portable versions of the "Standard End-cap Orifice" pipe flow measuring devices were explored. The Bangladesh Agricultural Research Institute (BARI) shortened the length and introduced a slit-(rectangular-shaped) orifice while the Bangladesh Agricultural University (BAU) lightened the weight using PVC pipe materials but kept the length and circular-shaped orifice features.

The results of the calibration, and the Froude Scaling technique to develop other sizes from a model, showed good agreement between theory and laboratory results.

Further improvements, including the combination of the features of the two approaches, are also presented.

Introduction

Several versions of a portable slit-orifice water flow meter, made from mild steel pipe, were developed at the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The first version, a 4-inch pipe orifice meter, suitable for a 1-cusec pump in lifting groundwater or river water was introduced and described in Hassan, et al (1986). To simplify the fabrication of other similar but different sizes, the Froude scale modeling was suggested. The procedure for a 6-inch, 2-cusec version was shown.

In this paper the laboratory calibration results of both versions are presented. A lighter end-cap circular orifice alternative made of PVC pipe materials by the Bangladesh Agricultural University (BAU) at Mymemsingh, is also offered. Further improvements are identified. The findings of the field testing will be reported elsewhere by the first author.

The Model

The first version developed at BARI shortened and improved the portability of the end-cap orifice meter described in Layne and Bowler, Inc. (1958). It was also desired to provide a better, more accurate and simpler options to the California Pipe method described by Ban Leer in 1922 and the Trajectory method developed at Purdue University by Greene in 1978 as cited in Bos (1976). It was hypothesized that with a portable, low cost, and simple pipe flow meter the chances of encouraging managers to account for the water withdrawn and delivered will be enhanced.

4-inch version – The first version of the portable slit-orifice meter was fabricated from a 4-inch diameter, 12-inch long mild steel pipe. A rectangular-shaped slit was provided at one end and a clamping device at the other and (**Fig. 1**). The orifice is made of two glass or hard plastic plates placed across the top and bottom of one pipe end and held in place screwed-in adjustable clamps. The glass or plastic plate used was 3.0 mm thick, less than 1/30 of the pipe diameter requirement in ASME (1959), and has a sharp edge. From here on the space between the glass strips is referred to as the "slit-orifice opening."

Pressure tap – The pressure tap, for determining the pressure head, was located one-pipe diameter distance upstream of the orifice. A plastic tube was fitted and, along with a meter stick, served as a manometer. It was placed along the plane and parallel to the center of the pipe to minimize errors in flow measurements caused by pipes which are not precisely leveled when in use.

Meter-to-pump-pipe connector – The meter-to-pump-discharge-pipe connection was formed from a similar piece of 4-inch diameter pipe, cut longitudinally, spread out, filled with an extra strip, and welded at the outer circumference of the other pipe end (**Fig. 1**). A number 18 gauge steel sheet served as a guide while a pad made from a thin rubber gasket served as a sealant.

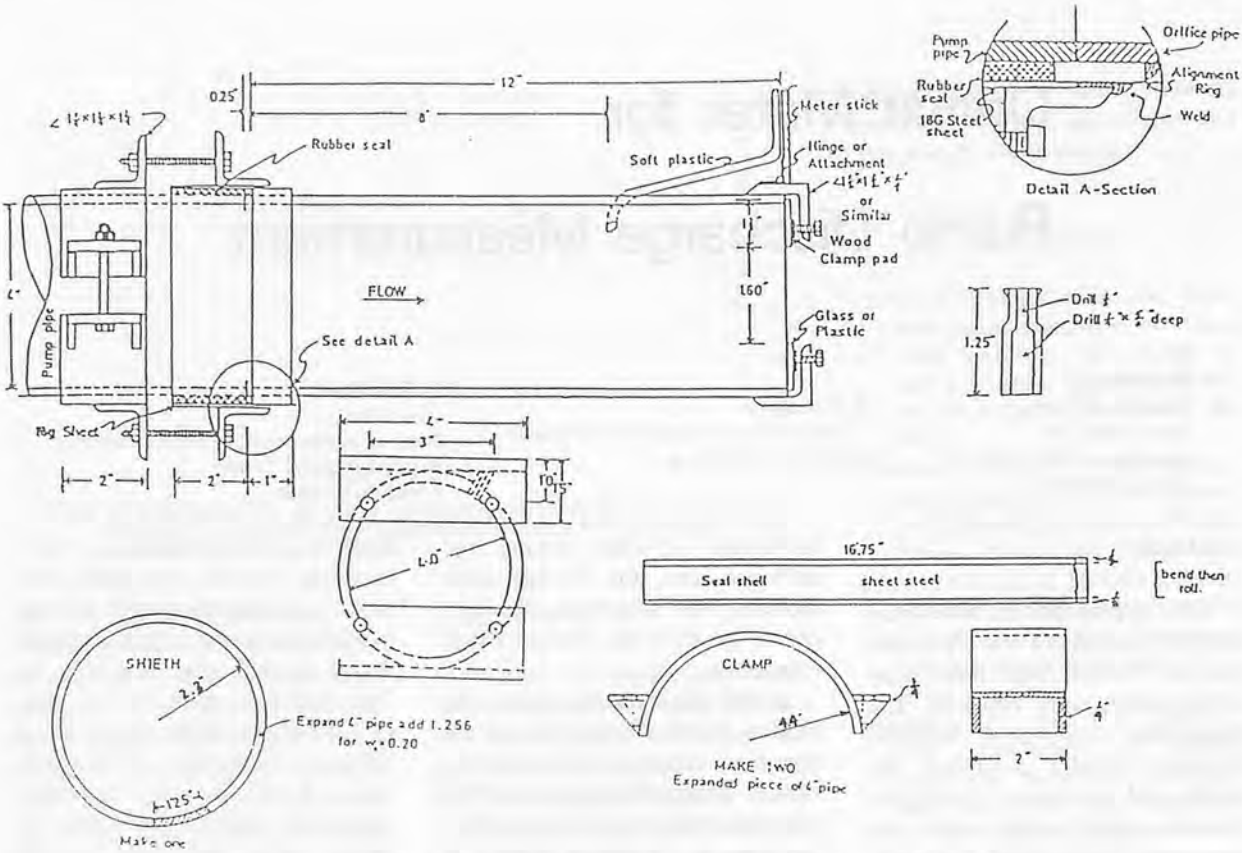


Fig. 1 Plan for the double-segmented slit orifice meter developed at B.A.R.I., 1985.

The C-clamp like device was made of two separate pieces of 2-inch long, 4-inch diameter pipe and attached to the meter with the dischage pipe end of the pump. Two pairs of 1-1/4" x 1-1/4" x 1/4" angle iron bar were diametrically welded on the C-clamp. A pair was attached to the discharge pipe of the pump, and another to the free end of the orifice meter. Two pairs of nuts and bolts secured them together.

Head-discharge relations – The theoretical head-discharge relationship was developed from the basic equation for an end-cap nozzle (ASME, 1959). However, the area of the vena contrata was used in lieu of the cross-sectional area of the contracted throat, along with the data and calibration results. These are: (1) for the vena contrata coefficient relationship, C = 0.6 + 0.454*(Ao/Ap)**2, where Ao/Ap are the orifice and pipe openings; (2) assumed velocity distribution coefficient, K = 1.02; and (3) best slit-orifice opening (1.60 inch). The relationship obtained was

$$Qt = 0.261*(h)**0.5 \quad \ldots\ldots(1)$$

Laboratory calibration – Calibration of the slit orifice meter was performed by using an improvised set-up developed at the Bangladesh Rice Research Institute (BRRI), Joydebpur. The set-up (Fig. 2), consisted of three empty barrels of 55-gallon oil drums connected in series and sits on a 2000-lb capacity platform scale. A flexible pipe was attached to the bottom of the middle drum for emptying the containers after each calibration run. A portable pump was operated at different discharges and the corresponding heights of water in the pressure head measuring tube were recorded. At pre-determined weights, the time elapsed to fill the containers were similarly noted. The weight and time recordings were then transformed into their flow rate equivalents.

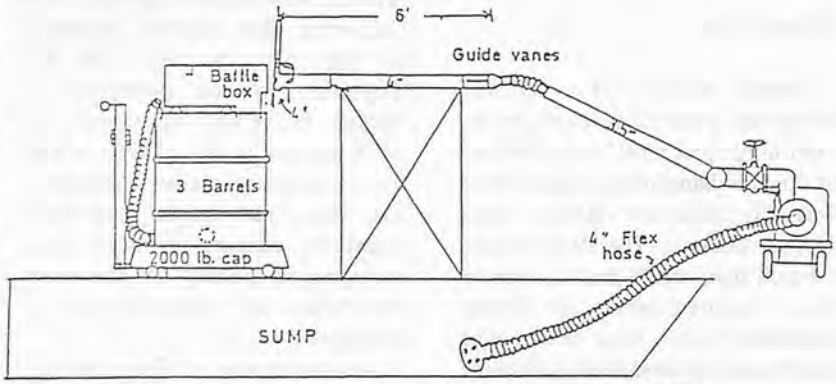


Fig. 2 Calibration equipment set-up developed at B.A.R.I., 1985.

Several slit openings were investigated: the best in the trial was 1.60 inches, for an area of the orifice to the area of the pipe opening ratio (Ao/Ap) of 0.4953. The results of the calibration for the best orifice size opening are shown in **Table 1**. The logarithmic transformed laboratory measured discharges, Q1, were then regressed with the similarly log-transformed measured pressure heads, h, to obtain the relationship

$$Q1 = 0.267*(h)**0.46 \quad \ldots\ldots (2)$$

The error analysis shown in **Figs. 3** and **4** clearly shows a good agreement between the laboratory calibration results and that predicted by theory. Errors from using the regression equation (2) to obtain discharges ranged from 0.09% to 2.17% (with root mean squared error = 0.539) when compared with the laboratory measured discharge; the errors ranged from 0.24% to 6.57% (root mean squared error = 0.924) for the theoretically derived relationship equation (1).

Table 1 Calibration Results for the Slit-orifice Meter Using 4-inch Mild Steel Pipe and 1.60-inch Drifice Opening*

Run No.	Weight of water trapped lb	Time to fill sec	Discharge Q cf	Head, h cm	Head, h ft
1	500	42.55	0.189	13.85	0.454
2	500	44.05	0.182	13.10	0.430
3	600	52.08	0.185	13.35	0.438
4	500	44.01	0.182	13.55	0.445
5	500	23.37	0.344	52.85	1.734
6	500	23.09	0.348	52.85	1.734
7	500	23.26	0.345	52.35	1.718
8	500	24.99	0.321	47.55	1.560
9	500	24.43	0.329	47.35	1.553
10	500	24.30	0.331	47.35	1.553
11	700	37.44	0.300	38.85	1.275
12	700	37.75	0.298	38.85	1.275
13	700	40.43	0.278	33.25	1.091
14	700	40.61	0.277	32.95	1.081
15	700	45.01	0.250	26.70	0.875
16	700	45.58	0.247	26.35	0.865
17	700	49.66	0.226	21.10	0.692
18	700	50.28	0.224	21.25	0.697
19	500	40.45	0.198	16.03	0.526
20	500	40.68	0.198	16.10	0.528

Water temperature at time of testing = 84°F
* Developed at Bangladesh Agricultural Research Institute, Hassan, et al (1986).

The Froude Scaled Version

A scale model of a large structure can be used for fluid flow investigations because the flow properties are similar by the principles of hydraulic similitude. In open channel flow, for instance, the square root of the ratio between the forces of inertia and gravity are the same for the model and the prototype – this ratio is known as the Froude Number. From the known properties of one structure another proportionately similar structure can be derived. The relationship is:

$$Q_{prototype}/Q_{model} = [L_{prototype}/L_{model}]**2.5 \quad \ldots\ldots (3)$$

where Q refers to the discharges, and L are the dimensions of the structures. This is valid when all the physical dimensions of the structures and the heads are of the same ratio (Bos, Replogle and Clemmens, 1984).

6-inch version – For a 6-inch pipe slit-orifice meter version and using the diameter to obtain the proportionality factor, the ratio is:

$$Q_{ratio} = [L_{pro}/L_{mod}]**2.5 = (6/4)**2.5 = 2.756 \quad \ldots\ldots (4)$$

The best equation for the 6-inch prototype using the relationship established for the 4-inch model, was obtained as follows:

$$Q_{pro} = Q_{ratio} * Q_{mod} = 0.611*(h)**0.46 \quad \ldots (5)$$

with an orifice opening of 6/4 x 1.60 = 2.40 inches, and pipe length

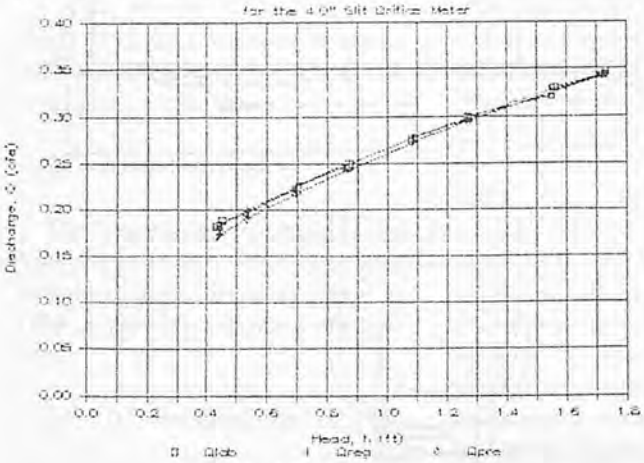


Fig. 3 Head-discharge relationships.

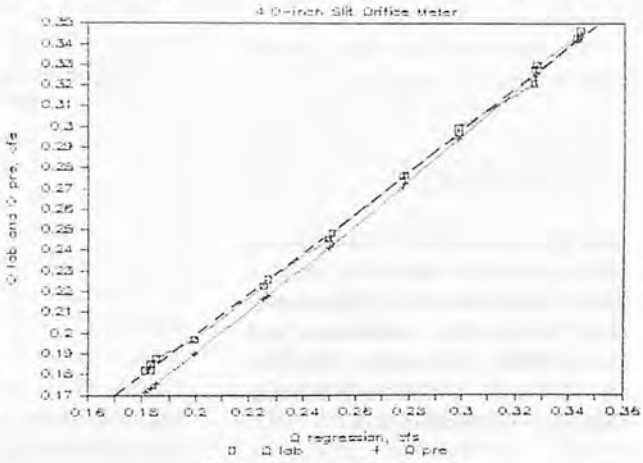


Fig. 4 Comparative analysis.

equal to 6/4 x 12.00 = 18 inches.

The 6-inch slit-orifice meter was then fabricated and similarly calibrated. The results of the calibration are shown in **Table 2**. The regression analysis yield the following head-discharge relationship:

$$Q_{6\text{-inch}} = 0.6133*(h)**0.3862 \quad ..(6)$$

The root mean squared error for equation (5) developed from theory was 0.003 and was 0.004 for regression equation (6) developed from the laboratory results.

Table 2 Calibration Results for the Slit-orifice Meter Using 6-inch Mild Steel Pipe and 2.40-inch Orifice Opening*

Run No.	Weight of water trapped lb	Time to fill sec	Discharge Q cf	Head, h cm	Head, h ft
1	300	16.6	0.640	34.0	1.116
2	300	17.0	0.625	32.5	1.066
3	300	16.0	0.664	36.5	1.198
4	300	16.0	0.664	36.5	1.198
5	300	16.0	0.664	36.5	1.198
6	300	16.6	0.640	34.0	1.116
7	300	16.5	0.644	34.2	1.122
8	250	14.1	0.628	32.6	1.070
9	250	14.0	0.632	33.3	1.093
10	250	13.65	0.649	34.9	1.145
11	250	13.57	0.652	35.0	1.148
12	250	14.3	0.619	31.9	1.047
13	250	13.9	0.637	33.5	1.099
14	250	14.0	0.632	33.4	1.096
15	200	11.5	0.616	31.7	1.040
16	200	11.5	0.616	31.5	1.034

Water temperature at time of testing = 25°C.
* Development at Bangladesh Agricultural Research Institute, 1987.

PVC Pipe Alternative

Inspired by the first attempt at BARI and BRRI, four undergraduate students in the Bangladesh Agricultural University (BAU) under the guidance of the third author came up with an end-cap orifice meter version made from PVC pipe materials. The orifice is a round hole cut out at the center of a circular plate and screwed into the PVC pipe. The test orifice, 4-inch in diameter, was fitted into a 6-inch diameter pipe. A piezometer, 1/4-inch in diameter, was set at the top center of the approach section about 27-inches away from the orifice. Excluding the meter-to-pipe connector, the length of the pipe is 54-inches. Details are shown in **Fig. 5**.

The reported head-discharge relationship was derived from

$$Q = CAV \quad .....(7)$$
$$= CAo(2gh)**0.5 \quad .....(8)$$

with the coefficient of discharge, C, taken as 0.84 obtained from a single discharge, Q = 0.90, measured during the calibration and area of the orifice, Ao = 0.0873 sq. ft. Thus, the reported head-discharge relationship was

$$Q = 0.5878*(h)**0.5 \quad .....(9)$$

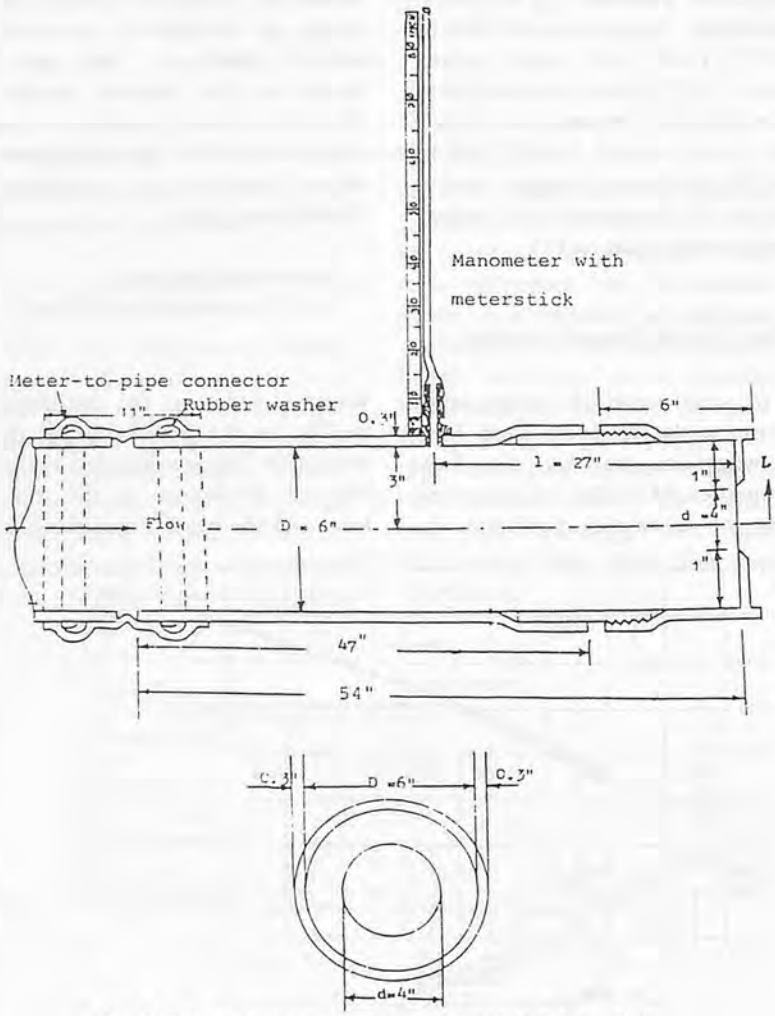


Fig. 5 PVC end-cap orifice meter developed at B.A.U., 1986.

Table 3 Calibration Results for the Circular Orifice Meter Using 6-inch PCV Pipe and 4-inch Orifice Opening*

Run No.	Head, h (in.)	(ft)	Discharge, Q cf	Computed C **
1	75	6.25	1.80	1.0288
2	54	4.50	1.50	1.0103
3	45	3.75	1.30	0.9592
4	35	2.92	1.15	0.9621
5	28	2.33	0.90	0.8418
6	24	2.00	0.85	0.8588
7	18	1.50	0.75	0.8750
8	8	0.67	0.55	0.9625
Average				0.9373

* Developed at Bangladesh Agricultural University, Islam et. al (1986)
** Computed from C = Q [Ao (2g) ** 0.5]; where Ao = 0.0872664 sq. ft.

Calibration of the end-cap orifice meter was done by using a container of known volume to trap the flow from an existing 2-cusec pump and noting the times to fill a predetermined volume. The results of the calibration are shown in Table 3. There are two ways, better than was reported by the investigators, to derive the head-discharge equation. One is to determine an average value for the over-all coefficient of discharge, C. The other is to run a regression analysis between the observed heads, h and the measured discharges, Q for the range of flows and heads measured the average value of C derived from

$$C = Q/[8.02*Ao*(h)**0.5] \quad \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

was 0.9373. The following relationship was then obtained using the other given constants:

$$Qt = 0.6564*(h)**0.5 \quad \ldots (11)$$

The regression analysis of the reported head and discharge measurements, using the data given in Table 3, gave the following relationship

$$Q1 = 0.548*(h)**0.626 \quad \ldots (12)$$

The error analysis gave a root mean squared error of 0.084 for the equation (11) and 0.071 for the regression equation (12).

Conclusion and Recommendations

Two approaches to make the pipe flow meter more portable were made. The approach followed at BARI was to shorten the length of the "standard end-cap orifice" meter and introduce a slit-(rectangular shaped) orifice. This took advantage of conventional tools and materials which are readily available. An added advantage with this set-up is that water flowing out of the slit-orifice meter spreads out like a fan which reduces the erosive force of the more concentrated flow from a conventional end-cap orifice. The approach followed at BAU was to lighten the weight of the "standard end-cap orifice" meter by using PVC pipe while retaining the circular shaped orifice secured on a cap and screwed unto an approach section of the pipe. A pump-pipe rubber-sleeve adapter from commercial slip-on fittings was used.

It appears that regardless of the approach taken to establish the head-discharge relationship the results obtained are close to each other. The Froude scale modeling simplified the development process once a model is already available.

Further improvements may be accomplished by combining the features of the two approaches adopted in BARI and in BAU. The PVC version, which is already lighter, can still be shortened. Replogle (1986) suggested and we concur: (1) that the pressure tap be located at about one-diameter upstream from the orifice; (2) that the pressure tap should be at a plane parallel to the center of the orifice to eliminate errors when the pipe is sloping; (3) that a constant head end-cap orifice meter with variable opening can be tried to eliminate the need for a ladder to read the pressure head at high flow rates; or (4) that a multiple manometer where back pressure to the first is provided by a second, placed in series beside it, etc. can also be considered.

REFERENCES

ASME 1959. Fluid Meters: Their Theory and Applications. A report of the ASME Research Committee on Fluid Meters, 5th Edition, New York. 203 P.

Box, M.G. (ed) 1976. Discharge Measurement Structures. Publication No. 20, ILRI, Wageningen, The Netherlands. 464 p.

Bos, M.G., Replogle, J.A. and A.J. Clemmens 1984. Flow Measuring Flumes for Open Channel Systems. John Wiley and Sons, New York. 321 p.

Hassan, M., Replogle, J.A., Lazaro, R.C., Mazed, M.A. and M.H. Rashid 1986. Portable Slit-Orifice Water Flow Meter for Pump Irrigation Systems. ADAB News a Bi-monthly Development Journal, Vol VII, No. 5. Dhaka, Bangladesh. pp. 8-22

Islam, M.S., Afazuddin, M., Islam A. and M.A.R. Mridha 1986. Design, Construction, and Calibration of a Portable Orifice Meter: A project report submitted to the Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymemsingh. 20 p.

Layne and Bowler, Inc. 1958. Measurement of Water Flow Through Pipe Orifice with Free Discharge. A Marley Company Publication with Orifice Calibration by Purdue University, Lafayette, Indiana. 28 p.

Replogle, J.A. 1986. Measuring and Control Devices for Irrigation and Drainage Systems in Bangladesh. A consultancy report submitted to the Bangladesh Agricultural Research Council and Winrock International Institute for Agricultural Development, Dhaka, Bangladesh. 31p.

Pulse Processing Machinery in India

by
S.D. Kulkarni
Scientist S-3
SPU Project
Central Instt. of Agric. Engg.
Nabibagh, Barasia Road
Bhopal 462018, India

Abstract

A survey report of the status of pulse (food legume) processing machinery in India is presented for information and as reference for further work in reducing milling losses. Pulses consumed mainly in India are in the form of *dal* (dehusked splits), hence the emphasis in the report is on dal mill machinery. Details of other pulse mills are also reported for the benefit of researchers not familier with these types of processing and products.

Introduction

The major part of pulse crops is converted into dal. The production of roasted pulses, pulse flour (besan) and polished whole pulse has been more or less a standard common practice in India.

Some 10 000 dal mills of different capacities are located in different parts of the country. However, the manufacture of dal mill machinery is not an organized local industry. Normally, the mills are fabricated by local artisans (mistry) at site. The power requirement, capacity, operating parameters and specifications of machinery vary from place to place and are often decided by the artisans. Many artisans depend on trial and error approach which leads to wastage and low yield of dal.

Modern dal mill plants designed by CFTRI Mysore and manufactured on commercial scale are not adopted by dal millers due to various reasons.

Existing Machinery

Pulses are processed for converting the raw material from threshing to consumption stage, i.e., dal making, polishing of whole pulses, roasting, besan (dehusked pulse flour), etc. Processing involves a number of operations, viz, cleaning, grading, elevating, conditioning, dehusking, drying, grinding, roasting, puffing, husk separation, splitting, polishing, etc. In order to fulfill these requirements, different types of machinery are manufactured.

Converntional Dal Mill Plants

In Southern India the single-storied, single and double set plant installations are common and are known as 'Hyderabad type' (**Figs. 1** and **2**). In comparison, in Northern India the dal mills are two-storied and commonly known as "Agra type' (**Fig. 3**) which are higher but require less space.

Cleaning and Grading Equipment

Raw pulse needs to be cleaned and graded before milling. Normally, two types of cleaners are available: rotary screen cleaner and reciprocating screen cleaner. Firms from South India[2,3,4] normally supply the reciprocating type whereas the rotary cleaners are supplied by North India-based firms[5]. However, some firms supply both types depending on the choice of the customer[3,4]. The screens are used to remove the foreign material on the basis of size difference. The suction fan removes lighter material such as dust particles.

Rotary Screen Cleaner – This type consists mainly of four compartments of different size screens fitted on 5 cm shaft (**Fig. 1**). The screens clean different pulse crops. The machine is fitted on a sloped foundation (slope 2" for given length) and operated at a low speed (18-30 rpm) for achieving better performance. The body of a machine can be either wooden or iron (mild steel) and the choice depends on manufacturer or customer.

