International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.XIV, NO.4, AUTUMN 1983

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

Kubota products provide power, economy and versatility wherever there's a need.

All over the world, Kubota tractors, tillers and engines are providing better ways of meeting specific needs in agriculture, construction, business and dozens of other fields. Kubota products have one thing in common: excellence. Excellence in careful design, quality-controlled manufacture, stringent testing and sincere after-the-sale service. Excellence in meeting the customer's needs. Excellence in overall versatility and economy. For all these reasons, you should feel assured when you select a Kubota to assist you in your tasks.

Kubota M7500DT diesel tractor



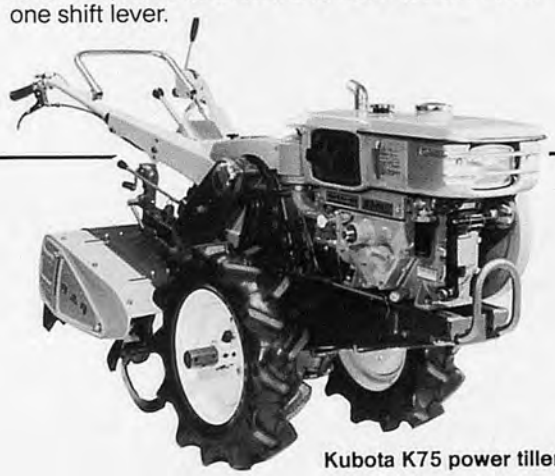
Kubota tractors are known 'round the world for their compact versatility.
Kubota diesel 2WD and 4WD tractors come in three separate series: B (14—19HP), L (25—38HP) and M (55.5—81HP). Our M7500 four-wheel drive diesel tractor gives you a choice of 16 forward and 4 reverse speeds, to let you easily adapt to any terrain or work conditions.

Kubota ER950DI diesel engine



Kubota engines are used wherever there's a need for reliable power for pumping or generating.
Ranging from 2.3HP to 1,650HP in size, Kubota generator and pump engines come in gasoline, kerosene and diesel models. Our ER950DI's large displacement provides surprising horse-power, torque and economy.

Kubota power tillers get the job done faster and better.
With Kubota power tillers, soil preparation is easy and fast. Tilling and harrowing can be accomplished simultaneously. Our K75 rotary type power tiller features 6 forward and 2 reverse speeds that are easily selected with only one shift lever.