Reciprocating Flat (Screen) Cleaner – This has three screens and one dust (suction) fan. The foreign material, dirt, dust, etc is

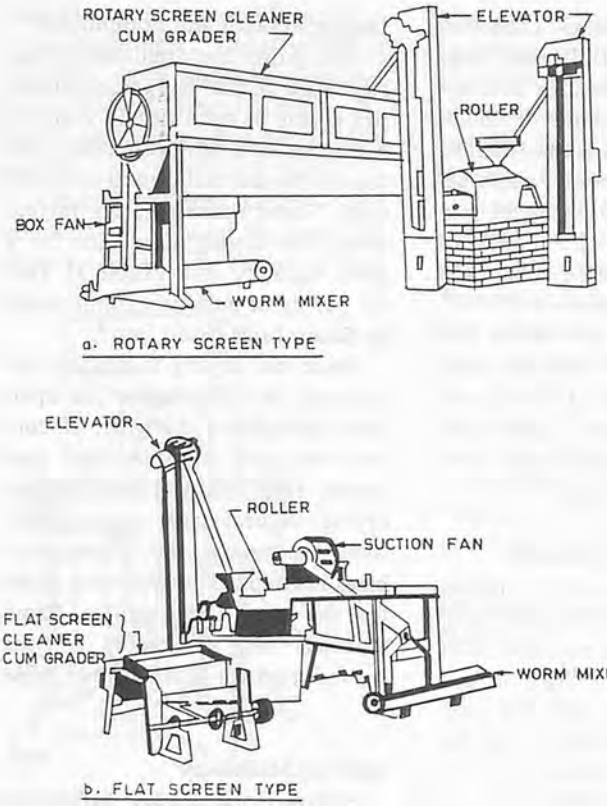


Fig. 1 Single set dal mill.

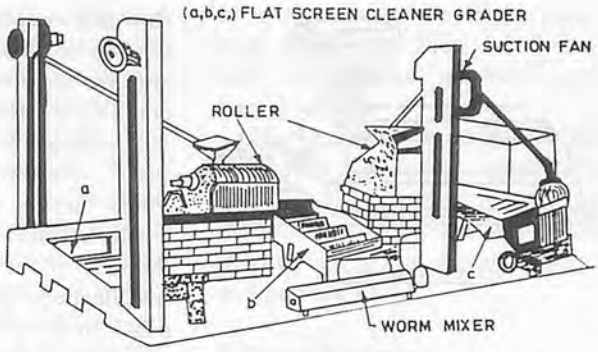


Fig. 2 Double set dal mill.

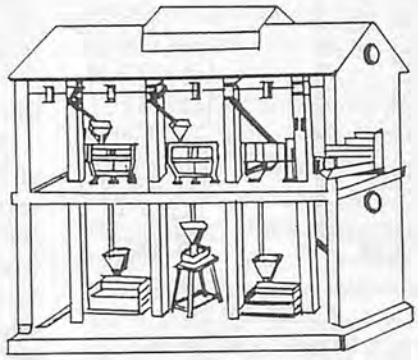


Fig. 3 Double-storied plant.

Table 1 Size, Capacity Range and Operational Details of Dal Mill Machinery

Machine and size	Speed, rpm	Power, bhp	Capacity, q/h
Rotay cleaner (7×5×3 to 13×5×4 ft)	18–60	0.5 –2.0	14–20
Roller (7×8×24 to 18×14×36 inch)	900–1 100	3.0 –5.0	4–30
Husk fan (16×8 to 48×30 inch)	500–1 000	0.5 –1.5	8–10
Flat screen grader (5×2.5 to 8×3 ft)	60–75 (stroke 1–1.5")	0.5 –1.5	5
URD Sheller (18 to 24 inch)	250–400	3.0 –5.0	10–20
Impact (patka machine) splitter (18×36 to 24×30 inch)	350–400	3.0	20
Worm machine (4 ft × 8 inch to 20 ft × 8 inch)	90–250	0.25–1.0	14–30
Elevators (bucket) (8 to 30 ft)	125–250	0.25–2.0	20–30

Source: ref. 1.

Table 2 Emery Sizes (No.) for Roller Machine

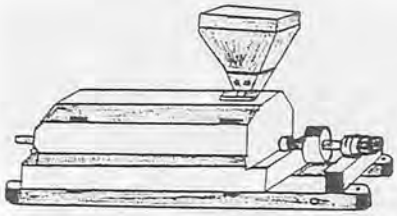
Crop	Operation		
	Dehusking/pitting	Splitting	Polishing
Arhar (pigeon pea)	16	24	–
Mung (green gram)	24	30*	35–40
Urd (black gram)	24	30*	35–40
Bengal gram	–	24*	–

Source: ref. 1

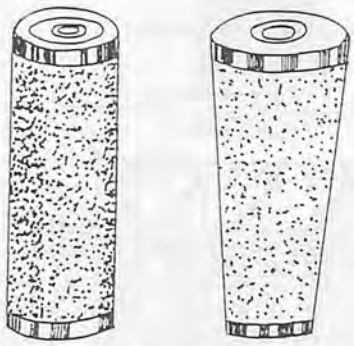
separated and pulse is graded for milling purpose. A stroke of 1.5 to 2" is provided for the reciprocating unit. Details of size, capacity, etc are shown in **Table 1**.

Dehusking Units (Rollers)

Carborandum emery-coated rollers are used for dehusking different pulses. The rollers are of two types: cylindrical and tapered (**Fig. 4**). The foundation is horizontal for the tapered rollers while it is sloped for the cylindrical roller. Normally, a slope of 15 cm in foundation for the entire length of the machine is recommended. The body of a roller is made of either wood or steel on which the mixture of carborandum emery, chemical cement and salt is applied and dried to make it uniform, circular abrasive surface. The granular size of emery varies from crop to crop and is recommended by manufacturers (**Table 2**). The inlet and outlet of the roller can be adjusted for regulation of



ROLLER ASSEMBLY



CYLINDRICAL TAP ERED

E MERY ROLLER

Fig. 4 Dehusker roller details.

Table 3 Suggested Drying Yard Sizes

Capacity (kg/h)	Drying yard (sq ft)
500	4 500
750	6 800
1 000	6 800
1 250	9 075
1 500	9 075

Source: ref. 13.

flow and retention time. These rollers are available in different sizes and are specified as 23 x 53.5 x 4 cm, i.e., 23 is diameter or roller, 53.5 is length, and 4 is size (dia.) of shaft[5]. However, some manufacturers indicate only diameter and length of roller, e.g., 23 x 53.5. In the case of the tapered rollers the specifications are given as 8" x 7" x 24" or 14 x 12 x 36" where first two figures denote diameters and last the length **(Fig. 4)**. The power requirement, capacity, roller size and speed (rpm) varies from manufacturer to manufacturer[3,4,5].

Oil/Water Treatment Machine

This machine is used for mixing of oil/water with pulses. Screw conveyors fitted with enclosed inlet and outlet with full flight or cut screw are used **(Fig. 10)**. The size, capacity and power requirement depend on the manufacturer and outlet of mill **(Table 1)**. The screw is rotated slowly to achieve proper mixing of oil/water with the pulse grains. Cut screw flights which are commonly supplied by manufacturer in South India[2,3] serve the purpose of agitator and help to increase retention time for better mixing.

Drying Methods and Equipments

The pulses are dried during milling. Most of the dal millers employ sun drying in open drying yeard. If the space is a limitation, the roof top of the dal mill is used as drying yard. Some manufacturers recommend the drying yard size for a given capacity mill **(Table 3)**. One ft^2 per kg of pulse is recommended by South India based firm[2].

Since sun drying is weather dependent, the mill cannot be operated throughout the year. If conventional mill is to be used year round, then artificial (mechanical) drying is necessary. Accordingly, some mechanical dal dryers have been introduced by different firms for the use of dal millers. Some technical data and claims of firms are reported for information **(Table 4)**.

Splitting Machinery

Splitting of dehusked pulses and pulse seeds is one of the major operations in the dal mill. It is aimed at the production of perfect splits with edges and without breakage. Different types of equipments are employed for the purpose: roller machine; under runner disc sheller; attrition mill (Chakki); elevator and hard surface; and impact sheller.

Roller machine – The machine similar to one used for dehusking is used for splitting of different pulses **(Fig. 4)**. Coarse emery coating is required for splitter roller **(Table 2)**. The rollers are used for splitting of green gram, piegeon pea, lentil, etc.

URD sheller – The machine is simple in construction **(Fig. 5)**. It has two horizontal discs with emery coating of 0.5" thickness. The upper disc is stationary while the lower one rotates to cause splitting of dehusked pulse *(gota)*. It is used for splitting of dehusked black gram, Bengal gram, lentil, pigeon pea and soybean. The capacity of a machine depends

Table 4 Details of Mechanical Dal Dryers of Various Makes

Description	Thermax Pune		S.R. Industries Madras	Ganesh Engg. Madras	Annapurna Industries Patna
	DD-10	DD-30			
Holding capacity, T	1.2	3	3.5	NA	0.8
Drying capacity, T/h	1.2	3	1.5	1	0.8
Moisture removal, %	5	5	4	NA	NA
Drying air temp., °C	60	80	60	150	150
Grain temp., °C	NA	NA	NA	75	NA
Heat exchanger	yes	yes	yes	no	no
Type of dryer	batch	batch	batch	continuous	batch
Power, hp	8	11	17	5	NA
Fuel/energy,/h	7-8 lit L.D.O.	10-121 lit L.D.O.	5 lit furnace oil	30×1.5kW	80kg coal
Price, Rs. (Ref. year)	60 000 (1984)	92 500 (1984)	60 000 (1984)	NA	24 000 (1980)
Extra yield claimed, %	NA	NA	2	1.5-2	NA
Dryers in operation (Ref. year)	200* (1984)	27* (1984)	6 (1980)	NA NA	1 (1980)

Note: *Includes uses other than dal drying.

upon its size and speed (Table 1).

Attrition mill – Attrition mill of vertically or horizontally rotating stone discs or emery discs is also used for splitting of pulses. (Figs. 6 and 7).

Elevator and hard surface – This combination is used by some dal millers and it is believed that breakage is reduced. Dehusked pulses are dropped from a height of about 10-15 ft on a hard surface and splits are obtained. This type of arrangement is normally used for pigeon pea only.

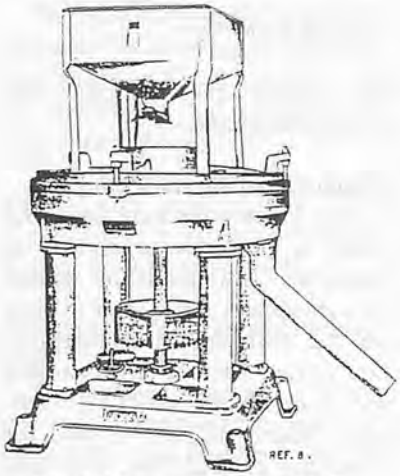


Fig. 5 Under-runner disk sheller.

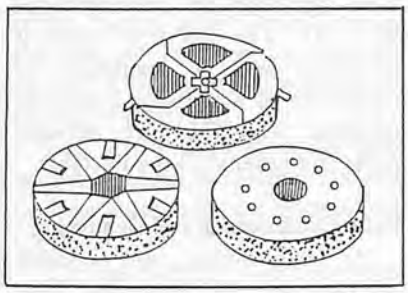


Fig. 6 Carbo-emery stones.

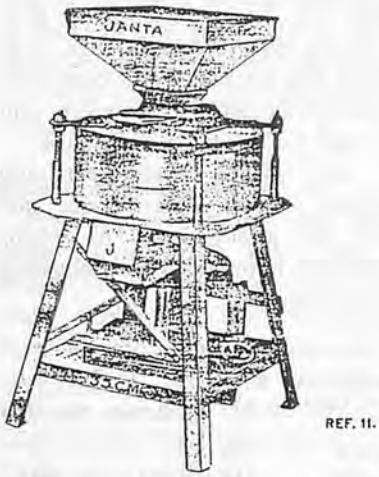


Fig. 7 Attrition mill (Horizontal stones).

Impact splitter – The machine consists of mild steel blades mounted on a shaft enclosed in a casing. The gota is fed to the machine and and rotating plades throw the gota on the hard body (casing) of the unit causing the splits. The gota is split by impact. The machine is popular in Bihar, West Nengal and some parts of Uttar Pradesh. It is manufactured[13] in different sizes (Table 1).

Dal Grading and Gota Separation Machinery

The machinery similar to that supplied for cleaning and grading of pulses is used for gota separation and dal grading (Figs. 1 and 8). Three and four compartment rotary sieve is supplied for gota separation and dal grading, respectively[3]. Some manufacturers, however, supply reciprocating type screen with 1.5-2" stroke length (Fig. 8) for gota separation and dal grading[2,3,7,9]. A combination of systems, viz., rotary screen cleaner for raw material cleaning and reciprocating screens for gota separation and DAL grading is also employed by some manufacturers. The size of perforations vary depending on the type of grain to be processed. The specifications of machine vary with the manufacturer and capacity of a particular unit (Table 1). These units are built in wooden or mild steel frame.

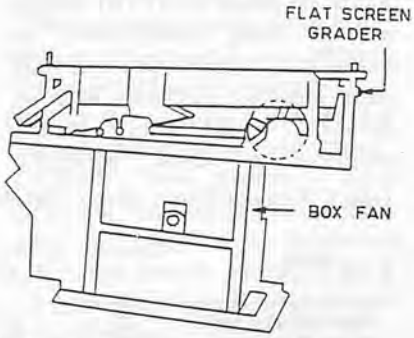


Fig. 8 Flat screen grader and box fan.

The machine is used for the separation of gota, splits and brokens. The dal grader receives the product of splitter unit and grades in gota, dal in two grades, brokens and powder, etc.

Polishing Equipment

Dal polishing mainly consists of either removal of powder from splits or application of oil and water to dal for proper colour and luster.

Removal of powder/dust – The cylindrical roller mounted with hard rubber[5], (Fig. 9) leather or emery cone polisher[9] is used for the purpose. Roller mounted with brushes is also supplied. The powder particles are removed by the rubbing action. Speed and sizes of these type of polisher are similar to that of cylindrical dehusking roller (Table 1).

Another type of machinery provided for this purpose is a set of screw conveyors arranged in a battery for repeated rubbings (Fig. 9). The flights and shaft are covered with nylon rope[5,13] or velvet cloth. The speed of each screw conveyor varies (Fig. 9). The repeated rubbing adds to the luster of the dal which makes it more attractive. These polishers are commonly known as nylon polisher or velvet polisher depending on the material used and are available in a set of 2,3,4 or 5 screw conveyors[5,13].

Oil/water polish – The screw conveyor similar to one supplied for oil/water mixing (Fig. 10) is provided for oil/water polish. The speed, size and capacity, etc are similar to oil/water mixture (Table 1).

Brokens and Husk Separation Machinery

The mixture of brokens and

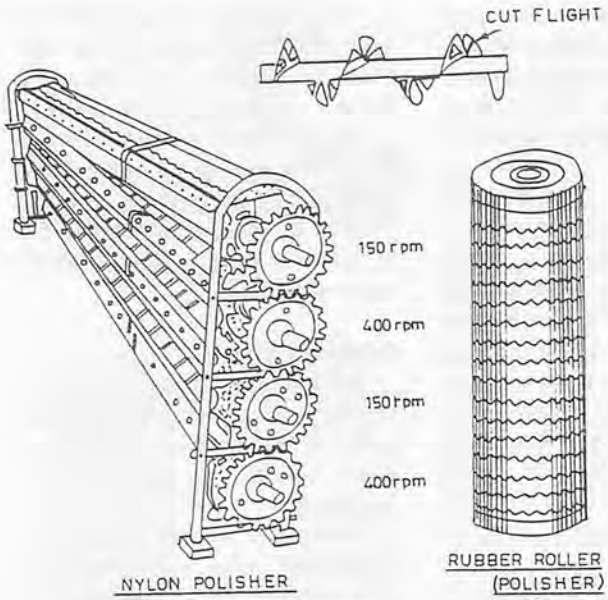


Fig. 9 Dal polisher.

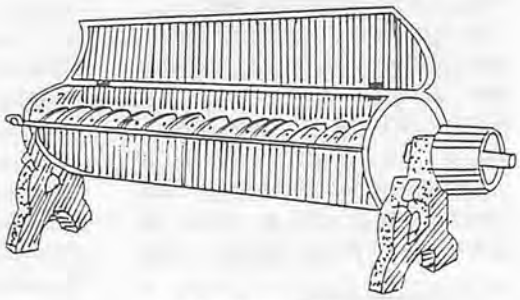


Fig. 10 Worm mixer.

husk is separated from the dehusked pulses and splits by using a suction fan or blower and the mixture is used as cattle feed. In order to separate the brokens for making available to human consumption, the use of a specific gravity separator is advocated by a manufacturer[12]. The firm has tried the machine and reported satisfactory results for separation of about 5% brokens available in the mixture. The machine is supplied with three, four, and five fans with a capacity ranging from 1400 lb (635.2 kg) to 10000 lb (4537.2 kg)/h.

Husk Dust Separation Equipment

A blower/suction fan for dust separation is supplied for the purpose. These are of different sizes (**Table 1**) and either with wooden or mild steel body. These units are fitted normally with the pulse cleaner-cum-grader, gota separator and dal grader for the separation of light materials, e.g., trash, dust, husk, fines, etc.

Elevating Equipment

Bucket elevators are used in dal mill plants for the vertical movement of raw materials in feeding the processing machine for continuous flow and at the proper feed rate. Capacity and height depend upon the capacity of receiving machine and plant layout, respectively (**Figs. 1, 2** and **3**). These are operated at different speeds ranging from 125-250 rpm. The suggested speed and power requirement varies with the manufacturer (**Table 1**).

However, in small capacity dal mills (**Fig. 1**) the raw material is fed to the machine manually or a combination of both manual and mechanical means is used.

Modern Dal Mill Plants

Modern mill and processing plants are based on CFTRI designs and are being manufactured on commercial scale[6]. The dal mill plant employs machines such as elevators, screw worm, graders (reciprocating sieves), aspiration fan, cyclone dust collectors and conditioning units.

Cleaning, Grading and Pitting

One grading machine with four sieves is used for separation of impurities and immature grains. One air suction fan is used to blow off the dust and light impurities. One pitting machine (emery rollers and emery-coated shell) with suitabley placed magnets is used for scratching of seed coat. The inlet of the machine has arrangement for flow regulation and instantaneous shut off. The delivery point is provided with a regulator for regulation of a pressure inside the machine. The clearance between roller and outer shell is adjustable.

Pulse Conditioning and Dehusking

A conditioning unit consists of two sets of tempering bins, two pulse heating units each having separate motorized blowers, air heat exchangers, grain heating chambers and feed hoppers. The temperature is controlled thermostatically. This entire unit is used for loosening of the husk.

One pearler (dehusker) with emery coated roller inside and all the arrangements of pitting machine is provided for dehusking operation.

Table 5 Technical Data of Modern Dal Mill Plant

Pulse	Capacity per 24 h	Space recommended L. × W. × H. (m)	Power kW	Labour	
				Skilled	Unskilled
Arhar (Pigeon pea)	12	15 × 8 × 8	70	1	8
Arhar (Pigeon pea)	24	20 × 8 × 8	110	1	10
Arhar (Pigeon pea)	48	25 × 13 × 8	220	1	15

Gota Conditioning and Splitting Unit

A gota conditioning unit consists of a motorized blower, air heat exchanger, gota heating chamber and thermostatic temperature control arrangement for gota heating and one blower for aeration chamber with mechanized delivery outlet for aerating gota.

The unit provides the conditions necessary for treating the gota and loosening the binding of the dals for minimizing the breakage and improving splitting.

One splitting unit and a dal grader with reciprocating sieves is used for gota spliting (by impact) and dal grading, respectively.

Dal Grading, Polishing and Packing Unit

One grading machine with two sieves for separation of fines and powdered husk, brokens and dal is used in grading, polishing and packing. The by-products are directly bagged while the dal passes through an aspirator for removal of dust. Gota is fed to gota conditioner for retreating.

One set of three aspirators connected to common suction fan and cyclone dust collector is provided for dust collection.

The dal polishing unit comprises of one water wheel dampener, water and oil mixing worm and one reciprocating sieve for final dressing of dal. This unit gives luster to dal by mixing oil and water and also to obtain commercially acceptable moisture level.

Stock Conveying and Handling

Five double elevators and one single elevator, all 6.2 m high, fabricated of steel, and used in stock conveying and handling. These elevators have provision for loosening or tightening of belts while in operation. Twelve bagging spouts of steel and other necessary pipings are provided.

Electrical Items

One 15hp/950rpm for common drive, one 10hp/950rpm for pitting machine, one 15hp/950rpm for pealer, one 5hp/1440rpm for gota separator, and heaters for conditioning units are required for 1 t/h capacity plant.

Advantages

As per the claims of the manufacturer[6] the modern dal mill has the following advantages over the traditional one:

i) Six to ten percent extra yield of dal;
ii) better quality – taste and appearance – dal;
iii) less space and manpower requirement;
iv) independent of weather conditions;
v) less working capital for stocks in process;
vi) lesser fixed capital when compared to investment on conventional dal mill for land, building, drying yard and machinery for similar capacity.

Other Machineries

Rice Polisher-cum-Dal Mill

Basically, this outfit is a rice polisher unit of under-runner emery disc sheller attached with a blower[10] with dimensions of 96 x 90 x 153 (height) cm and power requirement of 3 hp. It is claimed that the pulses can be milled using dal attachment.

Whole Pulse Polishing Machinery

Some pulses such as green gram, black gram, and pea are polished after cleaning and grading for upgrading the quality of pulses for consumption of whole pulse grains.

Cleaning and grading – Raw pulses are first cleaned and graded either in rotary sieve cleaner or reciprocating sieve cleaner (**Figs. 1** and 2). Grades I and II materials are then polished.

Polishing of pulses – Polishing of whole pulse adds luster to the dal. This involves either removal of dust from grain surface or application of some edible oil on the grain surface. Rubber roller polisher[5], which is used for dal polishing (**Fig. 9**), is also used for removal of dust from grain surfaces. On the other hand, the grain screw conveyor is used for thorough mixing of oil with pulses (**Fig. 10**). The speed of operation is similar to that in dal polishing.

Roasting plant – Bengal gram and peas are consumed in roasted form. These are processed on small (domestic) as well as industrial scale. The unit operations involved are cleaning, grading, moistening, roasting, puffing and splitting, husk separation, grading and packing.

A complete automatic plant is available[18] for industrial-scale production of roasted pulses and other grains. The plant includes a rotary cleaner-cum-grader, moistening unit, roaster, puffing hot plate and splitter roller (metalic with knurled surface) and husk separator. Fuel for roaster unit can either be furnace oil or husk.

The suggested[18] process is: Cleaning and grading of gram → roasting at about 120°C → cooling in shade for 4 to 6 h → water application (3-5%) → roasting at 200°C → puffing and splitting → husk separation grading and packing.

Besan (Pulse Flour) Plant

Besan making consists of three unit operations, viz., size reduction, conveying and elevating and flour dressing followed by packing.

A pulverizer is used for size reduction of gram dal up to fine size. A screw conveyor is used for conveying the ground material from the pulverizer outlet to the elevator inlet. The bucket elevator is used for feeding the material to the floor dressing machine.

Conclusions

The existing machinery needs to be modified, improved and brought to some standard level for avoiding or minimizing the milling losses. It is imperative to initiate some steps for the standardization of the pulse processing machinery with specific reference to energy requirement, design and operational factors and technical specifications for better yield and proper layout of the dal mill plant. There is a need to prescribe the optimum limit(s) of dal recovery for different types of pulse processing plant for avoiding the wastage of dal due to faulty process and machinery.

The machinery development studies or efforts are aimed mainly at modifications in existing plants or testing of some new ones. These studies are in isolation and non-continuous type and, therefore, do not reach the final stage. The GBPAU&T, Pantnagar developed a prototype of industrial scale dal mill and is under testing stage. The Indian Standards Institution (ISI) has also taken some initiative in formulating standards but much remains to be done.

The problem of the pulse processing industry with specific reference to machinery and process can be solved to considerable extent through detailed studies on machinery and process development/modifications and screening of pulses (varieties and types) for their milling and other post-harvest qualities.

Table 6 Machine Factors Affecting Dal Mill Performance

Machine	Design factor	Operational factor
Cleaner and grader	Type and number of sieves perforation size and orientation. Aeration facilities, screen cleaning facility	Feed rate, screen oscillation magnitude and frequency, air rate
Roller	Roller size and material properties, feed control, type (cylindrical, tapered emery size, foundation slope	Roller speeds, clearance, pressure on roller, feed rate
Husk separater	Screen type and size	Feed rate, air rate & pressure
Oil/water mixer worm	Type of screw (cut/full flight), length, capacity, material	Speed, feed rate, oil/water to raw material ratio
Under-runner disc sheller	Emery size and bonding disc	Disc speed, clearance, feed rate
Dal grader & gota separator	Type of the separater (rotary, vibratary) opening size, stroke length	Feed rate, deck/table oscilla-magnitude and frequency, slope
Dal polisher	Type of the polisher (Cone/oil worm, nylon) size, length, flight type	Feed rate, speed, clearances, air quantity & pressure

REFERENCES

1. Kulkarni, S.D. 1986. Pulse Processing in India – A Status Report. Division of Agricultural Engineering, IARI, New Delhi.
2. M/s G. Venkateshwara. Dal Machinery and Furniture Works, Shankar Bagh, Near Usmanganj, 5-3-744, Hyderabad-500012.
3. M/s Guru Nanak Engineering Corporation, 2-3-790/17, Golnaka, Amberpet, Hyderabad-500013.
4. M/s Mecano Industries (India), 2-3-723/A, Behind Karkhana Zinda Tilismat, Amberpet, Hyderabad-500013.
5. M/s Chhaju Ram Mistri Marwari, Bheron Nala, Belanganj, Agra-Pin. 282004.
6. M/s S.K. Engineering & Allied Works, Sheonagar, Bahraich-287801.
7. M/s Dahanu Industrial Works, P.O. Box No. 12, Dahanu Road-401602.
8. M/s Laxmi Engineering Works, C 113 Qrt. Spl. D class, 2-4-560, Behind Kachiguda, Amberpet road, Hyderabad.
9. M/s G.G. Dandekar Machine Works Ltd., Bhivandi-421302.
10. M/s Kisan Krishri Yantra Udyog, 64 Moti Bhavan, Collectorganj, Kanpur-208001.
11. M/s Saboo Udyog, 11, Shastri Nagar, Jodhpur.
12. M/s Krishiseva, Shed No. 83/1 Plot No. 76, Naroda Industrial Township, Ahmedabad-432330.
13. M/s Annapurna Industries, Lalimli, Patna-800009.
14. M/s Thermax Pvt. Ltd., Chinchwad, Pune-411019.
15. M/s Ganesh Engineering and Industries Company, 74 Perumal Mudali Street, Madras-600001.
16. M/s S.R. Industries, 77 Acharappan Street, Madras-600001.
17. M/s. Monarch Engineering Works., 13 Kharwa Lane, 6th Kumbharwada, Bombay-400004. (Leaflets, 1984).
18. M/s. Shanamugam Pillai and Sons., 12 Chellandiamman Kovil Street Dindigul-624010. (Leaflets, 1985). ■■

Some Factors Causing Rice Milling Loss in Bangladesh

by
N.N. Sarker
Assoc. Prof.
Dept. of Farm Power and Machinery
Bangladesh Agric. Univ.
Mymensingh, Bangladesh

Shah M. Farouk
Professor
Dept. of Farm Power and Machinery
Bangladesh Agric. Univ.
Mymensingh, Bangladesh

Abstract

Among all operations performed in harvest and post-harvest processing of rice, major losses occur during milling. With a conservative loss estimate of only 6% during the milling process, Bangladesh has a chance of losing rice of worth about US$170 million annually. From a study on some rice mills in the Mymensingh district of Bangladesh, it was observed that inadequate parboiling treatment, development of fissure in the grains, and the nature of milling equipment used were some important factors responsible for losses during milling: an individual grain may lose as much as about 25% of its head rice weight if broken during milling; and the major loss occured immediately after breakage of grains when the broken parts with sharp edges were subjected to rounding and smoothening actions as they moved onward by rolling through the milling chamber before being finally discharged as milled rice. Restricted degree of milling and introduction of a set of standards for milling equipment and the procedures are suggested as means of reducing the milling loss of rice.

Introduction

As found by de Padua (1974), the major loss occurs during milling which may range from 2% to as high as 10%. With a conservative loss estimate of only 6% from about 11.32 million t of brown rice produced in Bangladesh in 1983-84 (Year Book, 1985), there was a total loss of about 0.769 million t of edible rice, worth about US$170 million. This quantity of rice could have been used to feed a population of about 6 million for a year.

Breakage and over-milling of rice kernels are two distinct ways through which loss of rice takes place during milling (Yoshizaki, et al, 1983). Through both of these ways the weight of a rice kernel is reduced due to the scouring of the endosperm in the form of fine particles which usually accumulate with the bran as a non-separable product. The cumulative effect of this phenomenon is a reduction in milling yield accompanied by the degradation of milled rice. The major factors responsible for grain loss during milling are: i) fissures (cracks) in the grains; ii) type of milling equipment; iii) degree of bran removal; iv) physical dimensions of grains; and, v) content of immature kernels in the lot (Tani, 1983). Immature kernels do well in milling if parboiling treatment is done before milling (Matthews, et al, 1982), but the degree of parboiling may have direct influence on the loss during subsequent milling operations.

The thickness of the bran is not uniform throughout the surface of brown rice and, in addition, there are some longitudinal ridges and depressions along the surface of brown rice. This requires the rice grain to be milled more for complete bran removal and, as a consequence, results in a lower milling yield. Continuation of whitening for higher degree of bran removal causes further breakage of some sound grains (Yoshizaki, et al, 1983).

In some countries the degree of bran removal is restricted by law, e.g.; in India it is limited to 4% by weight of brown rice (Tani, 1983). The degree of loss due to over-milling is a comparative matter of judgement based on the degree of milling accepted as the standard in a country. Bangladesh, however, has yet to adopt a standard in this regard. The qualitative and quantitative effects of the various steps in rice processing as practised in Bangladesh need a detailed study for finding possible ways of minimizing milling losses and for suggesting milling standards.

Materials

Five large rice mills with individually operated parboiling facilities situated in the industrial

estate of Mymensingh and three others at Tarakanda, a well known rice producing area north of Mymensingh were visited to collect information on rice milling technology. Rice samples were collected from three of these rice mills. Another set of rice samples were collected from three small rice mills in Bhaluka south of Mymensingh. These small rice mills do not have parboiling facilities to which individual farmers bring parboiled paddy in lots of about 50 to 100 kg at a time for milling.

Rice varieties readily available in the mills were selected for this study in order to avoid the difficulty of getting an intended variety at a selected rice mill.

Methods

A pre-designed questionnaire was used in collecting information on soaking and steaming duration, additive uses in soaking water, milling capacity and milling yield. Physical dimensions of rough rice, brown rice and milled head rice were measured with a screw gauge. Weights of 1 000-grain samples of rough and milled head rice were measured with an analytical balance (The terms rough rice (paddy), head rice and milled rice used here are in comformity with the American and Japanese usage).

Data on actual milling output were obtained from the millers and were expressed in percentage of rough rice fed for milling. Expected milling output was determined at the laboratory by taking the weights of 1 000-grain of milled head rice and the corresponding weight of 1 000 grain of rough rice and then expressing the weight of milled head rice as a percentage of the weight of the rough rice. Any shortfall in actual milling output from this expected milling output was considered as the milling loss due to breakage of grains. The broken grains were separated from the head rice of a sample with a tray grader. The number of broken grains in a sample was determined by weight analysis. Loss due to the breakage of single grain was determined by dividing the loss in weight of milled rice (milling loss) by the number of broken grains. This loss was finally converted to percentages of single milled head rice weight.

Fissures that developed in the grain were determined by visual observation after hand shelling of the rough rice and were expressed as a percentage of the total grains tested. This crack counting test was performed after a few days of the sample collection when the possibility of further crack generation had ceased.

Results and Discussions

Parboiling Treatment

Large rice mills have parboiling facilities of local design in which the so-called "dho-bhamp" or double steaming technique is utilized. This technique is composed of the application of steam first time for about 4 to 7 min to the dry rough rice. This pre-heating is considered advantageous since the preheated grains cause a rise in temperature of the soaking bath and the total time required for soaking is reduced.

The usual soaking time, as reported by the millers, was between 24 and 36 h, but soaking might be prolonged for further period when weather did not permit immediate drying following the steaming process. The millers reported occasional addition of potash alum (K_2SO_4, $Al(SO_4)3$, $24H_2O$) to the soaking water in order to produce a shiny milled product at a rate of about 0.55 kg/t of rough rice to be soaked.

Steaming is carried out in a cylindrical hopper kettle made locally with sheet metal the capacity of which is about 370 kg soaked rough rice. After the kettle is filled with soaked rice the top is closed and steaming begins through a single steam pipe at the center. In about 10 to 15 min the steaming is considered complete and the rough rice is discharged through the bottom opening for transfer to the drying floor within the mill complex.

The use of single steam pipe was found responsible for over-steaming of the rough rice located at zones nearer the pipe while producing under-steamed rice at the further end of the kettle. Over-steaming resulted in over-opening of husk components followed by bulging out of endosperm which initiated surface scouring during milling and the resultant ground particle being lost into bran. On the other hand, under-steaming retarded gelatinization towards the center of rough rice grain which was identified by a white area at the center when viewed after dehusking by hand peeling. Under-gelatinized grains have less strength (Itoh, 1983) and may easily break during milling. Therefore, the degree of steaming is needed to be optimum and uniform in order to reduce the milling loss.

Rough rice was reported to be stirred intermittently in manual operations during sun drying for uniform moisture removal up to around 13.5%. Milling at high moisture level, when done carefully, helped increase the output of the milled rice, but this seriously affected the storability even for a month. Some samples had to be rejected due to mold growth before completion of all laboratory analysis.

Type of Milling Equipment

The traditional method of milling rice in the rural areas of Bangladesh is the use of "dhenki" comprising of mortar and wooden

Table 1 Rice Mill Performance and Some Laboratory Test Results

Rice mill	Variety	Actual milling recovery	Laboratory test results						
			1 000-grain weight, g		Expected milling recovery	Milling loss	Crack	No. of grain broken	Loss per grain if broken,
			Rough rice	Milled rice					
		a	b	c	$d = \frac{c}{b} \times 100$	f = (d–a)		g	$\frac{f}{g} \times \frac{1\,000 \times 10}{\text{(head rice weight)}}$
		%			%	%	%	%	%
1*	IR-8	68.50 (74.15) △	27.65	20.00 (21.50)	72.33 (77.76)	3.83 (3.61)	36	24.68 (37.75)	21.45 (12.30)
2*	IR-8	66.67 (72.67)	28.08	20.08 (20.90)	71.51 (74.43)	4.84 (1.86)	20	27.17 (33.97)	24.91 (7.22)
	Pajam	65.63 (69.35)	16.75	11.90 (12.25)	71.05 (73.14)	5.42 (3.79)	14	30.77 (41.33)	24.61 (12.54)
3*	Pajam	68.00 (70.90)	17.15	12.26 (12.86)	71.49 (74.99)	3.49 (4.07)	11	22.85 (28.34)	21.36 (23.86)
4**	IR-8	67.50	28.65	20.02	69.88	2.38	22	27.25	12.50
5**	IR-8	70.00	29.40	21.30	72.45	2.45	00	18.07	18.71
6**	Boro	70.00	19.90	14.30	71.86	1.86	11	10.56	24.52
	Pajam	67.50	16.00	11.60	72.50	5.00	09	30.15	22.87

* – Large rice mills, ** – Small rice mills, △ – Results of milling done by 'dhenki'.

pestle, and operated manually by rural women. The pestle applies a normal force onto the grains kept in the mortar, and the direct action of this force is to break rather than mill the grains. The friction force generated due to relative grain movement helps in milling operation. A friction type mill (Engelberg type steel huller), common in Bangladesh, dehusks and whitens the rice by friction whereas an abrasive type machine (under-run disc sheller, rubber-roll dehusker and other abrasive type stone whitener) does the same job through abrasive effect.

The figures in parentheses in **Table 1** show some laboratory results of milling done by the dhenki where the degree of milling was restricted to a lower level than the usual rating as preferred by consumers. In all the cases, the number of grain breakage was higher than that by the mills, but the losses per grain were lower. Initially, the broken grains have sharp edges but as a broken part of a grain moved onward by rolling through the milling chamber, it continued to be subjected to smoothening and rounding actions and the size of the broken part continued to be smaller and smaller (**Fig. 1**). Thus the major loss occured immediately after the breakage, the degree of such loss being a function of the resident time of the broken parts inside the milling chamber. But in the case of the dhenki milling where the degree of milling was restricted to lower levels, the broken parts and less time and chance for smoothening and rounding actions. The result was thus lesser loss from individual grain although the percentage of breakage was higher.

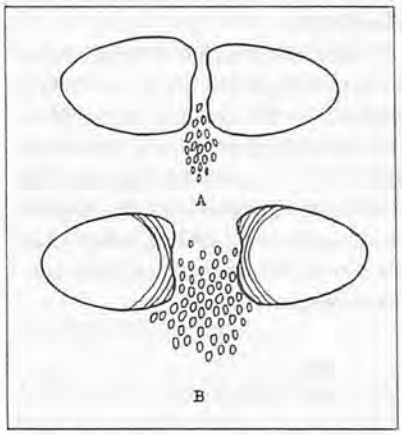


Fig. 1 Phenomena of breakage of rice:
A – Loss during breakage;
B – Loss during rounding and smoothening of broken parts.

Fissures in Grains

Rough rice milled by small rice mills had low number of fissures (cracks) (**Table 1**) which may be due to better care during drying by owners of the rice.

Although it is known that the fissures in the grains appear to be the single most important factor contributing to rice breakage during milling (Tani, 1983), the breakage, in this study, was found to have some poor linear relationship ($r = 0.4$, $n = 8$) with the presence of fissured grains in lots at mills. This poor relationship may be due to the different lag periods between drying and milling observed at different mills, since the development of fissures in grains continues to grow up to several hours or few days after drying. However, in most cases, the number of grain breakage were in excess of the number of the fissured grains present. This explains why breakage continued as the whitening operation proceeded. This observation agrees with the findings of Matthews (1970) and Yoshizaki, et al (1983).

Physical Dimensions of Grains

It is interesting to note from **Fig. 2** that thickness of grains do not always increase proportionately with the increase of length of grains. Rather, there may be some

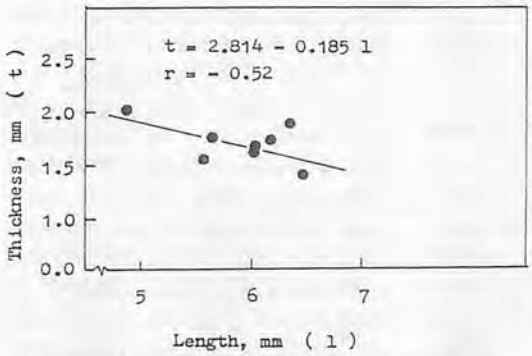


Fig. 2 Relation between length and thickness of brown rice.

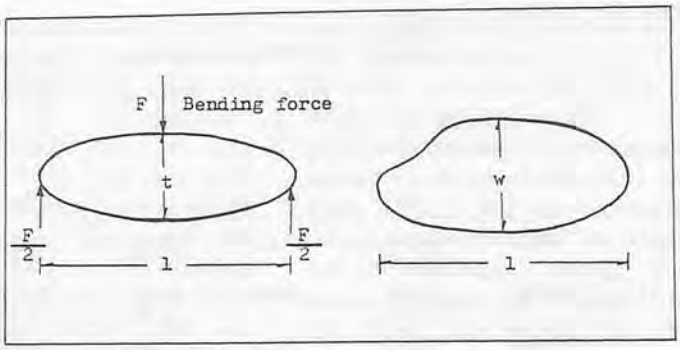


Fig. 3 Physical dimensions and forces acting on a rice grain during milling operation.

inverse correlation ($r = -0.52$, $n = 8$). This correlation includes the dimensions of one variety each from Japan, America and Thailand (Yoshizaki, et al, 1983), in addition to the other five varieties grown in Bangladesh.

Using the Flexure Formula for a simply supported beam, $s = My/I$, where s is the bending stress, M is the bending moment, y is the depth and I is the moment of inertia, the following equation can be derived to describe the bending stress that may be acted upon a rice grain during milling:

$$s = \frac{3Fl}{wt^2} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Here s is the bending stress induced at the center of the grain. The other notations are defined in **Fig. 3**.

Equation 1 suggests that longer grains face higher amount of bending stress because the thickness, t which should have stress reducing effect proportional to t^2, as with the width, w, cannot reduce as such as **Fig. 2** tells about an inverse relation between the length and thickness. This is why long-grain rice varieties are more susceptible to breakage than the short grain rice varieties during milling operation. Moreover, a short grain has much chance to escape from many stress situations within the milling chamber because of its shorter span (length). This agrees with the observation by Sarker, et al (1984) that the flowability of short grains is higher than that of long grains through the milling chamber of friction type whitening machine and results in lower degree of breakage during milling. However, they did not use the Flexure Formula in the analysis of breakage of grains with respect to physical dimensions. Also, the concept of Flexure Formula could have not been used directly in the present because of the methodological limitations of this study.

Quantitative Rice Loss due to Breakage

Table 1 shows the quantity of endosperm loss from each grain if broken. It has been estimated that an individual grain, if broken during milling, may lose from 12.5% to as high as 24.91% of its head rice weight. This loss from individual grain accumulated to a total average milled rice loss of 3.66 kg per 100 kg of rough rice fed for milling.

Conclusions

i) The use of single steam pipe for steaming rough rice was inadequate for uniformly parboiled rice. Improvements in the steaming equipment design should help minimize milling losses from breakage and surface scouring of rice resulting from non-uniform parboiling.

ii) Due to continued mechanical stresses on grains the breakage percentage was found to exceed the percentage of fissured grains in a sample.

iii) Individual grains were found to lose as high as about 25% of its head rice weight if broken during milling. However, this depended on the amount of smoothening and rounding actions imparted on the broken parts as they rolled through the milling chamber.

iv) The average rice loss due to breakage was 3.66 kg of milled rice per 100 kg rough rice fed for milling.

v) Restricted degree of milling tended to increase the milling yield and of retaining more nutrients in the milled rice.

vi) A set of standards regarding the degree of milling and the selection of parboiling and milling equipment are necessary for improving the performances of the rice-processing industry in Bangladesh.

REFERENCES

de Padua, B.D. 1974. Post-harvest Rice Technology in Indonesia, Malaysia, the Phillipines and Thailand: A State of Art Survey. IDRC. Canada.

Itoh, K. 1983. Processing and milling of parboiled rice. Report of the Special Research Project on Tropical Agricultural Resources, 2, University of Tsukuba, Japan: 133-141.

(Continued on page 56)

Resistance of Sorghum, Peanut and Seasame to Air Flow

by
Mustafa A. Hummeida
Lecturer
Dept. of Agric. Engg.
Faculty of Engg. and Architecture
University of Khartoum
Khartoum, Sudan

Ahmed El Tayeb Ahmed
Mechanization Specialist
Dept. of Agric. Engg.
Faculty of Engg. and Architecture
Univ. of Khartoum
Khartoum, Sudan

Abstract

Experiments were conducted in order to obtain information on resistance to air flow of local varieties of crops such as sorghum, peanut and sesame at various moisture content levels. The crop moisture content ranged between 9.4 and 25% (w.b.) for sorghum, 4.1 to 30% for peanuts, and only one moisture content for sesame, 4.0% (w.b.). Airflows in the range of 0.02 to 0.41 m^3/s were forced using a centrifugal fan. Pressure drops across various beds of sorghum, peanuts and sesame were measured using a micromanometer. The effects of moisture content and airflow rates on the resistance were analyzed. The resistance to airflow in sorghum and unshelled peanuts decreased with an increase in the crop moisture. The pressure drops across the grain beds were disproportionate with the increase in airflow rates. The resistance of the two varieties of peanuts were different due to varietal differences in shape and size.

Introduction

Sudan is a vast country with arable land of about 58.9 million ha of which only 8.4 million ha are under cultivation. The area planted to grains is about 4.8 million ha (58% of the cultivated area). The total production of sorghum in the rainfed area was estimated by the MFC (1987) at 3.4 million t and that of sesame at 0.12 million t. However, the total peanut production in the country was estimated by the statistics Division (1985) at 0.386 million t.

Because of the recent increase in the production of grains more attention has been given to storage facilities and storage practices. One area of concern which should be given more emphasis is the management practices of grain during the storage period. The practices, besides fumigation, include aeration of grain.

When air is forced through grain, resistance to the flow develops as a result of the energy lost through friction and turbulence. The determination of this resistance is fundamental in the design of drying and aeration systems. In order to select a fan capable of overcoming the resistance offered by drying or aeration systems, one has to know the resistance developed in a particular bed of grain.

The resistance to airflow of crops depends on the airflow rates, the surface area and shape, configuration of voids, the variability of particle size, grain bed depth, and crop moisture content (Brooker et al, 1974).

Because the resistance to airflow of agricultural crops is affected by all the aforementioned factors, it becomes necessary to determine the resistance of the local varieties.

The objective of this study was to obtain information on the air resistance of sorghum, sesame, and varieties of peanut at various moisture content levels.

Literature Review

Data on the airflow – static pressure relationship of a number of biological products have been published in graphical form by the ASAE (1983). Those curves known as "Shedd's curves" are widely used in the absence of data for a particular crop.

Several studies have been undertaken to obtain empirical and theoretical equations to fit experimental curves relating to airflow and pressure drop (Shedd, 1953; Jindal and Thompson, 1972; and Ahmed et al, 1982).

Materials and Methods

Experiments were conducted with a clean local variety (*Feterita Gadam* Elhaman) of grain sorghum (1% damaged kernels), two varieties

of clean unshelled peanut (Ashford and Barberton) and one local variety of sesame (white). The moisture content of the crop ranged between 4 and 40% (w.b.), the high moisture content being obtained by rewetting. Each crop was tested with six different airflow rates in the range of 0.02 to 0.41 m^3/sm^2. Three replications were done for each moisture level.

An apparatus was constructed to conduct the experiment (**Fig. 1**). The test column was constructed by rolling 0.6-mm galvanized steel sheets into a cylinder 0.20 m in diameter and 1.27 m long. The floor of the test bin was constructed of 1.55 mm galvanized steel sheet. Holes of 9.5 mm diameter were made on the floor, a total opening area of 35% of the floor aera.

A sieve mesh of 1.0 mm size was placed above the perforated plate to prevent the grain from falling into the plenum chamber.

At approximately 70 mm above the floor level, holes of 4 mm diameter were drilled through the wall in two vertical rows. In one row six holes were drilled at a distance of 0.2 m apart. In the other row, seven holes were drilled at intervals of 0.05, 0.05, 0.1, 0.1, 0.2 and 0.5 m. Copper tube pressure taps, 3 mm in diameter and 50 mm in length, were fitted into those holes and were welded to the test column wall. The plenum chamber was a 0.40 x 0.45 x 0.60 m rectangular box made of 1.55 mm galvanized steel sheet. The air duct composed of two sections, conical and cylindrical was made of 0.6 mm galvanized steel sheet to carry air from the fan to the plenum chamber.

Fig. 1 Laboratory apparatus for the experiments.

The air was supplied by a centrifugal fan powered by a single phase variable speed motor of 1.4 hp and of maximum speed 9 600 rpm.

Measurement of air flow forced into the test beds were made with a thermal anemometer. It was caliberated at the manufacture's laboratory to give direct velocity at 20°C air temperature. The air velocity was taken according to AMCA (1977, 78) recommendations and was corrected from the correction curves provided by the manufacturer. The corrected velocity was converted to apparent velocity and was expressed in m^3/sm^2.

The test bin was filled by loose-fill method as described by Shedd (1953). The crop was poured into a funnel the outlet of which was held just above the grain surface, making sure to raise the funnel gradually as the filling progressed. The top surface of the product was levelled by hand. The depth of the test beds was 0.60 m for grain sorghum, 1.07 m for peanut and 0.15 m for sesame. This was because of the limited power of the electric motor driving the fan.

After the test bin was filled with clean grains, the variable speed motor was turned on and the desired airflow was set by adjusting the speed control knob.

Static pressure drops between taps 0.5 m apart in the case of grain sorghum, 1 m apart in the case of peanut and 0.1 m apart in the case of sesame were measured with a micromanometer.

Results and Discussion

The static pressure drop data and the moisture content of each crop, for the three replications, were plotted on log-log graph against airflow (**Figs. 2, 3, 4 and 5**). The best lines of fit as determined by regression analyses were also plotted on the same papers. Also for comparison, Shedd's data (1953) was plotted on the same paper.

Fig. 2 shows that all the curves for sorghum run almost parallel to Shedd's curves. However, all the experimental curves obtained fell to the left of Shedd's plot. The slight displacement of the curves to the left of shedd's curves may be attributed to the varietal differences in size and shape of the grains. **Fig. 2** also shows that the high moisture grain sorghum displayed less resistance than the dry grains. This trend

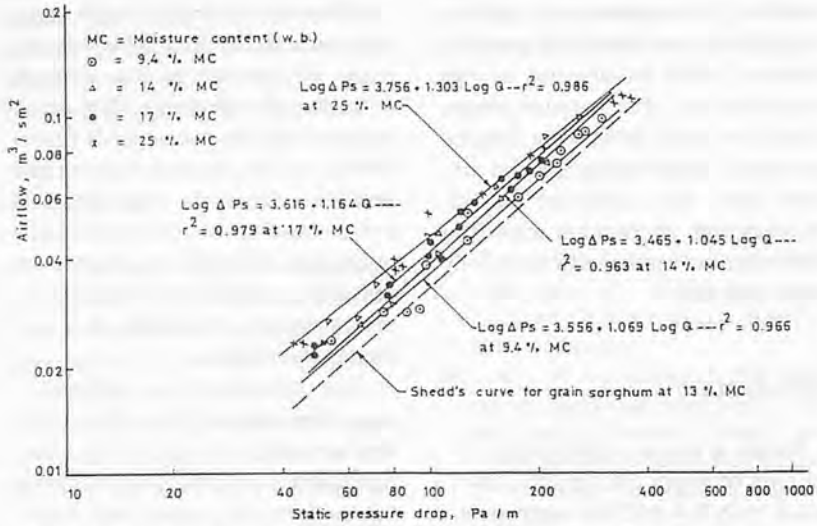


Fig. 2 Resistance of grain sorghum to airflow at various moisture content levels.

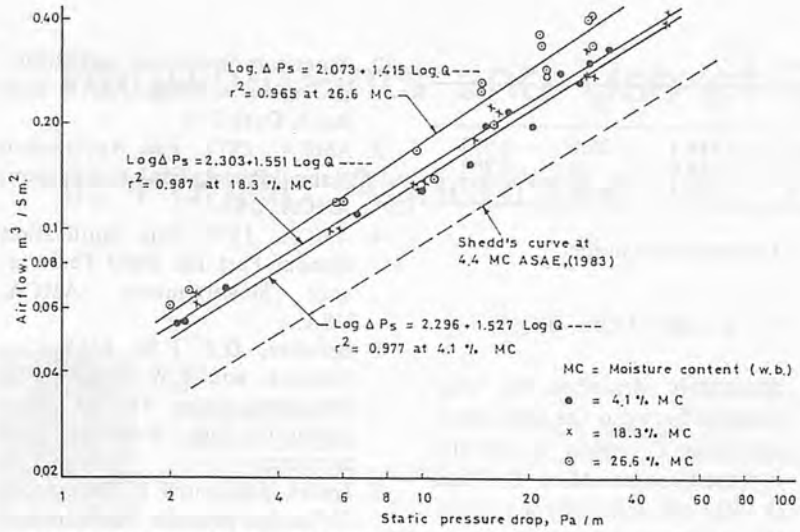


Fig. 3 Resistance of unshelled peanut (Ashford) to airflow at various moisture content levels.

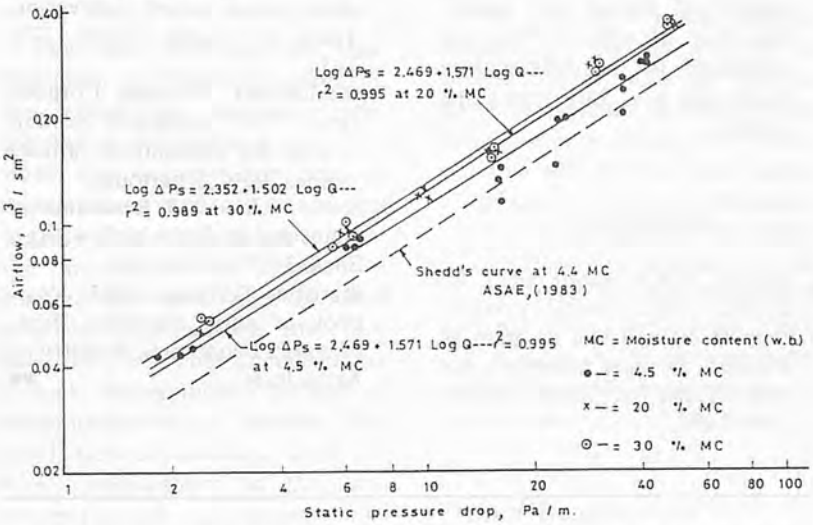


Fig. 4 Resistance of unshelled peanut (Barberton) to airflow at various moisutre content levels.

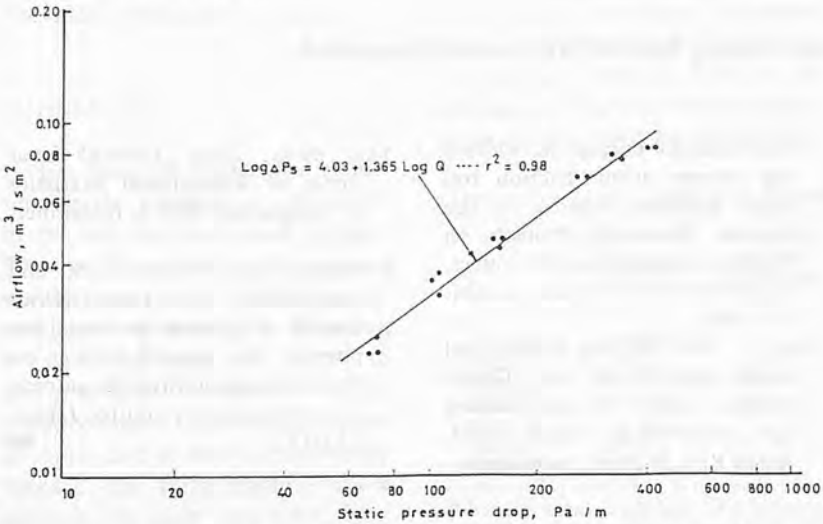


Fig. 6 Resistance of seasame to airflow at 4% moisture content (w.b.).

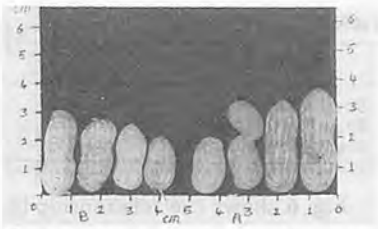


Fig. 5 Difference in shape and size of peanut samples: A – Ashford and B – Barberton.

was consistent over the tested range of moisture content.

Figs. 3 and **4** show that all the plot curves for peanut ran almost parallel and to the left of Shedd's curve. It also shows that plot curves for Ashford were far away to the left of Shedd's curve than Barberton. This was attributed to the effect of varietal differences in shape and size, where Ashford pod size is longer than the Barberton (**Fig. 5**). For each variety the high moisture peanut displayed less resistance than the dry one. This trend was consistent over the range of moisture content tested.

Prediction equations for the static pressure drop as affected by the airflow and moisture content were obtained for grain sorghum and the two varieties of peanut. The non-linear regression model of the form:

$$Ps = A + BQ + CQ + DQM,$$

where, Ps = static pressure drop in Pascal per meter depth crop

Q = airflow in m^3/sm^2
M = grain moisture content, % (w.b.)

A, B, C and D = product constants, gave the best fit as compared to other forms of equations.

Table 1 shows the values of the constants A, B, C and D for the tested crops and the coefficient of determination obtained for the fitting of data.

Table 1 Crop Constants

Sorghum	A	B	C	D	r^2
Sorghum	4.3	2 445.7	10 918.1	−35.6	0.995
Peanut (Ashford)	−3.2	101.2	54.6	−1.0	0.962
Peanut (Barberton)	−2.8	107.1	181.5	−1.2	0.983

Fig. 6 shows the relationship between static pressure drop and airflow through the sesame crop at 4% moisture content (w.b.). The pressure drop increased as the airflow increased. The equation of the form:

$$\log Ps = 4.03 + 1.37 \log Q \ldots\ldots \quad r^2 = 0.98,$$

adequately describes the relationship between the static pressure drop and airflow.

Conclusion

1. The static pressure drops in grain sorghum, and unshelled peanuts decreased with the increase in the moisture content of the grains. Estimation of the fan power requirement for aeration systems should be based on the resistance of low moisture crops.
2. The statistical model:

$$P = A + BQ + CQ^2 - DQM,$$

adequately describes the relationship between the static pressure drop P, airflow Q, and the moisture content M. A, B, C and D were constants dependent on the crop type and variety.

3. The resistance of Barberton variety of peanut was greater than that of Ashford. This was attributed to the difference in shape and size, Barberton being smaller.

REFERENCES

1. Ahmed, Y.N.E. Haque, and C.W. Deyoe, 1982. Static pressure drop in a fixed bed of grain as affected by grain moisture content. Trans. of ASAE 25(4): 1095-1098.
2. American Society of Agricultural Engineers. 1983. ASAE Year Book. Data 272.
3. AMCA. 1977. Fan Application Manual Part I. Fans and system. AMCA, USA.
4. AMCA. 1978 Fan Application Manual Part III. Field Performance Measurements. AMCA, USA.
5. Brooker, D.B., F.M. Bakker – Arkema, and C.W. Hall, 1974. Dry cereal grains. The AVI publishing Co. Inc., Westport, Connecticut.
6. Jindal, V.K. and T.L. Thompson, 1972. Air pressure patterns and flow paths into two-dimensional triangular shaped pils of sorghum using forced convection. Trans. of ASAE. 15(4): 373-741.
7. Mechanized Farming Corporation, 1987. Estimated production in the mechanized farming regions. MFC, Khartoum.
8. Shedd, C.K., 1953. Resistance of grains and seeds to airflow. Agr. Engg. 34(9): 616-619.
9. Statistics Division. 1985. Yearbook of Agric. Statistics. Dept. of Agric. Economics, Ministry of Agriculture. ■■

Continued from page 52

Some Factors Causing Rice Milling Loss in Bangladesh

Matthews, J. et al. 1970. Relation between head rice yield and defective kernels in rough rice. Rice Journal, 73(10): 6-12.

Matthews, et al. 1982. Characteristics of thin rice kernels before and after parboiling. TRANSACTIONS of the ASAE: 818-819.

Sarker, N.N. and Miyahara, S. 1984. Breakage characteritics and bran particle distribution of selected rice varieties during the whitening process using friction roll type machine. Report of the Special Research Project on Tropical Agricultural Resrouces, 3. University of Tsukuba, Japan: 157-168.

Tani, T. 1983. Milling quality and eating quality of rice. Group training course in post-harvest rice processing, fiscal 1983. Japan Rice Millers' Association.

Year Book, 1985. 1984-85 Year Book of Agricultural Statistics of Bangladesh. B.B.S. December, p. 16.

Yoshizaki, S.; Miyahara, S. and Sarker, N.N. 1983. Losses of rice during whitening process. Report of the Special Project on Tropical Agricultural Resources, 2. University of Tsukuba, Japan: 121-132. ■■

Requirements and Use of Tractor Power in Punjab Agriculture

by
Joginder Singh
Extension Specialist
Dept. of Economics and Sociology
Punjab Agric. Univ.
Ludhiana, India

S.K. Sekhon
Dept. of Economics and Sociology
Punjab Agric. Univ.
Ludhiana, India

Amarjeet Kaur
Dept. of Economics and Sociology
Punjab Agric. Univ.
Ludhiana, India

Abstract

The rapid technological transformation in Punjab agriculture in the recent past has necessitated the use of mechanical power. This study examines the gap between requirements and use of tractor for the State. It is suggested that the increase in the number of tractors have been faster than that of their requirements. But they have not been able to replace the bullock labour mainly because of under-utilization of tractors. The small size of holdings, trend towards specialization in the farm enterprises and thus seasonal use of tractors and their uneven spread in the State have been responsible for the under-utilization of tractors.

Introduction

The State of Punjab has shown remarkable progress in agriculture in the last two and a half decades. This rapid technological transformation is basically irrigation-seed-fertilizer technology. However, there is still need for farmer to perform farm operations well in time, to ensure uniform application of inputs and to meet the increasing demand for farm labour. In the context of these urgencies, farm mechanisation in Punjab became important.

The mechanical inputs recently adopted by the farmers are of different forms such as tractors, threshers, combine harvesters, tubewells, power sprayers, etc. Tractor and tubewell are the basic inputs which largely determine the extent of farm mechanization. This study was, therefore, undertaken to determine the extent to which tractors have substituted the bullock labour and to estimate the increase in the availability and requirements of tractor power.

Tractor Requirement

It is evident from **Table 1** that the number of tractors increased from 2 909 units in 1955-56 to 165 000 in 1984-85. The rate of increase in tractors was the maximum during 1965-66 to 1970-71 period which showed a simple annual growth rate of 54.84%. The growth rate slowed down in the latter period but the annual absolute increase went up to 12 149 tractors units during the period 1975-76 to 1980-81. The increment declined to 7 990 tractors in the next 5 years.

The average area operated by a tractor in the State was about 25 ha. On the basis of the cropping pattern in the State and the number of hours of use of tractor per acre, the total hours of tractor requirement was divided by 1000, the optimum hours of use of tractor per annum, in order to estimate the total tractor requirements as shown in the formula:

$$\text{Tractor requirements} = \frac{\Sigma A_i P_i}{1000}$$

Where A_i is the area under *i*th crop and P represents the tractor

Table 1 Tractor Requirements and Availability in Punjab State, 1955-56 to 1984-85

Year	Total no. of tractors available	Per annum simple growth rate (%)	Average annual increase (number)	Number of tractor required*	Tractor available to tractors required (%)
1955-56	2 909	–	–	107 260	2.71
1960-61	4 935	13.93	405	116 867	4.22
1965-66	10 636	23.10	1 140	125 781	8.47
1970-71	39 798	54.84	5 832	150 794	25.73
1975-76	64 307	12.32	4 902	167 450	38.40
1980-81	125 052	18.89	12 149	190 611	65.60
1984-85	165 000	7.99	9 987	204 671	80.62

* Based on tractors required for various farm operations (Enterprise Budgets, Department of Economics and Sociology, PAU, Ludhiana) and the Cropping Pattern in the State (Statistical Abstract of Punjab).

power requirements in hours.

It is clear from **Table 1** that in 1955-56, the tractor requirements of the State agriculture was 107 260. But the tractor requirements continuously increased due to:

1. Increase in cultivated area: from 3 648 000 ha in 1955-56 to 4 189 000 ha in 1984-85.
2. Increase in cropping intensity due to the introduction of varieties of crops from 126.6 per cent in 1955-56 to 167.4 per cent in 1984-85.
3. Increase in area under enterprises requiring more power, e.g., paddy has replaced pulses and oilseeds which require less power. As a consequence, the total power requirement almost doubled in 1984-85.

If the available tractors are utilized to the optimum level, i.e., 1000 h per year, 2.71% of the total draft power requirements will be met. The balance will be met by the animal power. The percentage of availability to the requirements of tractor power increased consistently: 80.62% in 1984-85 indicating that under conditions of optimum tractor use about 80% of the draft power can be met through tractors. But in reality, this is not the case because the replacement of existing cattle power has to be slow. For example, the number of tractors increased at a very fast rate but the available bullock number has also increased though slightly (**Table 2**). In addition, the available tractor force is not used up to recommended levels because of the small size of operational holdings.

Table 2 Total Cultivated and Cropped Area and the Bullock Labour Available in Punjab, 1955-56 to 1984-85

Year	Total cultivated area (000 ha)	Total cropped area (000 ha)	Cropping intensity %	Bullock pairs available
1955-56	3 648	4 618	126.6	605 150
1960-61	3 757	4 732	125.9	626 550
1965-66	3 803	4 889	128.5	643 150
1970-71	4 053	5 678	140.1	700 200
1975-76	4 158	6 255	150.4	670 700
1980-81	4 191	6 763	161.4	685 450
1984-85	4 189	7 013	167.4	678 050

Conclusion

The introduction of tractor has, no doubt, provided additional power requirements for the State agriculture. But this process has not been able to replace the bullock labour. As a result, the cost structure has also been building up. To overcome this, the region-wise requirements of tractor needs to be carefully assessed. Liberal loaning policy for this purpose in areas where already tractors are in surplus need to be curtailed. ■■

1989 EDITION

FARM MACHINERY YEARBOOK

The 1989 edition now available has 210 pages of the latest comments, statistics and useful addresses pertaining to agricultural mechanization in Japan. The commentaries focus on trends in Japan's agricultural development and agricultural machinery industry and production and results of farm machinery research efforts.

The statistical information pertains to agriculture, in general, and agricultural mechanization, in particular. The yearbook also contains addresses and references of administrative authorities, experiment stations, farm machinery manufacturers and foreign address of use to importers and exporters.

It measures 18.0 cm x 26.5 cm in hard cover and sells for ¥10,300 (sea mail) and ¥12,000 (air mail).

SHIN-NORINSHA Co., Ltd.
7, 2-chome, Kanda Nishikicho, Chiyodaku, Tokyo 101 Japan

Design of Group Mechanization System Using 'CAFARMS' Computer Model for Kada Area

by
Toshio Konaka
Professor
Institute of Agricultural and Forestry Engineering
University of Tsukuba
Tsukuba-shi, Ibaraki-ken
Japan

Wan M. Zakludin
Former Graduate Student
Institute of Agricultural and Forestry Engineering
University of Tsukuba
Tsukuba-shi, Ibaraki-ken
Japan

Abstract

In order to improve the level of mechanization of paddy cultivation in Malaysia, in general, and in KADA* in particular, the machinery utilization system must be changed from the present 'hire system' to Group Mechanization System (GMS). To design the GMS for double cropping irrigated areas, a microcomputer model called CAFARMS** (1) was adopted. The farm operations included in the analysis were land preparation (tillage), transplanting and harvesting only because these three operations accounts for 78% of the production cost and 79% of the labour requirement in paddy cultivation in KADA (2).

Four machine systems and 2 manual systems were analyzed in this report. Each system is a unique combination of some of these machines plus manual and animal power – buffalo, power tiller, 37 kW tractor, 4 row transplanter, 4 row power seeder, 2 row reaper binder, power thresher and 4 row combine.

Introduction

Malaysia produced about 1.95 million t of rice in 1985 (3), and by the year 2 000 an additional 1 million t are required in order to maintain a self-sufficiency level of 80 to 82%. Production of rice can be increased by: a) practicing improved cultivation techniques; b) increasing

Fig. 1 Major paddy-growing areas in West Malaysia.

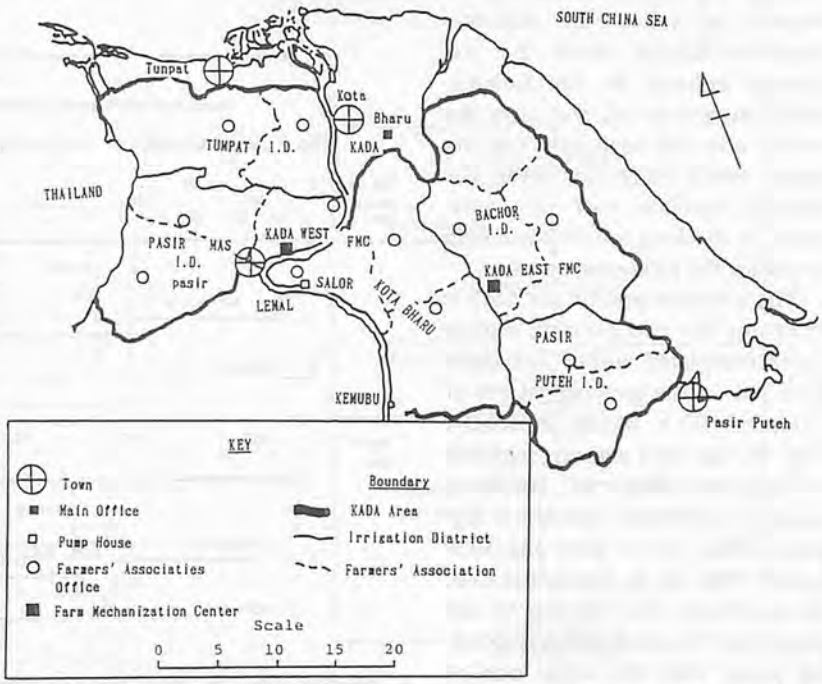


Fig. 2 KADA area showing the boundaries of Irrigation District and Farmers' Association.

Note: * KADA stands for Kemubu Agricultural Development Authority, an irrigation area in the north-east coast of West Malaysia (refer to map on Fig. 1 and 2).
** This model was designed by T. Konaka for the Japanese paddy cultivation condition, and its application procedure is described in detail in Reference No. 1.

the irrigated areas for double cropping; and c) increasing the cropping intensity in the irrigated areas to at least 200%.

The cropping intensity in KADA was only 131% and 115% in 1985 and 1986, respectively (4). These low performances can be attributed to the insufficient number of machines available to the farmers (Table 1). As a consequence, a significant area of KADA was left idle (4) and the 2 cropping seasons cannot be contained within 365 days (5).

Group Mechanization System

The Group Mechanization System (GMS) is a set up in which the machineries are owned, used and managed by each Farmers' Group. KADA officers have the responsibility of designing, promoting GMS and supervising the Farmers' Group on matters concerning the proper implementation of GMS (Fig. 3).

The main advantage of GMS is that the availability of farm machinery is guaranteed, enabling the farmers to follow the schedule fixed by KADA. Since the machinery belongs to the farmers, profit margin is nil, and after the capital cost has been paid for, the group needs only to cover the seasonal variable cost of operations. In the long run, this will help to reduce the production cost.

The ultimate goal of the GMS is to enable the two planting seasons to be completed within 365 days. So based on the growing pattern of a typical HYV paddy in KADA (Fig. 4), the ideal planting schedule is proposed (Fig. 5). However, initially, a different schedule is suggested (Fig. 6) for East and West KADA (Fig. 2). In this initial case, the machinery that belongs to one group can be used by a corresponding group from the other side of KADA.

Table 1 Machinery Requirement in KADA

Machine	Number of machines(unit)		
	Requirement(5)	1982(6)	1985(4)
Tractor 35 kW	1 420	193	177
4-row transplanter or power seeder	7 000	–	–
4-row combine	1 450	16	16

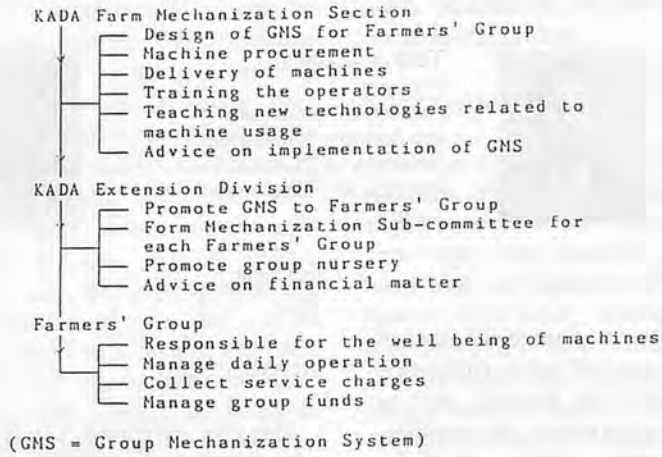


Fig. 3 Division of functions.

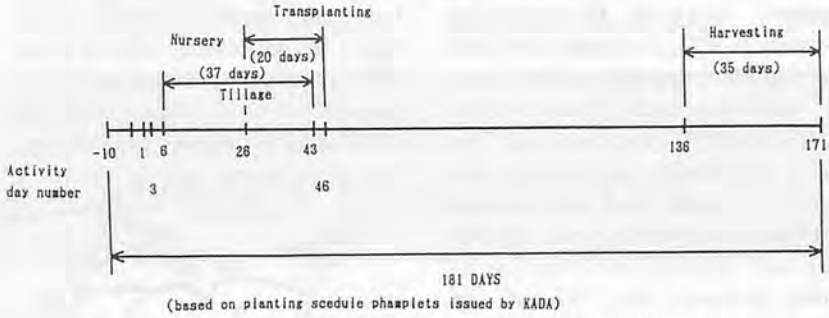


Fig. 4 Schedule chart of one cropping season of a typical HYV in KADA.

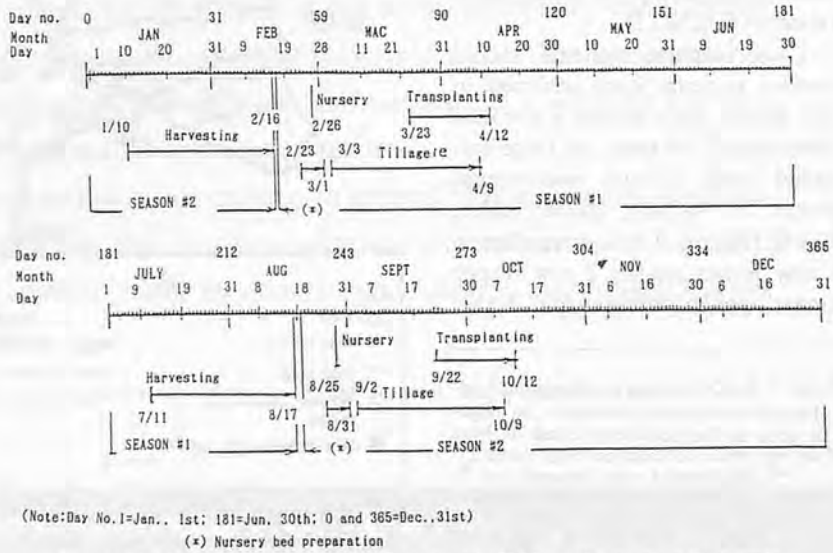


Fig. 5 Ideal planting schedule for 2 seasons in KADA, shown on a date scale.

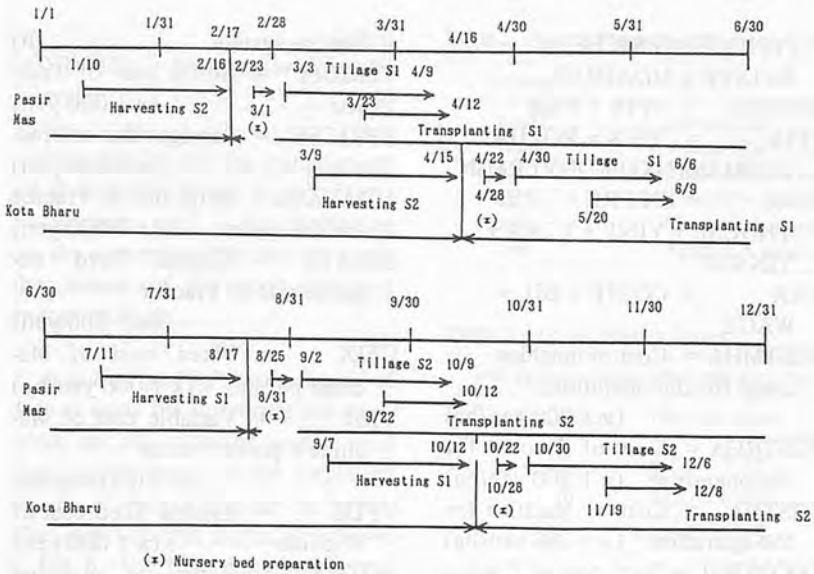


Fig. 6 Suggested planting schedule for Pasir Mas and Kota Bharu Irrigation Districts.

CAFARMS

In order to design the GMS, the CAFARMS planning model was used which consists of 8 separate programs (6 main and 2 utility programs) link through 2 MENU programs, coded in N88 BASIC (7) (Fig. 7a and 7b).

The 6 main programs are:

'cafarm. ine' – for the input of cultivation system and operations data. The data are saved in a random accessed file in the form '(file name). cin'.

'cafarm. cal' – for calculating the data input using 'cafarm. ine'. The main equations used are:

COVERAGE = FCAD x SDAY x SKNR / 100 / NOPET

FCAD = FCA x DAYT x ORAT / 100 x NDAI

FCA = WIMP x VIMP/ 10 x FEFC / 100

When the periods of two or more operations overlapped, the annual Working Area is:

TCCOVER < min [COVERAGE]

The annual Working Area for the system is:

COVERMIN = min [TCCOVER], where

COVERMIN = Max. annual

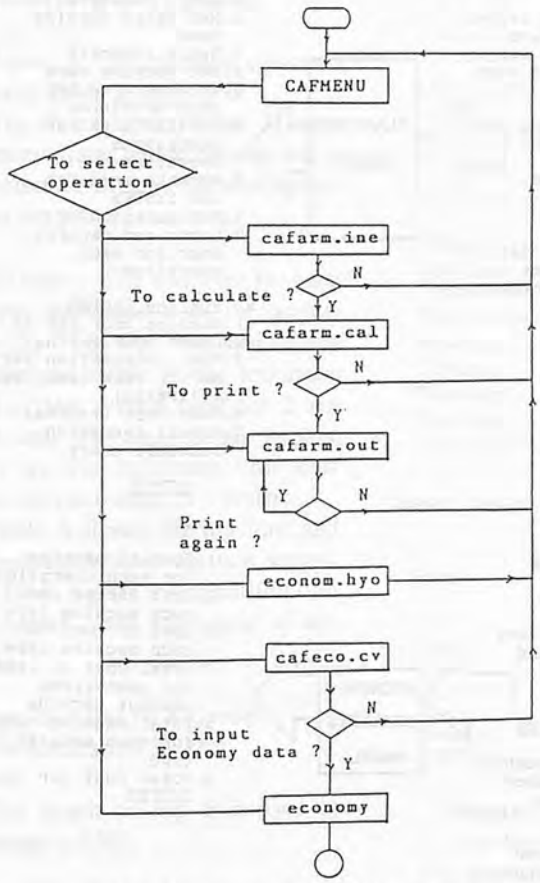


Fig. 7a Flow chart of MAIN MENU.

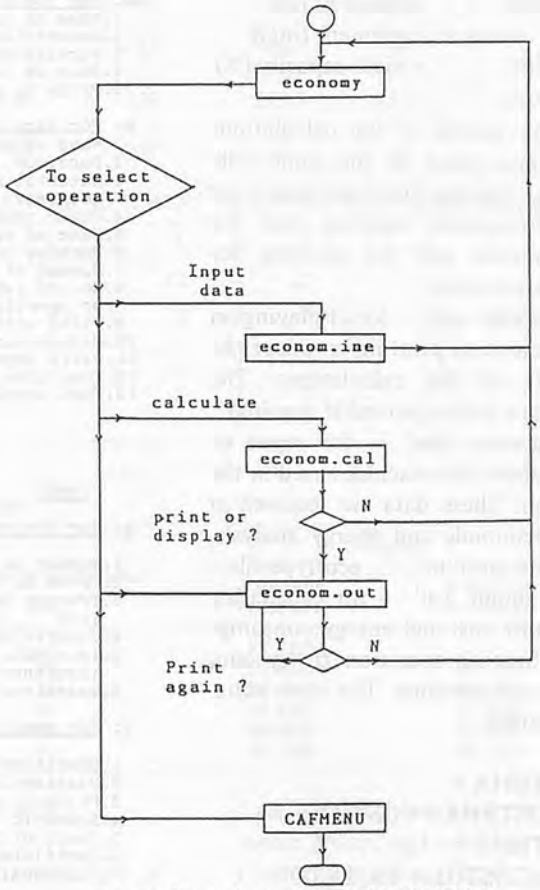


Fig. 7b Flow chart of ECONOMY MENU.

working area for the system (ha)

TCCOVER =Max. annual working area for overlapped operations (ha)

COVERAGE =The annual working area of each operation

FCAD =Daily field capacity (ha/day)

SDAY =Working period (days/year)

SKNR =Rate of available days

NOPET =No. of repetition per operation

FCA =Field capacity (ha/h)

DAYT =Daily working hour (h/day)

ORAT =Daily work rate (%)

NDAI =Number of machines or implements

WIMP =Width of machines or implements (m)

VIMP =Speed of machines or implement (m/s)

FEFC =Field capacity (%)

The results of the calculations are then saved in the same (file name). cin file. The main results are the 'maximum working area' for the system and the schedule for each operation.

'cafarm. out' – for displaying on the screen or printing on paper the results of the calculations. The schedule is also printed if required.

'econom. ine' – for input of data about the machines used in the system. These data are required in the economic and energy analysis, and are saved in _ _. eco type file.

'econom. cal' – for calculating the unit cost and energy consumption for each operation, the system, and each machine. The main equations used:

COSTMHA = COSTRHA + COSTHA

COSTRHA = TRCOSTOL = TR/TRTOL

TRCOSTOL= (TPRICEP-TPRICEE) x RFIXTR x MDAIMAX

COSTHA = CFIX + VAR

CFIX = YFIX x ROTHA/ ROTHAM(NKI)/CONVERMIN

YFIX = DEPRE + YREP + YHOUSE + YINT + YTAX + YINSUR

VAR = COSTF + OIL + WAGE

COSTMHA = Cost of machine usage for the operation (x 1 000 yen/ha)

COSTRHA = Cost of Tractor for the operation (x 1 000 yen/ha)

COSTHA = Cost of Machine for the operation (x 1 000 yen/ha)

TRCOSTOL = Total cost of Tractor for system (x 1 000 yen/ha)

TR = Tractor hour for the operation (h)

TRTOL = Total Tractor hour for the system (h)

TPRICEP = Initial cost of Tractor (x 1 000 yen)

TPRICEE = Salvage value of Tractor (x 1 000 yen)

MDAIMAX = Total no. of Tractor for the system (x 1 000 yen)

RFIXTR = Annual fixed expense rate of Tractor (x 1 000 yen)

CFIX = Fixed cost of Machine per ha. (x 1 000 yen/ha)

VAR = Variable cost of Machine + power source (x 1 000 yen/ha)

VFIX = Annual fixed cost of Machine (x 1 000 yen)

ROTHA = Hours of machine (NKI) usage for the operation (h/ha)

ROTHAM(NKI) = Hours of machine (NKI) usage for the system

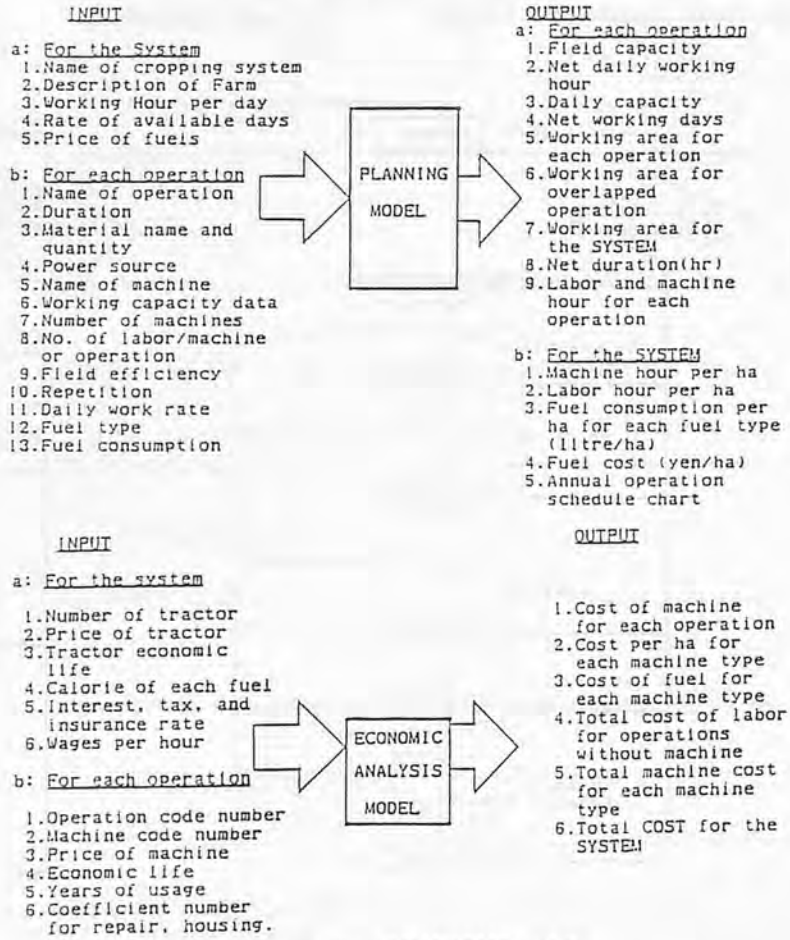


Fig. 8 Input-Output view of CAFARMS model.

(h/ha)
COVERMIN = Working area for the system (ha)

The results of the calculations are then stored in the ___.eco file.

'econom. out' – for displaying on the screen or printing on paper the results of the economic and energy analysis.

Input-output of data – Input of data is done by answering the questions on the monitor screen, and the output data can be displayed on the screen or printed on paper. The input-output items are shown in **Fig. 8**. The Planning Model computes the 'maximum annual working area and the schedule, and the Economic Model computes the costs of each operation and the system.

Simulations and Results

Input – The machine combinations in **Table 2** were used:

The dates input (**Table 3**) were 'dummy' dates which correspond to the number of days for each operations per year (2 seasons).

Results – The unti cost for each system decreases with the annual capacity (**Fig. 9**). The end of the continuous curve is the minimum unit of the system used for 2 seasons and the end of the broken curve is the minimum unit cost under an equivalent of 4 seasons.

Table 4 shows the machine and labour requirement for one season, and **Table 5** gives the minimum unit cost under 2 and equivalent of seasons.

Design Example of A Group Mechanization System

The graph on **Fig. 9** is used to design a GMS.

Group area, Ag = 24 ha

Table 2 System Name and Machines Combination

System	Combinations
man2	All manual
tilma	Power tiller + manual transplanting and harvesting
ptrt	Power tiller + transplanter + reaper + power thresher
ttrt	Tractor + transplanter + reaper + power thresher
trtc	Tractor + transplanter + combine
trsc	Tractor + seeder + combine

Table 3 List of Dummy Dates

Days/year	Dummy dates	ptrt, ttrt or tilma	trtc
For systems tilma, ptrt, ttrt and trtc:			
76	2/8 – 4/24	Tillage	Tillage
20	4/26 – 5/15	Seedlings prep.	Seedlings prep.
40	5/20 – 6/28	Transplanting	Transplanting
74	7/1 – 9/12	Cutting	Harvesting
72	9/15 – 11/25	Threshing	
For system trsc:			
98	2/1 – 5/9	Tillage	
66	5/10 – 7/14	Seeding	
74	7/18 – 9/29	Harvesting	

Table 4 Machines and Labour Requirement

System	tilma		ptrt		ttrt		trsc		trtc	
Annual working area (ha)	16		16		40		48		47	
Labour hour (h/ha)	544		279		252		57		205	
Machine hour (h/ha)	44		137		73		45		50	
Operation	NDAI	MENS	NDAI	MENS	NDAI	MENS	NDAI	MENS	NDAI	MENS
Tillage	1	1	1	1	1	1	1	1	1	1
Seedlings preparation	–	12	–	12	–	27	–	–	–	32
Transplanting	–	9	1	2	3	6	–	–	3	6
Seeding	–	–	–	–	–	–	2	2	–	–
Cutting	–	7	1	1	3	3	–	–	–	–
Threshing	–	–	1	1	3	3	–	–	–	–
Combine	–	–	–	–	–	–	1	2	1	2

Table 5 System Unit Costs

System	Annual working area (ha)	Unit cost 2 seasons (yen/ha)	Unit cost 4 seasons (yen/ha)
man2	–	57 780	–
tilma	16	51 860	47 500
ptrt10	16	51 960	42 000
trtc10	47	54 500	39 000
trsc10	48	40 000	26 500
ttrt10	40	49 500	39 500

. . Annual working area = 2 x Ag = 48 ha.

For this area only system trsc is acceptable.

Case #1: Machines used only for owner group, Ag1 = 24 ha.

From the graph on **Fig. 9**, Unit cost Cg1 = 40,000 yen/ha.

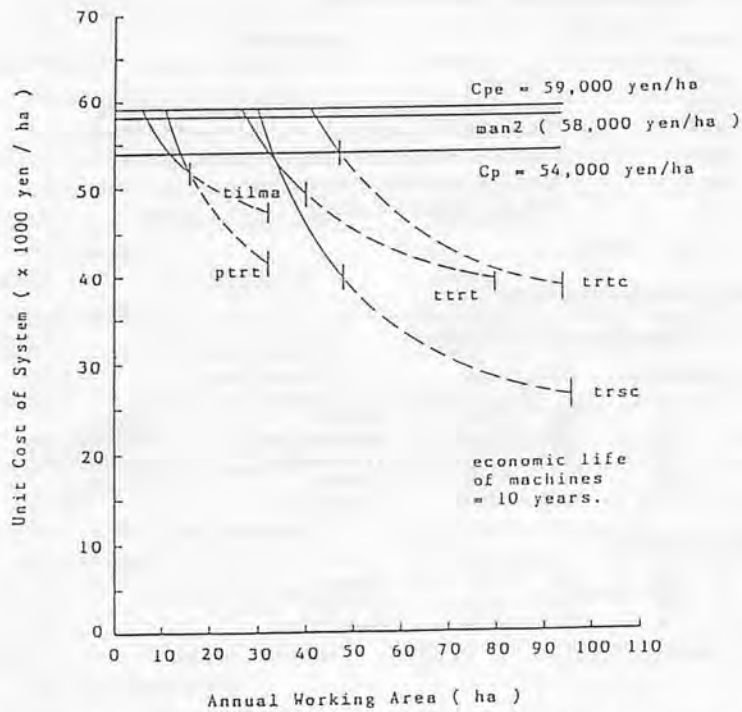


Fig. 9 Unit cost of systems 'man2', 'tilma', 'ptrt', 'ttrt', 'trsc' and 'trtc'.

which is 26% lower than the present cost.

Case #2: Machines also used for a second group with an area of 20 ha, or Ag2 = 20.

. . Annual working area =
2(24 + 20) ha = 88 ha.

This gives unit cost Cg2 = 29 500 yen/ha, or 46% lower than the present cost.

If the service charge is fixed at 45 000 yen/ha for area Ag1 (owner group member), and 52 000 yen/ha for area Ag2 (sharing group member), then the number of years to pay back the capital is,

= (28.32 × 48 × 10)/(((45 − 11.7) × 48) + ((52 − 11.7) × 40)))

= 4.5 years

Discussion

Six machine combinations or systems (Table 2) were used for this report, i.e., for the purpose of introducing the design method for Group Mechanization System by using CAFARMS model.

System 'man2' was analyzed for the purpose of comparison only. In system 'man2', although the system unit cost is below Cpe, animal power is rarely available for tillage operation, which has been mechanized since 1970.

System 'tilma' is acceptable for group areas between 3 and 5.5 ha. For areas between 5.5 and 8 ha, both 'tilma' and 'ptrt' are acceptable, however, the choice depends on the avilability of labour. Usually a farmer would plant up to 0.4 ha by himself, and the rest will be done by hired labour at the rate of 108.2 man-h/ha. The system 'tilma' is the same as the present system, except that the machine is to be owned by the group.

The machine size in system 'ptrt' is the smallest among the mechanized systems analyzed. The labour hour is 279 h/ha, 54% of the present labour requirement. Working at a maximum capacity of 8.ha per season, the unit cost is 51 960 yen/ha, just 4% below the present cost.

For group areas between 13.5 and 15 ha, system 'ttrt' is the best among the 5 systems. However, the unit cost is greater than the present cost but still below Cpe.

Between 15 and 20 ha, two systems are possible, 'ttrt' and 'trsc'. On comparing the unti cost, 'ttrt' is lower between 15 and 17 ha, but between 17 and 20 ha, 'trsc' is lower in unit cost. On considering the labour utilization, "ttrt' requires 252 h/ha, while 'trsc' requires only 57 h/ha (10% of present requirement). This huge difference is due to the preparation of seedlings in "ttrt' which is not required in the 'trsc' system. However, 'trsc' needs better water management and weed control in order to get a comparable yield.

For larger group areas, between 20 and 24 ha, systems 'trsc' and 'trtc' are both possible, and depend very much on the acceptance of the farmers and the standard of irrigation facilities in the block area. In areas where land consolidation has been completed, system 'trsc' is very attractive both in terms of unit cost and labour requirement. At 24 ha, the maximum working capacity per season, system 'trsc' cost 40 000 yen/ha, 26% lower than the current cost. The use of power seeder requires only sprouted seeds, which are very much simpler to prepare as compared to raising mat-type seedlings for transplanter. Manual and mechanical direct seeding methods have been accepted in many irrigated areas in Malaysia, including in MADA, Besut and KADA, so system 'trsc' is worth introducing.

For areas between 8 and 13.5 ha, which are not covered by the systems analyzed here, other machine combinations can be analyzed, for example, by using a system with a smaller (22 to 26 kW) and cheaper (<2 million yen) tractor.

It is also possible to join up smaller groups to enable owning machines of big system. For example groups of size 10 and 12 ha combining areas and management

to own either a "ttrt' or 'trsc' system.

If possible, during the initial implementation of GMS, two groups of different Irrigation Districts can share the machine utilization, and under this condition, unit cost of all systems are below the present cost (the broken curves in Fig. 9).

Refering to the design example, for a group area of 24 ha, the unit cost is 40 000 yen/ha or 26% lower than Cp. And if the machines are shared with a second group of 20 ha, the system operating cost is reduced to 29 500 yen/ha or only 46% or Cp. By fixing the service charges at 45 000 yen/ha for the owner-group and 52 000 yen/ha for the sharing group, the capital cost can be recovered within 4.5 years. For this example, the design planting schedule is as shown in Fig. 10.

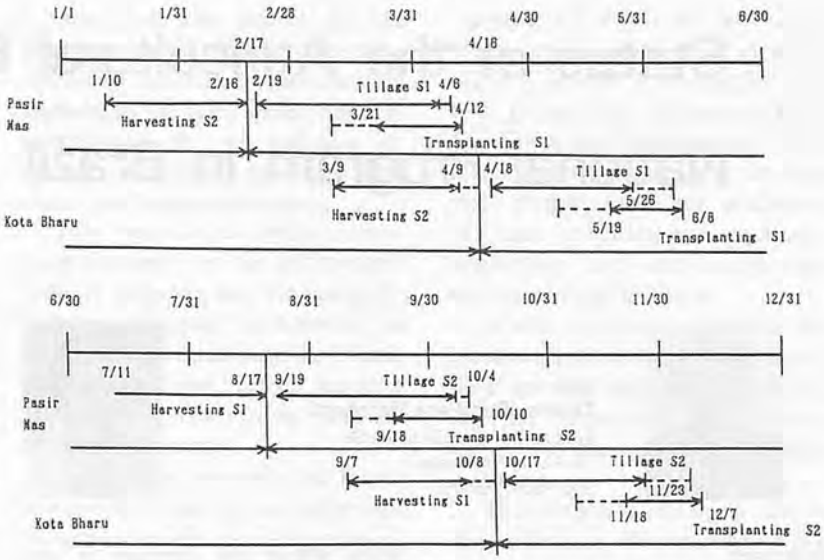


Fig. 10 Suggested planting schedule for Pasir Mas (Ag1=24 ha) and Kota Bharu (Ag2=20 ha) Irrigation Districts, using system 'trsc'.

Conclusion

In order to improve the intensity of cropping and, at the same time, solve the problems in paddy cultivation, improvement in the status of mechanization is inevitable. One method of increasing the number of machineries is by implementing the Group Mechanization System.

In desinging the Group Mechanization System, the microcomputer model CAFARMS can be adopted by inputting 'dummy dates' instead of the actual operation dates. The actual working schedule can then be planned by using the period of each operation, in days, obtained through simulation and adding it to the fixed beginning date of the respective operation.

The results of simulations show that all the mechanized system analyzed are acceptable for implementing the Group Mechanization System, depending on the size of the group area. However, the direct seeding cultivation system (system 'trsc') is the best because it has the lowest unit cost and labour requirement.

REFERENCES

1. Konaka, T.(1984). Farm Machinery Utilization Planning, AMA, Vol. 18, No. 3, 1987, Tokyo, Japan, pages 75-80.
2. Kemubu Agricultural Development Authority, (1983). Paddy Production Cost for Off-season 1981, KADA, Kelantan, Malaysia.
3. Information Malaysia 1987 Yearbook, Berita Publishing House, Kuala Lumpur, Malaysia.
4. Kemubu Agricultural Development Authority, (1987). Annual Report 1986, KADA, Kelantan, Malaysia.
5. Zakludin, W.M., (1988). Design of Group Mechanization System Using 'CAFARMS' Computer Model for KADA Area, A.M. Sc. Thesis submitted to University of Tsukuba, Japan.
6. Gajendra, S., Kiong L.C., (1985). Mechanization of Paddy Cultivation in West Malaysia, AMA, Vol. 17, No. 13, 1986, Tokyo, Japan, pages 32-36.
7. NEC. NEC-PC 9801E BASIC Manual, N88-BASIC (86), N-BASIC (86), Nippon Electric Company Ltd., Tokyo, Japan. ■■

Status of the Agricultural Engineering National Program in Brazil

by
Delmar Bandiera Marchetti
Assoc. Prof at ESALQ-USP
FEALQ, Piracicaba
São Paulo, Brazil

Irenilza de Alencar Nääs
Assoc. Prof. at FEAGRI-UNICAMP
Campinas, São Paulo, CxP 6011

Abstract

In order to improve research in agricultural engineering, the National Council for Scientific and Technological Development, a national program (PRONEA) established. Funds were allocated for training at all levels and also for research and transfer of technology in all regions of the country. For the first time Brazil invested in basic skills for agricultural engineering.

Introduction

The National Program of Agricultural Engineering (PRONEA) for Scientific and Technological Development – CNPq, emerged from an increasing need for improvement in agricultural production.

The problem facing the new program of agricultural engineering movement in Brazil, was not only to develop new technology, but also to build up an innovative system within the various regions in the country. This requires trained people and an effective layout for the transfer of technology from abroad or within the country.

The program has two main objectives: 1. To train students in various levels: technician, masteral and doctoral degrees and; 2. To support development projects in fields where the demand is unquestionable and legitimate.

In order to attain its objectives, the PRONEA emphasizes mainly all needs per region, as well as its scientific and technological problems, available technology within the country.

In the new frontier lands, with large clearings of agricultural areas, various stages for producing and storing crops were initiated for small rural societies living at subsistance levels.

The program at its beginning tried to gather all institutions which were concerned with development and to identify the real needs of regionally distributed communities, in order to develop, transfer or introduce afterwards, technology and organizational means which somehow meet these demand. Working toward this idea the PRONEA initiated a process of development, specially in agricultural engineering, based on the internal innovative forces of the local rural communities.

Role of Institutions in Development Process

The institutions involved in the program since its first discussion are the Federal and State University as well as the National Center for Agricultural Engineering and Empresa Brasileira de Pesquisa Agro-pecuária (EMBRAPA).

The university is primarily an institution of higher education and learning. Its function is neither to act as management consultant nor to play the part which belongs to government agencies, companies or non-profit organizations. Faculty members, however, in their individual capacity, become active parts of the innovation for generating and adapting agricultural engineering technology, specially because they are actually the main portion of human resources svailable at present. There is an obvious temptation to say that the university can do everything. Its limits may be established in order to promote a better understanding among many participating organizations. There are cases where the university is the only research center in the region. The EMBRAPA Research Center is the only place for development of technology projects.

Encouraging universities to develop and or adapt technology with other agencies has been the task of PRONEA. Developing technology is a continuous effort of PRONEA. A research program must be organized in such a way that the staff involved are aware of advances in their own and in related fields. The allocation of resources to the

production of research technology represents a capital investment in the capacity of the individual research worker, in the university or research center that makes the investment. In a broader research system of which the center is a part, the EMBRAPA is a case in point.

Product development is essential in the transformation of engineering research into a commercially usable form. For this reason the program involves also machinery companies that produce special tractors and implements as well as storage and irrigation equipment.

Analysis and Recommendations

The increasing world demand for food and raw materials from plant and animal sources, in addition to limited arable land and rural immigration, calls for an increase in food production through the optimization of basic agricultural inputs. Agricultural engineering plays a vital role in this context, providing subsidies for the development of integrated production systems, to maximize labor, optimize the use of resources and reduce losses.

The main goal of agricultural engineering and its related areas is to provide means for updating agricultural practices so that plant and animal productivity is increased as well as to generate technology which will allow economical land use.

Brazil is divided in 5 large geophysical regions, each one possessing different ecologic, socioeconomic and infrastructure characteristics and, therefore, with different conditions for agriculture and adoption of technology.

The new agricultural frontier land areas are located toward the western part of the country and due to their difficult acess, land ownership technology development is very slow. Also, due to the fast expansion in the food production system in the country, agricultural engineering is being called upon in contributing to the solution of complex problems involved with these new frontier land areas.

This report is an updated summary drawing from the institutional present situation and the scientific and technological development in agricultural engineering in Brazil. One hundred and fifteen teaching and research institutions were involved in this study.

It has been demonstrated that it is possible to develop an indigenous industry through carefully tailored research and development programmes with existing simple production process.

The effectiveness of the industrial involvement has been proven, especially because it would be unrealistic to introduce a technology, no matter how well it may meet the social objectives, if it cannot be commercially viable.

Agricultural Machinery

Agricultural mechanization represents 35% of all the agricultural engineering research: 16% of which refer to scientific production and 19% to research underway (**Table 1**). Agricultural mechanization research include: machinery development projects; trial and evaluation of farm machineries; machinery application and use; and inputs; and technology diffusion.

It will be shown in **Table 2** that emphasis is given to farm machinery development, particularly in studying the parameters that regulate the use of the machineries in agriculture.

This emphasis is largely due to the influence of universities that perform research work. There was also a considerable increase in the number of research work towards new concepts and projects in agricultural machinery due perhaps to the establishment of research institutes (**Table 3**).

The Northern region has the largest percentage in scientific agricultural mechanization as compared to the other areas. With regards to research underway, the Southeast is ahead. The North-eastern region

Table 1 Research in Agricultural Mechanization

Item	North	North-east	Middle West	South-east	South	Total
Scientific production (% by region)	41%	6%	19%	16%	18%	16%
Research in progress (% by region)	19%	13%	16%	22%	20%	19%
Number of research in agricultural engineering	22 55 75	114 160 274	117 58 175	932 351 1283	100 90 190	1985 712

Table 2 Category of Research in Agricultural Mechanization

Item	Development	Test	Machinery application	Technical extention publications	Total
Scientific production	141 – 69%	28 – 14%	8 – 4%	27 – 13%	204
Research in progress	114 – 84%	22 – 16%	–	–	135

Table 3 Percent Distribution of Agricultural Machinery Development Effort

Item	Machinery projects	Research	Adaptations	Total
Scientific production	26 – 18%	107 – 76%	8 – 6%	141
Research in progress	35 – 31%	66 – 58%	12 – 11%	113

registered the lowest percentage in agricultural mechanization research.

In spite of the peculiar characteristics of each geographical area under study, research duplication was not observed. In the North, work involved equipment and rudimentary tools while in the Northeast there was a predominance of work with animal-drawn equipment. In the remainder of the regions of the country, there was a predominance of research on the use of tractors and agricultural machinery in agriculture.

Table 4 Scientific Use of Soil and Water Engineering, by Region

Region	Water and soil engineering											
	Irrigation		Drainage		Meter.		Soil conserv.		Tot. Wes		Tot. General	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
North	1	(0.3)	–	–	1	(0.2)	–	–	2	(0.3)	22	(1.0)
Northeast	44	(14.0)	–	–	27	(9.7)	2	(5.1)	73	(11.1)	414	(64.0)
Middlewest	63	(20.0)	1	(4)	12	(4.3)	10	(25.6)	86	(13.1)	117	(73.5)
Southeast	185	(58.7)	19	(79)	222	(80.0)	23	(59.0)	449	(68.5)	993	(45.2)
South	22	(7.0)	4	(17)	16	(5.9)	4	(10.3)	46	(7.0)	100	(46.0)
Total	315	(100)	24	(100)	287	(100)	39	(100)	656	(100)	1286	–

Soil and Water Engineering

Among the 115 national institutions involved in the study, 48 reported on scientific production of which 33 reported publications relating to water and soil engineering, corresponding to 656 publications or 51% out of a total of 1285 publications.

Table 4 reveals that the Southeast is responsible for over 68% of the total number of scientific uses of soil and water. The Middle West is responsible for 13%, the Northeast for 11%; the South for 7% and the North for 0.3% of the scientific production.

The greater part of irrigation activities are carried out in the Southeast and Middle West regions; drainage, in the Southeast and Southern regions; meteorology in the Southeast and Northeast, and soil conservation, in the Southeast and Middle West. The Southeast and the South regions are responsible for 45% and 46% of the total number of uses of scientific methods of production and the Middle West and Northeast for 64% and 73%, respectively.

A specification of 20 lines of research in the scientific production analysis, considering 637 publications separated by region and by institute reveals that 447 (70%) of the publications relate to the Southeast region, followed by the Middle West (12%); Northeast (11%), and South (7%).

Attention is drawn to the low usage of scientific production practices in regions of the country where irrigation is of more relevant importance as is the case for the South and Northeast regions.

Several entities emphasize certain lines of research. For example, CENEA shows a tendency towards equipment testing, CENA towards studies on soil water movement and retention, EPAMIG toward irrigation and water management methods and climatology and ESALQ towards climatology studies. UFPb also shows a preference for publications relating to irrigation equipment testing and EMBRAPA for climatology studies.

The lines of research that have received the largest attention relate to irrigation and water management methods (23%); climatology (macro- and microclimatology level) (22%); and soil water movement and retention (14%).

This includes a number of publications on plant/water/nutrient interaction; economic evaluation of results and irrigation and drainage planning; and soil classification for irrigation.

With regard to crops, 19% of the papers published refer to sugarcane, followed by beans (13%), rice (11%), corn (10%), wheat (0.9%); cotton (5%) and soybean (3%).

In the case of sugarcane, 10% of the scientific methods of production was obtained from institutes in the state of São Paulo.

In the Middlewest region, the crops mentioned most are almost exclusively rice, beans and wheat. In the case of wheat, a greater part of this work are publications of UEPAE, Dourados.

Research in Progress

Only 98 of the 115 institutes involved in the study had research in progress, reaching a total of 728 research projects. Three hundred and seventeen (43%) of these projects relate to water and soil engineering which reveals the importance that has been placed on this subject in agricultural engineering, in general.

A closer examination, by region

Table 5 Distribution of Research in Progress

Region	Subject				Total	
	Irrigation	Drainage	Meteorology	Soil conservation	No.	%
North	3	1	6	8	18	5.6
Northeast	66	2	25	8	101	32.0
Middle West	19	3	8	4	34	10.7
Southeast	62	22	35	11	130	41.0
South	8	3	11	12	34	10.7
Total	158	31	85	43	317	100.0

and subject, reveals the following: for the four institutes where research on water and engineering is done in the North; a larger part of the research in progress deals with soil conservation and meteorology, with a marked lack of work on drainage. Some 33% of the research projects specifically relates to crops. There are three projects on the rubber tree.

In the Northeast there was an equal disbritution of research and educational institutes working in this field. There is a registered larger number of research in progress dealing with irrigation and meteorology (approximately 90% of total research). A more detailed study of the subjects shows research on irrigation engineering to be 16%, irrigation management 15%, water resources, 14%, climatology, 14%, salinity, 9%, and others, 32%. Of noteworthy is the fact that only 2% of the research reported deals, specifically with drainage, 24% are being carried out on crops which include cocoa (6 papers); cotton (9 papers) and garlic (3 papers). There was no research programmed on beans; only one paper on corn and two on rice and cassava.

The same situation prevails in the Middle West region where only one educational institute has participation in the research in progress and with only one paper. When separated by subject, one may observe a relatively equal distribution of the themes researched, where there are 15 (44%) papers on irrigation management attempting to introduce savanna agriculture. Seventy-three percent of this research is being carried out on crops, and of noteworthy importance are: rice, beans and wheat (4 papers each); tomatoes (3 papers) and vegetables (7 papers). Work on soybeans and corn was not documented.

In the South West there was an equal participation of research (9) and educational (9) entities, the least amount of research work underway deals with soil conservation. The subjects that are mostly researched include climatology (22 papers), irrigation engineering (21 papers) and irrigation management (19 papers).

A total of 31% of this research related to crops: rice, with 9 papers and beans with 7 papers.

In the South there was a relative predominance in the number of research institutes on soil conservation and meteorology, reaching a total of 68% of the work in progress. There was only 1 paper each on soybeans on wheat, two crops of outstanding importance in this region.

Energy

The energy sector was responsible for only 7% of all the scientific work in agricultural engineering, including projects on methods of scientific production as well as those in progress. Methods on scientific production was responsible for 5% to 11% when including research projects in progress. Thus, one may observe that there was an increase in the ratio: scientific papers on energy/scientific papers on agricultural engineering.

The survey recorded a total of 138 projects on methods of scientific production and research in progress in the area of energy (Table 6).

Tables 7, 8 and 9 show the distribution of 59 research projects on energy.

Research in Progress on Energy

During the period in which this survey was conducted, 79 research projects were being carried out, stressing rural energy or detection and development of alternative energy sources for application in agriculture or in the rural life.

From a quantitative angle, the distribution is as follows:

Table 6 Research in Progress on Energy

Region	No. of projects	Distribution %
North	15	10.8
Northeast	16	11.6
Middle West	11	7.9
Southwest	80	58.1
South	16	11.6
Total	138	100.0

Table 7 Scientific Methods of Production on Energy

Region	No. of projects	Distribution %
North	2	3.4
Northeast	2	3.4
Middle West	2	3.4
Southeast	48	81.3
South	5	8.5
Total	59	100.0

Table 8 Areas of Energy Research

Areas	No. of projects	Distribution %
Solar energy	9	15.3
Biodigestors	12	20.5
Energetic crops	9	15.3
Economic analysis and non-conventional energy	8	13.5
Vegetable oils	5	8.5
Fuel and motor tests	7	11.8
Others	9	15.3
Total	59	100.0

Table 9 Research in Progress on Energy

Region	No. of projects	Distribution %
North	13	16.5
Northeast	14	17.7
Middle West	9	11.4
Southeast	32	40.5
South	11	13.9
Total	79	100.0

The universities and EMBRAPA's network are responsible for 85% of the research in progress in the energy area and that the Southeast region has a concentration of over half of these research efforts.

Research projects on the use of solar/wind energy for grain drying, generation of mechanical energy and cooling are also being undertaken. This group of research cor-

responds to approximately 20% of all the research projects.

Another area of importance is the mining of coal and development of coal, straw and crop residues with the objective of generating heat for drying grains and other purposes. This area is responsible for 12% of the total research.

A fourth line of energy research deals with ethanol production from sugarcane and cassava that represents 9% of all research in progress.

Although not reaching a large number, one must stress the importance of the following pioneer research: those on the development of integrated energy systems, defined through the energetic matrices (3.8%); those that contemplate the use of currents to run water pumps and small generators (2.5%) and those aiming at making use of gazogen in motors attached to hydraulic pumps (2.5%). Other lines registered include those relating to the determination of parameters for the use of wood obtained from natural or man-made forests and the use of vegetable oil for energy purposes responsible for 2.5 and 1.2%, respectively.

Storage and Transport of Agricultural Products

This area includes all operations and stages after harvest to processing, or consumption of the agricultural products. These are the components of the physical structure of commercialization **(Table 10)**.

Structures and Environment

Rural reconstruction effort plays a fundamental role in housing the producer, his products and the means of production. The lack of proper orientation in the rural community along rational use of residues may bring about an increase in pollution causing ecological imbalance. This fact, together with the unsuitable technology transfered, whether from abroad or from the urban area to the rural area, deserves the attention of agricultural engineers in the search for autochthonous and regional solutions to local needs. **Table 11** shows the distribution of research work in progress of the institutes included in this diagnosis.

Conclusions

General and specific recommendations are made for the Government to consider in supporting the PRONEA:

General Recommendations

1) A greater flexibility among financing agencies to avoid duplication of work;

2) A greater support to the areas of rural construction; rural eletrification; photogrammetry and photo-interpretation which are the least developed;

3) Gathering of resources which would allow the universities as well as the research institutes to be better equipped;

4) Institutionalization to assure the rights to CNPq and the like for the coordination of work in agricultural engineering;

5) Establish research priority or lines of research with the aim of fulfilling the objectives of agricultural engineering and the interests of the Government;

6) Promote the development of basic research in the universities as well as in the research institutes, through the allocation of resources which permit personnel training at all levels and acquisition of laboratory equipment;

7) In machinery testing, there is a proposal for greater support with regard to normalization and standardization activities;

8) Support to research and trials that aim to evaluate and adapt machinery projects to the unique conditions of the Brazilian tropical agriculture;

Table 10 Scientific Production Methods in Storage of Agricultural Products

Region	Scientific production methods (%)	Research in progress (%)
North	0.7	1.6
Northeast	2.3	1.3
Middle West	0.4	0.7
Southeast	11.6	9.6
South	1.0	2.7
Total	16.0	16.0

Talbe 11 Research in Progress in Structure and Environment

Region	Research in progress	Distribution %
North	1	3.2
Northeast	7	22.5
Middle West	–	–
Southeast	18	58.0
South	5	16.3
Total	31	100.0

9) Support to projects that aim to survey the needs and aspirations in terms of agricultural mechanization; and

10) Incentive proposals for the various regions of the country.

Specific

1) Biannual updating of this research as it is of great value in giving the status of this sector as to allow one verify the evolution of agricultural engineering;

2) Meetings between workers of various areas of agricultural engineering; for adjusting respective programs, avoiding duplications, or, when this is the case, search for different approaches;

3) Implementation of service training programs, with the object of specializing professionals from universities for later admission to research institute or universities;

4) Promote and support regional seminars to discuss papers and research underway; and

5) Search for mechanisms which permit the dissemitation of technology in the sector, with the aim of reaching the users as fast as possible. ■■

Agricultural Mechanization Prospect in Papua New Guinea

by
Surya Nath
University of Technology
PMB, Lae
Papua New Guinea

Introduction

Like in many developing countries, subsistence farming contributes towards a greater part of food production than large scale farming in Papua New Guinea (PNG). Of course, large farms are semi-mechanized but subsistence farming depends mainly on hand tools. There are about 556 000 families directly dependent on subsistence farming covering about 300 000 ha at any particular time. When mechanical equipment to undertake tillage, planting, harvesting, primary processing and transport operations are so costly, a single farmer or group of subsistence farmers cannot afford to finance it. Using local resources to improve the efficiency of hand tools so that a farmer can work in the field for prolonged period of time with lesser effort is one step forward towards mechanization which will likely result in increased farm production and productivity of labour.

About 24.5% of employment in Papua New Guinea is within the primary industry, mainly agriculture (Dept. of Industrial Development, 1984). As such, agriculture forms the backbone of the national economy. Inspite of the 55% of 1.5 million workforce employed in agriculture (National Planning Office, 1984), the import bill of food products continues to increase from kina 69.402 million in 1975 to kina 129.88 million in 1983 (Goodman et al. 1985). On the other hand, the value of principal exports of agricultural commodities fell to kina 223.655 million in 1982 from kina 306.598 million in 1979 (Dept. of Industrial Development, 1984). To be sure, there is need to increase food production, especially at the subsistence level. Rural families produce their food in gardens of varying sizes depending on the number of family members. There are 19 provinces in PNG covering about 561 479 km^2 area. Farming is spread from coastal to highlands and acocunts for 389 217 ha producing varieties of food and cash crops (Densley and Dick, 1978).

Hence, there is a need for developing efficient and suitable agro-based rural development systems in which mechanization would play an important role. This will involve identifying and developing intermediate technology, making farm and related work more attractive and beneficial to the rural people. In this paper, the status of agricultural mechanization in Papua New Guinea is explained. Problems are identified and suggestions are discussed.

Status of Farm Mechanization

Traditional culture and diverse agro-ecological conditions have a direct impact on the type of food and cash crops grown throughout the country. Shifting cultivation within a location is very common in subsistence agriculture. The practice allows the land to lay in fallow in order to replenish the nutrients for the plants. It is estimated that 6 million ha land is under subsistence cultivation, whereas at a particular time, only 5% of the land is planted to crops.

In years to come, the population is expected to increase and the labour force will continue to swell. The economic activity of the population shows that 58% of them are engaged in subsistence farming of one kind or the other (**Table 1**). In addition, large holdings cover about 395 270 ha of different farm sizes. The number, size and area covered of such farms are shown in **Table 2**. Inspite of huge areas under cultivation, the equipment used are not adequate and most of them are imported. This creates a situation wherein one is bound to think whether such equipment (exception of tractors) has been tested for the suitability of PNG's agro-climatic condition. According to the sales office of the Boroko Motors at Port Moresby

Table 1 Economic Activity of PNG Population, 1980

Description	Male	Female	Total	% of Total
Formal sector wage employment	174 430	25 982	200 392	9.7
Informal money raising activities (mainly farming and fishing)	266 803	265 611	532 414	25.7
Subsistence farming or fishing and house keeping	245 921	424 038	669 959	32.3
Not economically active (too old/young/sick or student)	231 349	182 399	413 748	20.0
Others (including unemployed)	166 872	88 276	255 148	12.3
Total	1 085 375	982 286	2 071 661	100

Table 2 Size Distribution of Large Holdings (1981)

Range in area, ha	Number	Total are, ha
1 – 49	230	4 792
50 – 99	121	8 928
100 – 199	144	19 730
200 – 299	108	25 730
300 – 399	80	27 317
400 – 499	51	22 236
500 – 599	48	27 500
600 – 699	39	32 718
700 – 799	21	24 888
1 000 – 1 499	16	27 763
2 000 – 4 999	29	88 258
5 000 and above	8	85 410
Total	895	392 270

Source: Shaw, 1985.

about 2533 tractors were sold during a 10-year period (1976-85) distributed by manufactures as follows: Ford, 1 443; Massey Ferguson, 940; and John Deere and Mitsubishi, 150 units.

Some of these tractors may be engaged only in mining and road construction, hence it is rather difficult to estimate the number of tractors per 1 000 ha crop-land.

At subsistence level, most of the tilling work is normally done using a spade and a bushknife. The use of a bushknife to till the soil is tiring and often the depth covered is limited to 7 to 10 cm. A hand rake is used to level the soil and to collect cut grasses (**Figs. 1, 2 and 3**). A strong stick with a sharp edge (**Fig. 4**) is commonly used for digging root crops grown on mounds. Animal-drawn equipment is seldom observed. Some unique method of transplanting vegetable seedlings were observed at the Seventh Day Adventist farm at Goroka in the Eastern Highlands Province. A 44-gallon drum is used as a seedling dibbler (marker) through a series of 30 spikes (about 18 cm long and spaced at about 20 cm) welded on the surface This equipment is held and pulled forward by two men and seedlings are planted in the grooves left behind by the equipment (**Fig. 5**). Transplanting, chemical spraying and harvesting are done manually.

Fig. 1 Spade and fork.

Fig. 2 Hand rake.

Fig. 3 Bush knife and sickle.

Fig. 4 Digging root crops with sticks.

Fig. 5 Seedling marker/planter.

Farm Mechanization and Rural Economy

The resources related to agriculture vary greatly from province to province and thus needs the right kind of equipment/operations in order to make farming profitable and sustainable. This, of course, needs the right type of research, aimed at appropriate technologies suited for PNG's conditions.

The areas under large-scale and subsistence farming in PNG are 395 270 ha and 300 000 ha, respectively. Assuming the availability of about 2 533 tractors (different sizes) for each 10-year span and replacing them by the end of 10 years, the tractor population could reach over 12 000 by the year 2005. The matching equipment for such a large number of tractors, plus the workshop tools and the equipment to maintain all the machinery on farms, will involve considerable numbers of unskilled and skilled labourers. It will also generate small-scale industries which will help strengthen the rural economy. Two major steps seem necessary: i) improvement of existing equipment and exploring the methods of production using local material and skill; and ii) development of new appropriate equipment.

Local manufacture of hand hoes, hand operated wooden-packer, weeder, handsickle, seeder, stationary thresher, burr mill for grain grinding, etc. need be improved also.

Subsistence Farming and Custom-hiring Services

Farm mechanization in PNG should be such that a worker's well-being, safety, and work efficiency are improved. Owning a tractor and matching equipments on the part of a subsistence farmer is not necessarily economical nor advisable. Rather, improved hand-tools and services available through custom-hiring should first be emphasized in partial farm mechanization.

On the other hand, educated unemployed youth can be trained to operate and maintain farm machines on a custom-hire basis. The Government may subsidize such machines on private enterpreneurial basis. Of course a four-wheel tractor with the right type of machinery for a particular location has to be justified in terms of the number of work-hours a year. Such ventures will go a long way in strengthening business as the enterpreneur will be responsible for the repair and maintenance and shall need no supervision. In a Government-owned custom-hiring service, supervision can pose a problem. The private enterpreneurial services would generate rural employment by diversifying the custom work such as road making, operating irrigation pumps, shellers, decorticators, oil expellers, pole diggers, tree stump pullers, and transportation, besides tillage and seed-bed preparation.

Some Suggestions

The strategy to improve agricultural production, rural employment of agro-based rural industries, and transport facilities is a complex one and should be responsible to the needs of social, economic, and traditional values in the larger interests of PNG's population. The country's 1984 National Public Expenditure Plan (NPEP), aims at:

> "Decentralization of economic activity, planning and government spending with emphasis on agricultural development, village industry, better internal trade, and more spending channelled to local and area bodies."

Agricultural mechanization in PNG remains an important input in conserving soil, efficient utilization of human and animal labor for crop-production, post harvest techniques, construction of farm buildings, rural transport and employment.

REFERENCES

1. Baldwin, George B., Bose, Swadesh R., Galenson, Alice C., Mouline, Paul C. (1978). Papua New Guinea – Its economic situation and prospects for development published by World Bank, Washington D.C. 20433, U.S.A.
2. Densley, D.R.J., and Dick, G. (1978). Agriculture in the Economy: Rural Extension and Agricultural Education. Vol. 1. Department of Primary Industry, Konedobu. Papua New Guinea.
3. Goodman, Raymond., Lepani, Charles., Morawetz, David. (1985). The Economy of Papua New Guinea. An independent review. Development Studies Centre. The Australian National University, Canberra, Australia.
4. Hardaker, J.B. (1975). The Subsistence Sector in the South Pacific. University of the South Pacific, Suva, Fiji.
5. Koley, C. (1979). Handbook on Agricultural Statistics – 1978. Department of Primary Industry – Planning, Economics & Marketing Branch, Konedobu, Papua New Guinea.
6. PNG University of Technology. (1973). Agricultural Engineering Working Party – Report of working party on courses in Rural Engineering and Rural Technology, Lae, Papua New Guinea.
7. Papua New Guinea Statistical Digest. (1984). Prepared by Department of Industrial Development and published by Word Publishing Co. Pty Ltd., Port Moresby.
8. Power, A.P. (1980). Technology Transfer and Rural Development. Unesco's Expert Meeting on New Modalities for the Action of the Organization in the field of Technologies for Rural Development held in Brussels, Belgium.
9. Profile and Planning Study for Subsistence Food Production. Vol. II. (1983). Department of Primary Industry, Govt. of Papua New Guinea. UNDP Project No. PNG/82/002.
10. Rural Industries. (1981). National Statistical Office. Waigani, Papua New Guinea.
11. Shadow, John. (1986). PNG Rural Industries published by National Statistical Office, Port Moresby, Papua New Guinea.
12. Shaw, B. (1985). Agriculture in PNG Economy. Institute of National Affairs, Port Moresby, Papua New Guinea.
13. Snowden, Catherine., Denoon, Donald. (1978). History of Agriculture. Discussion Paper No. 29 University of Papua New Guinea and Department of Primary Industry. University of Papua New Guinea, Port Moresby.
14. The Role of the Commonwealth Association of Survey and Land Economics (CASLE) Professions in Rural Development Programmes in the South Pacific held in Papua New Guinea Sept. (1980) and published by 12 Great George St. London SWMP 3AD, U.K. ■■

Scope and Implications of Mechanizing Rice Production in Pakistan

by
Abdul Majid
Agronomist
Farm Machinery Institute
NARC
Islamabad, Pakistan

A.S. Khan
Agricultural Engineer
Farm Machinery Institute
NARC
Islamabad, Pakistan

S.I. Ahmad
Agricultural Engineer
Farm Machinery Institute
NARC
Islamabad, Pakistan

Abstract

The non-availability of suitable farm machines for major rice production operations is considered to be the main reason for low rice production in Pakistan.

Various studies were reviewed in order to have a guideline for mechanizing the rice production operations in the country. The use of rotary cultivator with properly sealed gear box seems a better substitute for the conventional wooden plough/tine cultivator in preparing a good seedbed. Direct sowing of paddy is another operation which offers a convenient substitute for the conventional manual transplanting. The Farm Machinery Institute (FMI) reaper and combine harvester can also be employed to minimize post-harvest losses. At present none of the farm operations for rice production is satisfactorily mechanized, hence the need for systematic efforts for the development /introduction of suitable farm machines in rice -wheat cropping systems.

Introduction

Rice is both a food and cash crop in Pakistan. It is grown on 2 million ha with an annual production of 3.32 million t (Anonymous, 1986). Pakistan is earning a sizeable foreign exchange annually from its rice export. The country's average rice yield of 1.6 t/ha has hardly improved over the past decade **(Table 1)**. One of the main reasons of this low crop yield is the non-availability of suitable farm machines for major rice production operations, namely; land preparation; transplanting; fertilizer and pesticide application; interculture; and harvesting and threshing.

The present common method of wet land preparation involves the use of animal drawn plow + wooden plank or tractor operated spring tine cultivator + wooden plank in standing water. Rotary cultivator is also used on a limited scale. This is not only a cumbersome operation but also lowers the life and efficiency of farm machines as these are not properly water-sealed, particularly the tractor engines and rotary cultivator gear boxes. The dry method of land preparation is also practiced in new rice growing areas of Punjab and in Sind province.

Table 1 Trends in Rice Yield, 1970-86

Year	Yield (kg/ha)
1970-71	1 466
1971-72	1 549
1972-73	1 577
1973-74	1 623
1974-75	1 439
1975-76	1 531
1976-77	1 565
1977-78	1 553
1978-79	1 615
1979-80	1 581
1980-81	1 616
1981-82	1 736
1982-83	1 741
1983-84	1 671
1984-85	1 714
1985-86	1 616

Source: Planning Unit, Ministry of Food and Agriculture, Govt. of Pakistan.

Manual transplanting in puddled fields is the rule. The non-uniform distribution and inadequate number of rice seedling transplanted by manual labour on contract basis (Boldman and Shad, 1979; and Khan, 1987) demands research efforts either to mechanize rice transplanting operation or explore

other rice sowing methods. In an effort to mechanize rice transplanting operation, both root-washed and mat-seedling types transplanters were tested but none of them was found suitable to local requirements.

For the past few years, FMI has initiated a study to investigate various rice sowing methods suitable for rice-wheat cropping pattern. Direct seeding of rice on dry soil has been found most appropriate as it avoids puddling operation and gives better yield than existing manual transplanting practice as the method ensures better plant population.

Though the FMI multi-crop tractor front-mounted reaper has been introduced, farmers still resort to manual harvesting of paddy in the absence of a suitable rice thresher. Combine harvesters started to gain popularity on custom hiring basis during the past few years. Under existing rice-wheat cropping pattern, the use of harvesting machinery disturbs the level of the already wet-puddled fields and deteriorates their soil structure and thus delays proper land preparation operation for wheat sowing.

Land Preparation

Both dry and wet methods of land preparation are practised in rice cultivation in the country. The dry method is used in new rice growing areas of Punjab and Sind province. In this method, the land is prepared dry with the use of either animal-drawn wooden plow or tractor-operated spring tine cultivator/rotary cultivator and irrigation water is applied to the field just before transplanting operation.

In the wet method, saturated soil is worked in standing water condition to prepare puddled fields. The most common implements used in puddling operation are animal-drawn plough + wooden plank and tractor-drawn spring tine cultivator + wooden plank. The land is tilled 6 to 10 times with these implements to have reasonable puddled field. Tractor PTO-operated rotary cultivator is also used on a limited scale. The use of rotary cultivator for puddling has been found superior over time cultivator. (Majid et al., 1985).

Even as puddling facilitates transplanting operation and controls weed growth, it is a tiring task and the new farming generation is reluctant to do this operation. The wet puddled fields are compacted by the harvesting machinery and cannot be well prepared for wheat sowing. Moreover, the present makes of tractors and rotary cultivators employed for wet cultivation in the country are not designed to operate in muddy or flooded fields.

Transplanting/Direct Sowing of Rice

Plant spacing is an important production factor in transplanted rice. Planting rice closer than necessary increases the cost of transplanting and contributes to increased probability of lodging. On the other hand, too wide spacing results in lower yield (De Datta, 1981). In Pakistan rice seedlings are randomly transplanted by hired labour. They tend to transplant less plant population in the centre of the fields. A survey carried out by the FMI during 1985 in Northern Indus Plains confirmed this observation. The manual labour was found to transplant only 68% of recommended plant population (200,000 seedling hills/ha). The plant population along the border of field was found higher. The farmers are also experiencing serious difficulties in getting labour for rice transplanting. Such type of situation stresses the need for mechanizing rice production.

In an effort to mechanize the rice transplanting operation in Pakistan, both root-washed seedling and mat-seedling transplanters from China, Korea, India, Philippines, and Japan were tested for their suitability. These machines were not found suitable for Pakistan because the transplanter required precise field levelling, good water management and high technical skills for growing the mat-type seedlings.

Direct seeding, on the other hand offers a convenient alternative to transplanting with comparable yeild. Many experimental evidences from different countries have reported that yields of directly seeded paddy were similar to that of

Table 2 Effect of the Seeding Techniques on Yield and Yield Components of Paddy

Treatment	Weed population			Rice	
	30 DAS*	60 DAS	90 DAS	1 000 grain weight (g)	Grain yield (t/ha)
A) NARC 1982					
Broadcasting of pre-germinated seed.	8.75	5.25	3.00	25.13	5.10
Seed drill	18.25	7.25	6.76	22.65	3.63
Transplanting	6.68	6.00	4.00	21.50	3.28
B) Gujranwala, 1983					
Broadcasting of pre-germinated seeds.	362.75	94.25	96.50	20.03	3.25
Seed drilling	423.75	153.50	123.75	16.63	1.88
Transplanting	–	113.75	39.75	16.88	1.83

*DAS = Days after sowing.

transplanted paddy (Lokaphadhan, 1976, Parasad and Singh, 1975). The adaptation of direct seeding would avoid delay in cultural operations and ensure timely seeding of the rice crop. Thus under adequate water supply, this technique may contribute considerably to increasing the cropping intensities and planting densities. Consequently heigher production should be expected.

Chinese peasants are known to be growing rice successfully in dry fields and have obtained an average yield up to 6.75 t/ha (Qinghua, 1985). Direct seeding can be done on both wet and dry soils. Among the different methods of direct seeding known, drilling is most efficient because of low labour and seed requirements, uniform sowing in lines and uniform germination. Direct drilling gives higher grain yield as shown in a few studies conducted in some rice growing areas (Khan, 1975; Navasero, 1969), even as it results in more weed growth. If weeds are properly controlled either through mechanical means or use of herbicide, then direct drilling of rice in dry soil is the simplest method of rice growing.

The introduction of dry sowing technique requires the same environment as for wheat crop in rice zones. An increase of 6% of wheat yield was recorded in India in areas previously under direct-seeded rice (Chatterjee and Khan, 1978). The FMI initiated a pilot study in 1982 to compare different rice sowing methods. The effect of seeding techniques on yield and yield component of paddy for 1982 and 1983 are summarized in **Tables 2** and **3**.

The results of 1985 trials shown in **Table 3** proved direct drilling on dry soil is superior than broadcasting of the soaked seed on puddled soil. The effect of sowing date on yield and yield components of direct-seeded rice on dry soil was significant as shown in **Table 4**. According to these experiments, the seeds should be drilled at the beginning of the 3rd week of May which does not seem feasible as wheat fields are not cleared by that time. The seeds can be sown, however, at the end of May if wheat fields are cleared by the mid-May which is possible with the help of machines for wheat harvesting. Many agronomic studies are underway in this regard.

Table 3 Effect of Different Direct Sowing Methods on Yield of Rice

Sowing method	Weed population	1 000 grain weight (%)	Grain yield (t/ha)
Puddle broadcasting (PB)	101.1	21.2	4.3
Dry line sowing (DLS)	156.4	22.2	4.6
Dry broadcasting	123.9	20.8	3.9

Table 4 Effect of Sowing Time (ST) on Yield of Direct Sowing of Rice

Date	Weed population	1 000 grain weight (g)	Grain yield (t/ha)
16 May (ST_1)	115.4	25.8	6.4
31 May (ST_2)	120.2	25.5	5.2
16 June (ST_3)	144.8	23.8	3.6
30 June (ST_4)	128.2	10.3	1.8

Weeding and Pesticide Use

Weeds are the major pests of rice because they reduce yield by 17% compared to 8 and 7% for insects and diseases, respectively. Under present conventional transplanting practices, weeds are not serious problems and farmers do manual weeding by uprooting the weed plants.

The major problems of direct seeding on dry soil so far observed by the FMI is heavy weed infestation. This can be solved by either developing a suitable mechanical weeder or use of appropriate herbicide. In 1986 the FMI trials conducted at farmers' fields gave maximum yield when direct seeded rice was properly weeded by manual labour (**Table 5**).

The pests cause severe damage to rice crop and results in low crop yield. Presently, granular pesticides are manually broadcast with standing irrigation water in the paddy fields. This method is not suitable because the pesticides are not effectively utilized by plant. The pesticides can be sprayed by manual knapsack sprayers. These machines did not gain popularity for rice crop despite their availability in the market at subsidized rates. Extension efforts are needed to introduce these machines for proper application of pesticides. Because of wet field conditions in rice fields, the use of tractor-operated sprayer is not feasible.

Table 5 Effect of Irrigation and Weed Control Measures on Dry Direct Rice Production

Treatment	Yield (t/ha)
First irrigation 20 DAS + manual weeding	5.9
First irrigation 15 DAS + machete @ 1.98 l/ha	5.1
First irrigation 10 DAS + saturan @ 14.8 kg/ha	3.2
First irrigation 10 DAS + no weeding	2.3
Transplanted rice + machete @ 1.98 l/ha	5.3

DAS: Days after sowing

But these machines can be used to control pests in early growth stage of direct seeded rice.

Fertilizing

Proper application of fertilizer at the right time is necessary for its effective utilization by the plants. The practice of manually broadcasting fertilizer soon after transplanting is commonly followed by most Pakistani farmers. This is not an efficient application method because great quantities of fertilizer are lost through volatilization, nitrification, leaching and water runoff. Through research studies, it has been observed that fertilizer placement in puddled soils at a depth of 5 cm can improve fertilizer efficiency considerably. In addition, about 50% fertilizer can be saved by this method. Studies by the PARC/IRRI Rice Research Project also indicate that the incorporation of fertilizer in dry soil could improve paddy cultivation efficiency.

A few prototypes of IRRI fertilizer applicators were imported and tested for their evaluation in the country. These gadgets required a lot of manual power to operate. In addition, they can only work satisfactorily in row-transplanted paddy fields. Research is being done in Japan on mechanical transplanter which could place fertilizer at depths of about 2-4 cm below the soil surface along with rice seedlings. Similarly, a few models of rice-cum-fertilizer drill have been developed for direct seeding of rice. The introduction of such types of machines in Pakistan is definitely needed due to high cost and low utilization rate of fertilizer.

Harvesting and Threshing

Almost all the Pakistani farmers are still burdened with laborious task of manual harvesting which is considered to be the most labour-intensive operation in rice production representing about 25% of the total labour requirement of the crop (Khan, 1971). Improved communication between rural and urban areas is exposing the rural population to modern conveniences. There is a growing reluctance amongst the young rural generation to perform laborious farming in traditional ways. The wages of rural labour are also increasing. These conditions create labour availability problem during transplanting and harvesting seasons. Harvesting losses range from 3% in the first week to 7% in the third week after ripening of the crop (Iqbal et al, 1980). Another important reason for timely reaping is when a second crop follows immediately, the period available for land preparation becomes short. The introduction of reapers seems one feasible solution to the problem.

Among the reapers, the FMI machine (a redesigned version of vertical conveyor-type China reaper) has gained acceptance among farmers. According to a comparative study undertaken between this machine and the hand-reaping practice, indicates that the former requires only 8.2 man-hour/ha as compared to 83.4 man-hour/ha for manual reapers (**Table 6**). The FMI reaper operating cost was estimated to be about Rs. 164/ha as compared to Rs. 208.50/ha for the manual reaper (Amjad and Khan, 1983). At present more than five local farm machinery manufacturers are fabricating the FMI reaper in the country.

Table 6 Labour Requirement for Paddy Harvesting by Machine and Manual Reaping Systems

Reaping system	Labour requirement (Man-hours/ha)						
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Average
1. Machine Reaping							
a) Operational requirement (cutting)	9.3	9.4	3.9	9.1	9.6	7.7	8.2
b) Gathering, bundling and transporting to one corner of the harvested field	25.1	–	–	47.6	26.5	30.0	32.3
			Total				40.5
2. Manual Reaping							
a) Operational requirement (cutting)	80.5	86.3	–	–	–	–	83.4
b) Gathering, bundling and transporting to one corner of the harvested field	–	–	21.8	–	–	–	21.8
			Total				105.2

Just like harvesting, almost all paddy crop grown in the country is threshed manually or by trampling under animal feet. These methods result in heavy grain losses. In the developed countries, rice is threshed with self-propelled combines. These machines are expensive and complicated. The grain loss by these machine is under 3% and grain damage under 0.5% in good field conditions. The rice combines are operating in Pakistan on custom-hiring basis. The FMI also imported a Korean paddy thresher under the RNAM Mutual Exchange of Prototypes Programme in 1982. Its performance was found satisfactory hence, the need to develop a bigger version of this thresher.

None of the rice production

operations in Pakistan is satisfactorily mechanized. There is a great need to start systematic efforts for developing/ introducing suitable farm machines for rice-wheat cropping system. Adaptation of dry direct sowing of rice is considered to be a better substitute for the labour-intensive manual transplanting. However, this technology requires a comprehensive study before it becomes acceptable.

REFERENCES

Amjad, N. and M. Khan (1983). Test Report on Field Performance of FMI Reaper-Windrower FMI, PARC, Islamabad, Pakistan.

Anonymous (1986). Pakistan Agricultural Basic Statistics, Statistic Department, Agricultural Development Bank of Pakistan.

Chatterjee, B.N. and S.A. Khan (1978). Growth of wheat establishment with different amount of tillage after the harvest of direct seeded and transplanted rice. Indian J.Agric.Sci., 48(11): 569-654.

De Datta, S.K. (1981). Principles and Practices of Rice Production. John Wiley and Sons Inc., New York, USA.

Goldman, R.H. and R.A. Shad (1979). Technical and common factors influencing rice planting densities in Punjab. Paper presented in the Workshop on Constraints to Agricultural Productivity, May, 1979. Int. Rice Res. Inst. Los Banos, Laguna, Philippines.

Iqbal, M.; G.S Sheikh and J.K. Sial, (1980). Harvesting and threshing losses of wheat with mechanical and conventional methods, A.M.A., Tokyo 9(3):66-64.

Khan A.U. (1971). Harvesting of paddy. Paper presented at the International Rice Research Conference, at IRRI Los Banos, Philippines, April, 18-21.

Khan A.U. (1975). Mechanization technology for tropical agriculture. AMA 6(1): 30-35.

Khan A.S. (1987). Soil and rice seedling characteristics affecting seedling distribution of a root washed rice transplanter. unpublished Ph.D. thesis, Cornell University.

Lokaphadhan, T. (1976) Economic comparison of broadcasting and transplanting of dry season rice in Thailand. M.S. thesis Thamonasat Univ. Bangkok, P. 193.

Majid, A; S.I Ahmad and M. Farooq (1985). Comparative studies of wet and dry tillage practices in paddy production. Paper under publication.

Navaser N.C. (1969). A row seeder for low land rice soils. Saturday Seminar, Agric. Engg. Dept. IRRI, Philippines.

Parasad, R. and V. Singh (1975). Note on methods of land preparation and weed control in directly sown and transplanted rice. Indian J. Agric.Sci; 45(8): 377-379.

Qinghua, W. (1985). China's dry grown rice. The Pakistan Times, July 5, 1985.

AMA ABSTRACTS AND INDEX, 1971–1980

— A Key to Wealth of Information —

As the AMA enters its 13th year of publication this year, the Editorial Staff deems it appropriate to commemorate the event by publishing "Abstracts and Index 1971-80" in May, 1983 for only ¥2,000 a copy, including sea mail postage.

During the decade 1971-1980, more than a thousand articles were received by AMA from readers and co-editors. Over 600 of these contributions were published from which the abstracts and index in various aspects of agriculture and agricultural mechanization in developed and developing countries were arranged for use as a handy reference by students, government officials, ressearchers and academicians interested in agriculture and agricultural mechanization. For example, at a glance, the abstract and index tell about the content of the article, author and AMA issue number. The publication form is A3 size (18.5 cm x 21 cm) 82 pages.

A limited number of copies are still available for which reason they will be sold on a first-come, first-served basis. In order that interested readers get their copies of the publication, it will be very useful for them (and convenient for the AMA Staff) to fill up the order from inserted in this issue and mail it to –

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

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

1st International Animal Husbandry/Systems China '89 Exhibition and Trade Conference

August 18-22, 1989, Huhhot, Inner Mongolia Autonomous Region, China

The extensive grasslands and livestock breeding areas of Inner Mongolia extending into neighbouring regions, are considered to have reached the stage of being a definite and organized market. A market which seeks advantages from overseas leaders in the field, expertize in animal husbandry, advanced technology of modern farm machinery and farming systems etc.

The Inner Mongolian authorities, supported by their 7 provincial grassland neighbours will be holding, as the opening phase of their development program, the first ever International Exhibition covering all aspects of the agro-animal husbandry industry.

US$ 80 million have been specially set-aside for on-the-spot purchases of farm equipment, technology, systems etc. The opportunity for overseas expertize and products are immense.

For information contact:
Exhibition Technics Pte Ltd.
5 Tank Road
Singapore 0923
Republic of Singapore

11th International Congress on Agricultural Engineering

September 4-8, 1989, Dublin 2, Ireland

For further information contact:
John Carvill
Dept. of Agriculture and Food
Dublin 2, Ireland (Phone: 353-1-789011)

EIMA – International Exhibition of Agricultural Machinery Manufacturers

November 8-12, 1989, Bologna, Italy

EIMA, promoted and organized directly by UNACOMA, the Italian Association of agricultural and earth-moving machinery manufacturers, has, over the years, maintained unchanged its professional character. The absence of company advertising, admission reserved exclusively to manufacturers, access to the general public limited to the last two days, division of exhibited manufacture into product groups, well-run facilities to support and assist both exhibitors and visitors. This, in synthesis, is the formula which has, year after year, multipled the success of EIMA.

EIMA represents the appointment which must not be missed for those-ranging from the Italian and foreign industry of agricultural mechanization and gardening to the economic, technical and agricultural dealers and businessmen – whose livelihood is in this sector at whatever level. EIMA also stands for updating with respect to technical innovations in the area of agricultural mechanization besides offering direct confrontation with the most modern production that industry makes available for a forward-looking and technically advanced agriculture.

To conclude, EIMA constitutes a moment of synthesis between the technical, scientific, economic and mercantile themes which leads back to the use of machines, from the simplest to the most complex, spanning the entire field of agriculture worldwide. The meetings, conventions, conferences which take place during EIMA represent material for reflection, stimulation and cultural debate which finds ample space in the informative media and arouses considrable interest within international public opinion.

XX EIMA, Bologna, fair centre of the Ente Autonomo Fiere of Bologna; total area 250,000 m^2, exhibition area in covered and heated pavillions for 92,000 m^2, meeting rooms of all sizes; logistic and interpreter services, press service, business centre for encounters and information.

Airport at 6 km, motorways at 500 m, railway station and city centre at 2 km.

Product Sectors:

I – Endothermic engines
II – Land-reclamation and forestry equipment
III – Tractors, walking tractors, motor hoes, motor mowers and multi-purpose farm vehicles
IV – Soil-working, sowing and fertilizer-distribution equipment
V – Plant and crop protection equipment
VI – Irrigation equipment
VII – Harvesting machines
VIII – Threshing, selection and conditioning equipment
IX – Animal-husbandry equipment
X – Product processing and Dairy-work equipment
XI – Crop handling and transportation equipment
XII – Components and accessories
XIII – Gardening equipment, small powered and manually-operated machines

★★★★★★★★★★★★★★★★★★★★
★★★★★★★★★★★★★★★★★★★★

Middle East Agriculture 89
3rd Agriculture, Irrigation and Agri-industry Show for the GCC States
November 20-23, 1989
Dubai International Trade Centre
United Arab Emirates

Middle East Agriculture 89 is again set to fulfil its role as the prime showcase for international agribusiness expertise and equipment now available to the Arab Gulf States.

The Exhibition, the only international trade show serving the six States of the Gulf Co-operation Council, has now achieved a reputation as the most comprehensive source of world-wide agribusiness suppliers who can assist the States towards their goal of food security.

The Show will prove an essential date in the calendar of the States farmers and officials responsible for implementing the regions ambitious agricultural programme.

Food security by the turn of the century remains the key policy of the Gulf Co-operation Council.

The six member States – United Arab Emirates, Oman, Qatar, Bahrain, Kuwait and Saidu Arabia – see the achievement of their goal as the cornerstone which will promote long term stability and security in the region. The agricultural secretariat of the GCC has announced a unifed policy to streamline development. Current budget allocations in excess of US$ 15 billion are now being directed towards the achievement of this policy.

GCC resolutions aimed at promoting development include moves to ease the establishment of joint venture projects and lifting of red tape to allow free movement of agricultural produce within member States.

Meanwhile State governments are continuing to offer major incentives not only for agricultural development but for useful research projects.

Stabilising oil revenues, the GCC States expected to receive US$ 44,200 million last year – an increase of US$ 6,300 million on 1986 – appear to provide a strong base for the far reaching advances planned for the agricultural sector.

For information contact:
Abdullah Mohammed
Dubai International Trade Center
P.O. Box 9292
Dubai, United Arab Emirates

AGRITECHNICA '89
International DLG-Exhibition for Agricultural Machinery and Equipment, Accessories and Sapre Parts
November 28-December 2, 1989
Frankfurt am Main, F.R. Germany

"AGRITECHNICA" will continue to offer to the international agricultural machinery industry every other year an opportunity to present its offer. The visitors expected at this event will be German and foreign dealers of the agro-technological industry, as well as decision-makers on investments from supra-national institutions, state trade nations and threshold and developing countries. Besides to expert advisers, the exhibition is to appeal to experts from the repair crafts, from maintenance and service, and particularly to the users of agro-technology: the farmers, contractors and representatives of machinery pools and forestry operations.

The exhibition program of "AGRITECHNICA '89" comprises the entire agro-technological offer for crop production. One of the centers of attention at this exhibition will be the sector of accessories and spare parts. Generally, the exhibition is classified into the following categories:

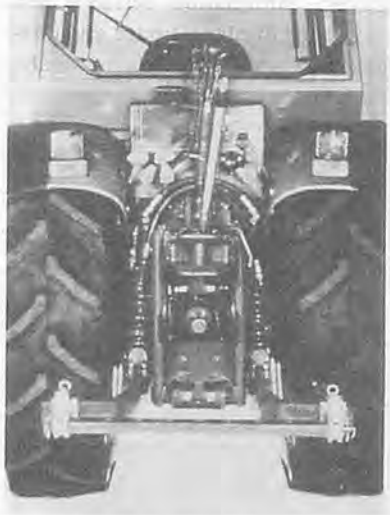
- Tractors and transportation vehicles
- Machines and equipment for
  - soil cultivation
  - seed materials and plant maintenance
  - fertilizer application and plant protection
  - crop harvesting
  - crop treatment and processing
  - sprinkling, irrigation and drainage
  - fruit cropping, horticulture, viticulture and special crops
  - landscaping
  - forest technology
- Accessories and spare parts
- Organization, consulting, farm management and electronic data processing.

For further information contact:
Deutsche Landwirtschaf-
gesellshaft, Zimmerweg 16
D-6000 Frankfurt/Main 1
F.R. Germany ■■

NEW PRODUCTS

The mission of the Committee to Encourage Technical Research is to show the advantages of the technical achievements of French and foreign manufacturers which are exhibited at the SIMA, SIMAVER, SIMAVIP SITEVI, offering a character of novelty or original improvements which can be considered as progress in the field of agricultural Mechanization.

No. 1 GOLD MEDAL at 60th SIMA
Swinging Hitch (Linkage) for Farm Tractors by FENDT FRANCE



This hitch (linkage), which is more particularly designed for slope-work and the use of tools on slopes, offers the advantage of maintaining the verticality of attached tools and of offsetting the lateral stresses due to the slope while avoiding tractor draft. The whole linkage is articulated at a single point, located under the tractor in front of the rear axle.

The lower bars (draught bars) are attached by means of ball couplings to a frame that can pivot both vertically and horizontally. This frame supports the jack cylinders and provides for monitoring the position and tool stresses.

The traction plate can be shifted horizontally in order to bring about a lateral off-centring offering directional stability for the tractor-tool unit.

Finally, the articulation framework can swing vertically thanks to two screw-jackets in the interest of adjusting verticality, and can pivot over a great width in the interest of instantaneous reversibility of the tools.

The results is comfortable driving and greatly improved handling characteristics, with continuous correction of the positions of the tools.

No. 2 SILVER MEDAL
Programmed Beet Distributor for Milk Cows by ALFA LAVAL ÉLEVAGE

This product is a line for rationed distribution of beets in feeding cows aimed at limiting the consumption of concentrated feeds.

An initial item of equipment carries out cleaning by means of a brushing process, and then washing and crushing before distribution take place. A programmable automatic system manages the supply process and then the distribution to the feed stalls on the basis of electronic identification of the animals.

The time-programming of portions and ingestion of beets make it possible to considerably increase the level of consumption per cow, and to make the best possible use of this type of feed, known for its high energy value.

No. 3 SILVER MEDAL
Aligner-grader for Carrots Packed lengthwise by CIME AGRO

In the washing-sorting chain for edible carrots, this new aligner-grader offers separation of short or broken carrots at the exit from the unit for sorting by diameter, and for each product line to be commercialized.

The alignment is carried out by a system of moving partitions moving back and forth above the conveyor belt, and the elimination of carrots that are too short is performed by a tipping action in a calibrated opening at the end of the conveyor, before the discharge spout.

The simplicity of the principle involved makes it possible to lower the price of this equipment considerably..

No. 4 SILVER MEDAL
Spray Boom with a Double System of Projected Jet and Accompanying Air Flow by HARDI FRANCE S.A.

In the interest of improving the coverage and the distribution in application of pesticides, the use of small-size nozzles producing fine droplets under high pressure seems to be an interesting solution, which may also lead to better control and

a reduction in the quantities distributed per hectare.

Still, this use with a normal boom with projected jet requires some special working conditions: low wind speed, and the avoidance of sunny weather, as well as treatment near sensitive crops or homes.

The innovation we describe here is aimed at reducing such drawbacks, while also maintaining the many advantages of projected jets.

The secret it to equip the 12-meter to 18-meter booms with an air turbine characterized by adjustable speed and flow (up to 30 m/sec and 1 500 m^3/hr), and to ensure movement of the fine spray droplets toward the plants.

No. 5 SILVER MEDAL

Arrangement Allowing Instantaneous Calibration of a Hydraulic Nonstop Safety Circuit on Plough by HUARD S.A.

With an eye on improving the operation of NSH safety systems, and more particularly in heavy, stony or dry packed ground, in which there are substantial stresses on the ploughshare tip, the "MAXIBAR" system is inserted between the pneumo-oil accumulator and the safety screw-jacks, making it possible to raise the triggering threshold.

The additional resistance offered by the hydraulic of the system is effective only at the beginning of the movement of the bottom encountering an abstacle, and the extent of the MAXIBAR effect is connected with the setting of the circuit pressure. The NSH performances are thereby improved, and offer greater comfort in use. There are fewer untimely triggerings in heavy ground, and there is a reduction in the drumming effects that are often a source of wear and tear, mechanical fatigue, and poor work quality.

This device is well adapted to fast tillage with numerous bottoms, and fewer stones should be cast up.

No. 6 SILVER MEDAL

Computerized Milk Refrigeration Tank by SELI-HUGONNET

The main characteristic of this milk refrigeration tank for farm use is the use of a microprocessor making it possible to enjoy:

1 - Automation of the basic functions: and 2 - Operational data management.

The principal innovations relate to: – The adaptation to the real operating conditions and the programming and monitoring of the operating parameters, namely; – Monitoring the volumes (of milk or water) by using sensors, making it possible to adjust the functions and constituting a harbinger of the development of computerized measurement; – Recording anomalies and triggering alarms in connection with variations from the programmed values; – Outside connections (Minitel, microcomputer, printer, information retrieval service...) for display, storage and publishing information allowing analysis and maintenance.

No. 7 SILVER MEDAL

Regulation and Monitoring Control for a Farm Milk Cooler by PROMINOX

The special feature of this new control system is that it is programmable and modulable hence the system is evolutive changing to refleet the demands of farmers in very diffrent situations, particularly in connection with milk collector.

This regulation control system therefore includes 3 modules.

Control of the cooling unit and of automatic agitation as a function of a temperature probe to which one may add a programme for delayed start-up of agitation at the time of the first milking the time-delay lowering of the instruction point memorization of the temperature of the last wasching, the 3rd level covering the programming of the start-up of cyclical agitation, especially as a function of the collection runs. ■■

INQUIRY and REQUEST to AMA

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

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

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

7–2 Kanda Nishikicho Chiyoda–ku Tokyo–Japan 101

ADVERTISED PRODUCTS INQUIRY

Product	Advertiser	Vol., No., Page

EDITORIAL REQUEST TO AMA

Your Name :

Address :

Occupation :

SUBSCRIPTION/ORDER FORM

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

Issued Quarterly

Subscription Rate (includes surface mail postage)

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

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

★Spring, 1971	□Vol.7 No.2, Spring, 1976	□Vol.9 No.4, Autumn, 1978
□Vol.2 Autumn, 1971	□Vol.7 No.3, Summer, 1976	□Vol.10 No.1, Winter, 1979
□Vol.3 No.1, 1972	□Vol.7 No.4, Autumn, 1976	□Vol.10 No.2, Spring, 1979
□Vol.3 No.2, Summer, 1972	□Vol.8 No.1, Winter, 1977	□Vol.10 No.3, Summer, 1979
□Vol.4 No.1, Spring, 1973	□Vol.8 No.2, Spring, 1977	□Vol.10 No.4, Autumn, 1979
□Vol.4 No.2, Autumn, 1973	□Vol.8 No.3, Summer, 1977	★Vol.11 No.1, Winter, 1980
□Vol.5 No.1, Summer, 1974	□Vol.8 No.4, Autumn, 1977	□Vol.11 No.2, Spring, 1980
□Vol.6 No.1, Spring, 1975	□Vol.9 No.1, Winter, 1978	□Vol.11 No.3, Summer, 1980
□Vol.6 No.2, Autumn, 1975	□Vol.9 No.2, Spring, 1978	□Vol.11 No.4, Autumn, 1980
□Vol.7 No.1, Winter, 1976	★Vol.9 No.3, Summer, 1978	★: Indicates issues out of stock.

□ **Abstract and Index, 1971-80 (Special Issue, 1983)**

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

Back Issues from 1981, ¥.1,700 per copy (Vol. 12 No. 1 and No. 4 are out of stock)

Abstract and Index, Special Issue, 1983, ¥2,000 per copy.

Vol._____No._____,_____19_____,_____copy/copies

(check one)

□ Please invoice me/us

□ I/We enclose remittance for ¥_____

****

Name: _____

Firm: _____

Position: _____

Address: _____

(block letters)

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

7, 2-chome, Kanda Nishikicho, Chiyoda-ku,
Tokyo 101 Japan
Tel. (03)−291−3671~4, 5718

STAMP

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

7, 2-CHOME, KANDA NISHIKICHO, CHIYODA-KU
TOKYO, 101 JAPAN

1st FOLD HERE

2nd FOLD HERE

Tractors 10-35 hp: Catalogue with an Introduction in English

(F.R. Germany)

by Rudolf Holtkamp

This catalogue provides a survey of those agricultural tractors which

- are produced and used in developing countries, or
- are being offered for use in developing countries or have been specially developed for this purpose.

With few exceptions, only tractors are considered which have more than two wheels and a maximum engine output of 35 HP (26 kW). The objective pursued by this catalogue is to illustrate the diversity of solutions available in the field of tractor technology for use under the unique conditions of the tropics and subtropics. A total of more than 90 different models from 23 different countries are presented.

This catalogue addresses persons who

- need to select and purchase tractors and are looking for sources;
- are engaged in the development and/or production of tractors and require a survey of technical solutions available;
- are involved in the selection of suitable models on the basis of comparative tests; or
- are interested in obtaining more detailed information on the role of small tractors in rural and industrial development.

Size: 21 x 15 cm, 158pp, paper cover

Published by:
Verlag Josef Margraf
Postfach 105
D-6992 Weikersheim
F.R. Germany

Computer Modelling in Agricultural Mechanization

(Ireland)

by Shane M. Ward

The main objective of this book is to provide an introduction to the use of computers in the modelling of agricultural mechanization systems. This is particularly important in view of the fact that mechanization systems are the largest items of capital investment on many farms, with total investment costs exceeding IR£100,000, in many cases. While, in the past, computer modelling has been somewhat removed from practical on-farm applications, recent developments in computer technology (particularly in microcomputers) have made it possible for agricultural advisers, and indeed farmers, to obtain access to a computer. The potential of this new technology is vast and has a major role to play in the advancement of agricultural technology and management practices.

This book illustrates the development of a computer-based model of silage mechanization systems; but the approach adopted is generalized and can be applied, equally well, to other agricultural mechanization systems. It was specifically avoided to introducing complex concepts in modelling theory but, rather, have structured the content of the book in a format that can be readily understood by a person with no previous knowledge of systems modelling or computer programming. It is hoped that this simplified but practical approach will make the topic appealing to the reader and thereby whet his/her appetite for more.

Size: 21 cm x 15 cm, 110pp, soft cover

Published by:
Boole Press Limited
51 Sandycove Road
Dun Laoghaire
Co. Dublin, Ireland

Proceedings of International Workshop on Farm Mechanization – Present Situation in Developing Countries; April 3, 1989 at The Faculty of Agriculture, Utsunomiya University, Japan

(Japan)

This issue has been prepared in order to update the information contained in the JSAM guidebook of agricultural mechanization planning at the developing countries, published in 1976. In the 13 years since the previous publication, many experts of agricultural technology were sent to the developing countries. And now, many foreign students and researchers are visiting the center and the local government in Japan. Some of them are also a member of JSAM.

Fortunately, 24 participants came to the Tsukuba International Agricultural Training Centre of JICA from seventeen countries. Two experts, Mr. Shuji ISHIHARA and Mr. Kensuke AMANO took part in a discussion.

In this session, we will discuss and exchange information on agricultural mechanization by the country reports and the technical reports on Egypt and Thailand. It is hoped that this issue will be a useful guide for development planner and others concerned with developing and supporting appropriate agricultural mechanization. This programme is supported by the executive committee of the International Committee.

Size: 25.5 x 18 cm, 107pp, soft

cover.
Price: 2000 Yen.
Published by:
Japanese Society of Agricultural Machinery
c/o IAM, BRAIN
Nissin-cho, 1-40-2
Omiya-shi, Japan

Off-the-road Wheeled and Combined Traction Devices — Theory and Calculation
Russian Translation Series 59
(Netherlands)

---

by Ageikin, Ia. S.

The topics covered in this book include the operating conditions of off-the-road vehicles, the theory of interaction between wheeled vehicles and the deformable surfaces over which they move and the influence of design and operating parameters of the vehicles on the mobility as well as other properties of the machines.

Methods of determining the basic parameters of off-the-road vehicles have been elaborated.

This book is intended for engineers specializing in automobile construction. It will also be useful for scientific personnel engaged in the design of automobiles with a high maneuverability.
Size: 24.5 x 16 cm, 202 pp, hard cover.
Price: US$37.50.
Published by:
A.A. BALKEMA Book Distributors Postbus 1675
NL-3000 BR Rotterdam, Netherlands

Proceedings of the 2nd Asia-Pacific Conference of the International Society for Terrain Vehicle Systems **held December 6-10, 1988 at the Asian Institute of Technology, Bangkok, Thailand**
(Thailand)

The proceedings, 635 pages, comprising from 56 papers (US$50 plus postage) is now available for sale from:
Asian Institute of Technology
G.P.O. Box 2754, Bangkok
10501 Thailand

British Agricultural Machinery 1988/89
(U.K.)

The Agricultural Engineers Association (AEA) is the trade association responsible for co-ordinating the activities of the British Agricultural Engineering Industry.

The Association represents over 90 per cent of the Industry in Great Britain and includes among is members all the principal manufacturers of tractors and machinery. It is involved in marketing and trade promotion, the collection and circulation of statistical information, preparation of safety and other standards and the representation of the industry in its dealings with government, the European Commission, and many other organizations.

Farm machinery is big business for Britain and has massive export sales to over 160 countries, running at a level of £670 million sterling per annum.

'British Agricultural Machinery 1988/89' is the second in a series of directories to be published by AEA giving details of the products of the British Agricultural Engineering Industry. This 1988/89 edition is the most comprehensive reference source of British Agricultural Machinery companies for the industry throughout the World.

For more details of the products included in this directory, contact should normally be made direct with the manufacturer concerned. However, in the case of difficulties or for additional information, the AEA will be delighted to assist.
Size: 30 x 21 cm, 66 pp, soft cover
Published by:
The Agricultural Engineers Association Ltd
Samuelson House
Paxton Road
Orton Centre
Peterborough
Cambs PE2 OLT
U.K.

INSTRUCTIONS TO AMA CONTRIBUTORS

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

Criteria for Article Selection

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

a. are written in the English language ;
b. are relevant to the promotion of agricultural mechanization, particularly for the developing countries ;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission ;
d. deal with practical and adoptable innovations by small farmers with a minimum of complicated formulas, theories and schematic diagrams ;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article ;
f. are typewritten, double-spaced, under 4,000 words (approximately equivalent to 8 pages of AMA-size paper) ; and those that
g. are supported by authentic sources, reference or bibliography.

Rejected/Accepted Articles

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

Procedure

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

Format/Style Guidance

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

Co-operating Editors

J G Van Lancker | E A Baryeh | A M Hossary | A Kandiah | D B Ampratwum | R J Bani | I K Djokoto | D K Some | M S Choudhury | J C Igbeka

E U-Odigboh | K C Oni | N G Kuyembeh | A H Abdoun | A B Saeed | A I Khatibu | S Tembo | I de A Nääs | A E Ghaly | A A Valenzuela

— AFRICA —

Julien G. Van Lancker
Professor Visitor (Agricultural Engineering), University of Brundi, Brundi

Edward A. Baryeh
Professor, ENSIAAC, BP455, Nagaounde, Cameroon

Ali Mahmoud El Hossary
Senior Under-Secretary for Engineering Affairs, Ministry of Agriculture, Dokki, Cairo, Egypt

Arumugam Kandiah
Institute of Agricultural Research, P.O. Box. 2003, Addis Ababa, Ethiopia.

David Boakye Ampratwum
Part-Time Lecturer, Agricultural and Food Engineering, University of Ghana, Legon, Ghana

Richard Jinks Bani
Lecturer & Co-ordinator, Agric. Engineering Div., Faculty of Agriculture, University of Ghana, Legon, Ghana

Israel Kofi Djokoto
Senior Lecturer, University of Science and Technology, Kumasi, Ghana

David Kimutai arap Some
Lecturer, Dept. of Agric. Engineering, University of Nairobi, Nairobi, Keniya

Md. Shahansha Uddin Choudhury
Professor of Agricultural Engineering, University of Sokoto, P.M.B. 2346, Sokoto State, Nigeria

Joseph Chukwugozium Igbeka
Associate Professor, Dept. of Agricultural Engineering, Faculty of Technology, University of Ibadan, Ibadan, Nigeria

E.U. Odigboh
Professor & Head of Agricultural Engineering Department, University of Nigeria, Nsukka, Nigeria

Kayode C. Oni
Senior Lecturer, Dept. of Agric. Engineering, University of Ilorin, P.M.B. 1515, Ilorin, Nigeria

N.G. Kuyembeh
Dean, Faculty of Agriculture and Head, Dept. of Agric. Engineering, Njara University College, University of Sierra Leone, Sierra Leone

Abdien Hassan Abdoun
Member of Board, Amin Enterprises P.O. Box 1333 Khartoum, Sudan

Amir Bakheit Saeed
Lecturer, Dept. of Agric. Engineering, Faculty of Agriculture, University of Khartoum, Khartoum, Sudan

Abdisalam I. Khatibu
National Project Coordinator and Director, FAO Irrigated Rice Production, Zanzibar, Tanzania

Solomon Tembo
Lecturer and Acting Chairman, Dept. of Soil Science and Agric. Engineering, University of Zimbabwe, Harare, Zimbabwe

— AMERICAS —

Irenilza de Alencar Nääs
Professor, Agricultural Engineering College, UNICAMP, Agricultural Construction Dept., P.O. Box 6011, 13081 – Campinas – S.P., Brazil

Abdelkader Elmetwally Ghaly
Associate Professor, Agric. Engineering Dept., Faculty of Engineering, Technical University of Nova Scotia, Halifax, Nova Scotia, Canada

A.A. Valenzuela
Dean, College of Agriculture, University of Concepción-Chile Chillan, Chile

Armed Hossain Mirdha
Professor & Head, Area of Research in Agril. Production, Academic Div. of Agril. & Livestock Sc., Sierra Unit. Autonomous University Juarez of Tabasco, Apdo. Posta-960, Admon. de Correos No. 2 Villahermosa, C.P. 86100 Tabasco, Mexico

William J. Chancellor
Professor, Agricultural Engineering, University of California, Davis, California 95616, U.S.A.

Merle L. Esmay
Professor Emeitus, Agricultural Engineering, Michigan State University, East Lansing, Michigan 48823, U.S.A.

Megh Raj Goyal
Associate Agric. Engineer, Fruits Substation HC-02 – Box 7115, Juana D'iaz, PR, 00665-9601 U.S.A.

Allan L. Philips
Director, Agric. Engineering Dept., the University of Puerto Rico, Mayaguez, Puerto Rico 00708, U.S.A.

— ASIA and OCEANIA —

Shah M. Farouk
Professor, Dept. of Farm Power & Machinery, Bangladesh Agricultural University, Mymensingh, Bangladesh

Mohammed A. Mazed
Chief Scientific Officer & Head of Agric. Engineering Div., Bangladesh Agricultural Research Institute, Joydebpur, Dhaka, Bangladesh

Manbahadur Gurung
Horticulture Extention Officer, Ministry of Development, Dept. of Agriculture, HA Bhutan P.O. HAA, Bhutan

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

Satish Chandra
Assistant Director of Agriculture, Koronivia Research Station, Ministry of Agriculture and Fisheries, P.O. Box 77, Narsori, Fiji

A.M. Michael
Director, Indian Agricultural Research Institute, New Delhi 110012, India

J.P. Mittal
Project Coordinator, All India Coordinated Research Project on Energy Requirements in Agric. Sector, College of Agric. Engg., Punjab Agric. Univ. Ludhiana, India

A H Mirdha | W J Chancellor | M L Esmay | M R Goyal | A L Philips | S M Farouk | M A Mazed | M Gurung | Wang Wanjun | S Chandra

A M Michael | J.P. Mittal | T P Ojha | S R Verma | Soedjatmiko | M Behroozi-Lar | J Sakai | B A Snobar | C J Chung | Imad Haffar

M Z Bardale | B K Shrestha | M Afzal | A D Chaudhry | M S Chaudhry | B T Devrajani | A Q Mughal | Surya Nath | R M Lantin | B P Venturina

T.P. Ojha
Director, Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal 462018, India

S.R. Verma
Daan, College of Agric. Engineering, Punjab Agricultural University, Ludhiana 141004, India (Presently; Chief Adviser to Head, National Centre for Agric. Mechanization, P.M.B. 1525, Ilorin, Nigeria)

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

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

Jun Sakai
Professor, Dept. of Agric. Engineering, Faculty of Agriculture, Kyushu University 46-05, Hakozaki, Higashi-ku, Fukuoka B12, Japan

Bassam A. Snobar
Professor & chairman, Plant Production Dept., Faculty of Agriculture, University of Jordan, Amman, Jordan

Chang Joo Chung
Professor, Dept. of Agric. Engineering, College of Agriculture, Seoul National University, Suweon, Korea 170

Imad Haffar
Assistant Professor of Agric. Mechanization, Dept. of Soils, Irrigation and Mechanization, Faculty of Agriculture and Food Sciences, American University of Beirut, Beirut, Lebanon

Muhamad Zohadie Bardaie
Associate Professor, Faculty of Engineering, Universiti Pertanian Malaysia, 43400 UPM, Serdang, Selangor, Darul Ehsan, Malaysia

Bala Krishna Shrestha
Agricultural Engineer, 4/141, Pulchowk Behind the Fire Brigade, Lalitpur, Nepal.

Mohammad Afzal
Senior Engineer (Mechanization Engineer), Farm Machinery Institute, National Agric. Research Centre P.O. NIH, Islamabad, Pakistan

Allah Ditta Chaudhry
Associate Professor & Charman, Dept. of Farm Machinery and Power, Agric. Engineering and Technology, University of Agriculture, Faisalabad, Pakistan

Muhammad Siddique Chaudhry
280 Roger Williams Ave. #35 East Providence, R.I. 02916, U.S.A.

Bherulal T. Devrajani
Principal Investigator, Sind Agriculture University, Tandojam, Sind, Pakistan

A.Q. Mughal
Professor & Dean, Faculty of Agricultural Engineering, Sind Agriculture University, Tandojam, Sind, Pakistan

Surya Nath
Lecturer II (Agric. Engineering) Dept. of Agriculture, University of Technology, Lae, Papua New Guinea

Reynaldo M. Lantin
Agricultural Machinery Expert. Regional Network for Agricultural Machinery, c/o United Nations Development Programme P.O. Box 7285 ADC Pasay City Metro Manila, Philippines

Richardo P. Venturina
Assistant Scientist for Agricultural Research, National Science Development Board, P.O. Box 3596, Rizal, Manila, Philippines

M.H. Abdel Aziz
Professor of Irrigation Engineering and Head, Agricultural Engineering Dept., Riyadh Univ., Saudi Arabia

S. Illangantileke
Head, Dept. of Agric. Engineering, Faculty of Agriculture, University of Peradeniya, Sri Lanka

Suppiah Kathirkamathamby
Head, Agricultural Engineering Research and Development Div., Dept. of Agriculture, Peradeniya, Sri Lanka

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

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

Gajendra Singh
Professor of Agric. Engineering, Div. of Agricultural & Food Engineering, Asian Institute of Technology, GPO 2754, Bangkok 10501, Thailand

Yunus Pinar
Assistant Professor, Agric. Engineering Dep., Faculty of Agriculture, University of Ondokuz Mayis, Kurupelit, Samsun, Turkey

-- EUROPE --

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

T. Touggaard Pedersen
Professor, Agric. Engineering at the Royal Veterinary and Agricultural University, Copenhagen, Denmark

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

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

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

A A Wanders | J Kilgour

M H A Aziz | S Illangantileke | S Kathirkamathamby | S F Chang | C Rojanassaroj | G Singh | Y Pinar | A P Kaloyanov | T T Pedersen | G Pellizzi

BACK ISSUES

(Vol. 19 No. 1, Winter 1988 ~)

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA, AND LATIN AMERICA (Vol. 19, No. 1, Winter, 1988)

Editorial (Y. Kishida) 7
Farm Mechanization in West Java, Indonesia (G. Singh, H. Siswasumarto) 9
Cost of Operating Tractors on Quetta Farms, Pakistan (S.B. Bukhari, J. M. Baloch, S.H. Naqvi) 14
Mechanical Transplanting of Rice in Pakistan (A.S. Khan, W.W. Gunkel) 21
Design and Development of a 6-Row Korean Transplanter (A.S. Khan, W.W. Gunkel) 27
Field Performance of Seeding Devices in Rainfed Situation in Orissa, India (P.C. Senapati, P.K. Mohapatra, D. Satpathy) 35
The AMRI Sugarcane Planter (M. Yasin, C.A. Salam, M.A. Farooq) . . 39
Mechanization of Sugarcane Ratoon Culture in India (M.P. Sharma, K. Singh) 45
Supplemental Mechanical Weed Control for Maize-Cowpea Rotation in Mucuna Mulch (E.A. Baryeh) . . . 48
Effects of Electrostatic Charging and Vertical Air Current on Deposition of Pesticide on Cotton Plant Canopy (Y. Zeren, E. Moser) 55
Disign and Construction of a Simple Rice Parboiling Hardware for Use in Nigeria (O. Oje) 61
Operational Safety Requirements for Farm Machinery: A Case Study in Pakistan (A.I. Mufti, S.I. Ahmad, I.S. Ahmad, A.P. Chaudhary) 64
Agricultural Mechanization in Orissa, India (S.K. Dash, S.C. Pradhan) . . . 69
Field Reliability of Farm Machinery (A.P. Chaudhary, S.I. Ahmad) 73
Abstracts 44
News 79
Book Review 81

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 19, No. 2, Spring, 1988)

Editorial (Y. Kishida) 7
A Study on Engineering Design Theories of Hand-Tractor Plows II (S. Phongsupasamit, J. Sakai, T. Kishimoto) 9
Use of Conical Rotors for Multi-purpose Wetland Farming Machines (A.U. Khan, M. Diestro, R. Bautista, E. Calilung, A. Vasallo) 20
Comparative Tractive Performance of Three Tractors (J.G. Shebi, K.C. Oni, F.G. Braide) 25
Comparison of Zero-Tillage and Conventional Tillage in Wheat and Maize Production under Different Soils and Climatic Conditions in Nigeria (P.R. Maurya) 30
Working with Bangkok Clay Soil— Some Experiences (V.M. Salokhe, D. Gee-Clough) 33
Development and Fabrication Techniques of Improved Grubber (G. Singh) 42
A Small Scale, Non-Destructive Tropical Grass Seed Harvester (R.T. Peterson, I. Romero, D.B. Tinker) 47
Handling and Transportation of Vegetables in Ghana (E. Kra, R.J. Bani) 52
Using Agro-Processing Equipment in Enhancing Rural Industrialization in India-Case Studies (R.P. Kachru, P.K. Srivastava, S.D. Deshpande, T.P. Ojha) 55
Small Farmer Mechanization in Chile (E.J. Hetz) 63
Status of Farm Mechanization in Iraq (L.M. Ali, A.M. Al-Khafaf) . . 69
A Successful Model for Introducing Agricultural Machinery (P. Datt, T.P. Ojha) 74
Standardization Efforts in Agricultural Engineering (R.N. Sharma) 77
Abstracts 54
News 82
New Products 83
Book Review 85

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 19, No. 3, Summer, 1988)

Editorial (Y. Kishida) 7
Modeling Flow of Irrigation Water Discharge Uniformity in Microtube Emitters (M. Gueye, J. Yonemura, A. Sasao, A.R. Shajary) 9
Power Requirements of Different Cropping Systems in Bangladesh (M.A. Hossain) 15
Computer Programme for Selecting Farm Machinery for Small Farms (H.O. Laurel) 20
Design of Extended Octagonal Ring Dynamometer for Rotary Tillage Studies (T.C. Thakur, R.J. Godwin) 23
Wet and Dry Tillage Practices in Paddy Production (A. Majid, S.I. Ahmad, M. Farooq, A.I. Mufti 29
A Compression Ignition Engine on Biogas-Diesel Fuel (T.K. Bhattacharya, B. Singh, T.N. Mishra) 32
A New Multi-crop Inverted-T Seeder for Upland Crop Establishment (M.A. Choudhary) 37
Optimum Sprout Length for Sowing Pre-Germinated Paddy Seed in Puddled Soil (A.P. Srivastava, J.S. Panwar) 43
Performance Evaluation of Mechanical Reapers in Pakistan (G. Singh, A.P. Chaudhary, D. Gee-Clough) . . 47
Cost of Using Power Reapers: Malaysian Experience (K. Aribi, I.Y. Md. Salleh) 53
Threshing Efficiency of Pulses Using Step-wise Regression Technique (S.K. Tandon, B.S. Sirohi, P.B.S. Sarma) 55
Storage of Farm Products in Rural Papua New Guinea (S.N. Misae) 58
Husk Utilized as Fuel (B.S. Pathak, A. Singh) 65
Improved Equipment for Castor Bean Crop Cultivation (A.C. Varshney) 71
Run-off Farming in Ghana: A Mathematical Approach (S.K. Agodzo) 75
Effect of Restrained and Un-Restrained Linkage on Implement Performance (J.M. Baloch, A.N. Mirani, S. Bukhari) 77
Abstracts 82
News 83
Book Review 85

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 19, No. 4, Autumn, 1988)

Editorial (Y. Kishida) 7
Performance of Selected Tillage Implements (S. Bukhari, M.A. Bhutto, J.M. Baloch, A.B. Bhutto, A.N. Mirani) 9
Effects of Load and Speed on Performance of Clod Crushers (T.C. Thakur, B.P. Varshney, A. Yadav, P. Chand) 15
Development and Testing of Bullock-drawn Land Scraper and Land Grader (S.C. Pradhan, S.K. Dash, H. Raheman) 21
An Animal-drawn Mechanical Ridge Tier for the Cereal Farming Systems of Burkina Faso (J.G. Nagy, H.W. Ohm, L.L. Ames, L.D. Schaber) 25
The Tir Seeding Method and Tir Drills: A Literature Review (M. Yilmaz, N. Yilmaz) 31
Laboratory Studies on Spray Distribution Pattern of the Wide-swath Spray Boom (H.S. Bisen, N.S.L. Srivastava) 34
Comparative Use of Self-propelled and Tractor-drawn Combines (A. Razzaq, C.B. Ahmad, C.B. Ahmad Sabir) 39
Testing and Evaluation of Improved Yaatra Ox-cart (S.D. Deshpande, T.P. Ojha) 44
Modern Food Grain Silos in Bangladesh (J.N. Samaipati, T.T. Pedersen) 49
Possibilities of Mechanizing Paddy Production in Kenya (S. Furuichi, D.K. Some) 53
Potentials for Computer-aided Farm Machinery Decisions in Pakistan (M.A. Choudhary, S.W. Brown) . . 58
Cotton Cultivation in Haryana State, India (V.P. Bahl, D.N. Sharma, M.L. Jain) 63
Performance of Oil Milling Technologies in India (B.S. Pathak, A. Singh, R.N. Verma) 68
A Wood Chip-fired Residential Boiler (K. Jusoff) 73
Alcohol as Tractor Fuel— Is There Any Future? (R. Janius) 75
Abstracts 78
News 79

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATAIN AMERICA (Vol. 20, No. 1, Winter, 1989)
Editorial (Y. Kishida) 7
Comparison of Tillage Equipment for Small Rice Farm (E.J. Calilung, R.E. Stickney) 9
Soil Manipulation with Tillage Implements (S.B. Bukhari, J.Md. Baloch, A.N. Mirani) 17
Puddled Characteristics of Soil with Selected Implements (R. Manian, P. Jivaraj) 20
A Methodology for Performance Evaluation of Puddling Implements (N.K. Awadhwal, C.P. Singh) 25
Comparative Performance of Four-wheel Tractor and Two-wheel Tractor in Small Plots (Md.W. Ullah, S.S. Kofoed, T.T. Pedersen) 27
Simplified Approach for Evaluating Longitudinal Stability of Agricultural Tractors (J. Prasad, G. Meena) 31
Use of Seed-cum-fertilizer Drill in Wheat Crop Production (A.P. Sharma, M.K. Garg, P.S.R. (Gupta) 38
Design Development and Testing of Hand Rotary Broadcasting Device for Seeds, Fertilizers and Granular Insecticides (A. Tajuddin) 41
Selection of Appropriate Solar Pump for Agricultural Applications (K. Malhotra, M. Kaur) 45
Socio-economic and Technical Performance of Mechanical Reapers in the Philippines (F.S. Juarez, B. Duff, A. Te, E. Stickney) 49
Status of Mechanization of Harvesting and Threshing of Soybean in India (S.K. Tandon, J.S. Panwar) 55
Design and Development of Bullock-drawn Potato Digger (A.C. Varshney, K.V. Patel, A.S. Patel) 61
Comparative Performance of Machine Milking Methods in Turkey (M. Nalbant, P. Ulger) 63
Steering of Rear Axle Wheels in Three-axle Trailers (M. Yilmaz) . . . 66
Vegetable Oil Derivatives: Fuel for Diesel Engines (A.R. Tahir, M.Z. Khan, H.M. Lapp) 69
Farm Accidents in Pakistan (A.I. Mufti, S.I. Ahmad, A. Majid) 73
In-service Training for Agricultural Extension Staff in Pakistan (A. Razzaq) 76
Abstracts 44
News 79
Book Review 82

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 20, No. 2, Spring 1989)
Editorial (Y. Kishida) 7
Draft Oxen Energy Expenditure: A Mexican Case Study (B.G. Sims, A.A. Ramirez) 9
Development of Tractor-operated Hoist for Fruit Harvesting (A. Tajuddin, K.R. Swaminathan) 15
Grain Losses of Various Wheat Varieties Harvested by Power Reaper (S. Bukhari, K.A. Ibupoto, G.H. Jamro, M. Zafrullah) 17
Predicting Dryer Performance Using Similitude Analysis (S. Sokhansanj, D.S. Jayas, J.D. Wasserman) 19
An Ambient-air In-storage Paddy Drying System for Korean Farms (K.S. Kim, M.G. Shin, B.C. Kim, J.H. Rhim, H.S. Cheigh, W. Mühlbauer, T.W. Kwon) 23
Separation of Asparagus Berries Using Stationary Plot Thresher (M.R. Goyal, O. Colberg, W. Vicenty) 30
A Resource Efficient Approach to Potato-Stone-Clod Separation (G.C. Misener, C.D. McLeod) 33
Orifice Meter for Pump Discharge Measurement (M. Hassan, R.C. Lazaro, M.R. Hoque) 37
Pulse Processing Machinery in India (S.D. Kulkarni) 42
Some Factors Casuing Rice Milling Loss in Bangladesh (N.N. Sarker, S.M. Farouk) 49
Resistance of Sorghum, Peanut and Seasame to Air Flow (M.A. Hummeida, A.El T. Ahmed) 53
Requirements and Use of Tractor Power in Punjab Agriculture (J. Singh, S.K. Sekhon, A. Kaur) 57
Design of Group Mechanization System Using 'CAFARMS' Computer Model for Kada Area (T. Konaka, W.M. Zakludin) 59
Status of the Agricultural Engineering National Program in Brazil (D.B. Marchetti, I. de A. Nääs) 66
Agricultural Mechanization Prospect in Papua New Guinea (S. Nath) . . . 71
Scope and Implications of Mechanizing Rice Production in Pakistan (A. Majid, A.S. Khan, S.I. Ahmad) . . . 74
News 79
New Products 81
Book Review 83

COMPUTERIZED AMA INDEX AVAILABLE

A computerized index of technical articles in *Agricultural Mechanization in Asia, Africa and Latin America* has been compiled for the years 1971 through 1987. Each citation includes truncated versions of the title, first and second authors' names and four keywords. Year, issue and page number of each article are given. The citations along with software for searching the database are all included on a single computer diskette for use with IBM-PC, -XT, -AT or compatible type computers.

Anyone wishing to receive this material may send one formatted. 5 1/4-inch, 360 Kbyte, double-sided, double-density diskette to William Chancellor, Agr. Eng. Dept., Univ. of Calif., Davis, CA 95616, USA. The database and searching software will be copied to that diskette, and it will be returned by airmail along with software documentation. There is no charge. Any special customs or postal designation or specifications required should be stated in the letter of request. Annual updates will be available in the future.

EIMA BOLOGNA

BOLOGNA
8-12 NOVEMBER 1989

Admission by invitation:
8-9-10 November

Admission to public:
11-12 November

international exhibition of agricultural machinery manufacturers

exhibition of gardening machinery

Organized by **UNACOMA**
with the collaboration of the ENTE AUTONOMO FIERE DI BOLOGNA

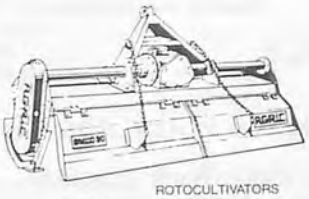
for further details:

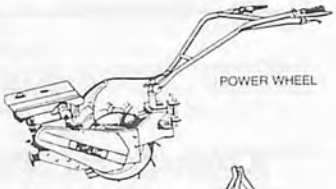
eima (00161 ROMA-VIA L SPALLANZANI 22/A
TEL. (06)844-9441 TELEX.4402722 TELEFAX. 06-844-1997

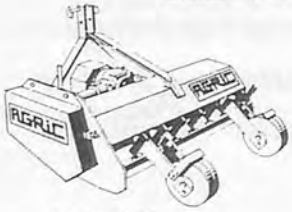
AGRIC®

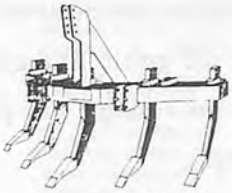
OFFERS

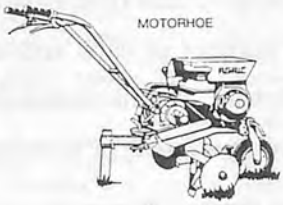
A COMPLETE RANGE AND A RELIABLE NAME IN FARM EQUIPMENT

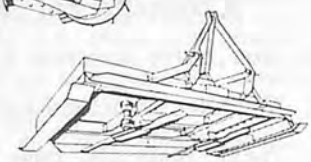

ROTOCULTIVATORS

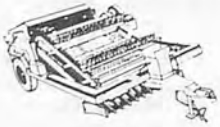

POWER WHEEL

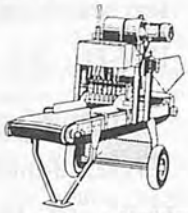

FLAIL MULCHER


SUBSOILERS


MOTORHOE


GRASS TOPPER


ROCK PICKERS

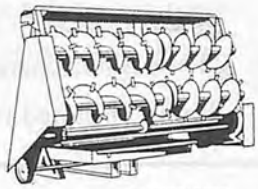

BLOCK PRESS

Selected Range

ROTOCULTIVATORS	MANURE SPREADERS
ROTARYCUTTERS	SUBSOILERS
GRASS TOPPERS	DISC PLOUGHS
MOTORHOES	M.B. PLOUGHS
POWER WHEELS	ROCK PICKERS
BLOCK PRESS	TRAILERS
FLAIL MULCHERS	HYDRAULIC CRANES

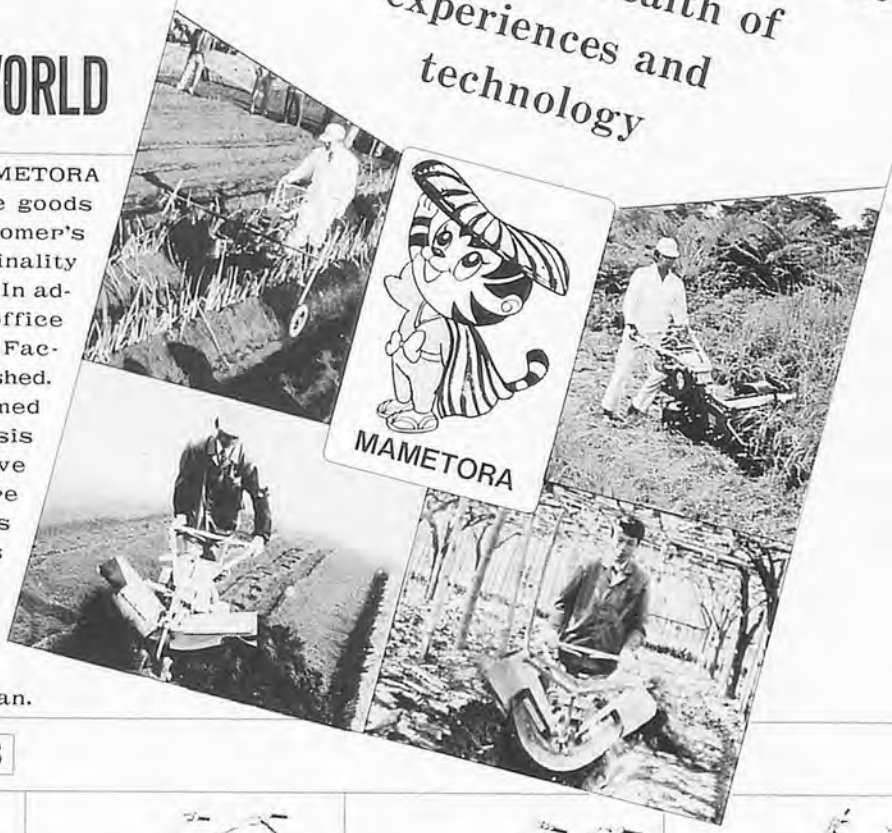
PLOUGHS

For further information, please contact
AGRIC, S.A. Maquinaria Agricola
Carretera N-152, Km.80
Masias de Voltregá (Barcelona), España
Tel. 857 03 75*
Telex 52.029 ROTO E
Fax 34.3.857 0893


MANURE SPREADERS

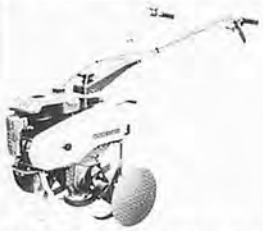
MAMETORA DEDICATES TO AGRICULTURE ALL OVER THE WORLD

Researches and Development
Unequaled Wealth of experiences and technology



It is the motto of MAMETORA that we manufacture goods in order to meet customer's benefits with originality trusty and hearty. In addition to the head office in Okegawa Kisakata Factory has been established. Now that we have formed the much steadier basis as a comprehensive manufacturer. We are always making efforts to manufacture goods of high quality and are pleased to devote ourselves to the food industry in the world as well as that in Japan.

EXPORT SERIES



MC-80R Multing Rotor Set

MC-100

MC-130E

MC-181SB

MC-200

MC-210 スキ付

LV-1

LV-2

MAMETORA AGRIC. MACHINERY CO., LTD.

HEAD OFFICE ADD : 9-37, NISHI-2 CHOME, OKEGAWA-SHI, SAITAMA-KEN, JAPAN.
TELEPHONE : 0487-71-1181 TELEX : 2922561 MAMETO-J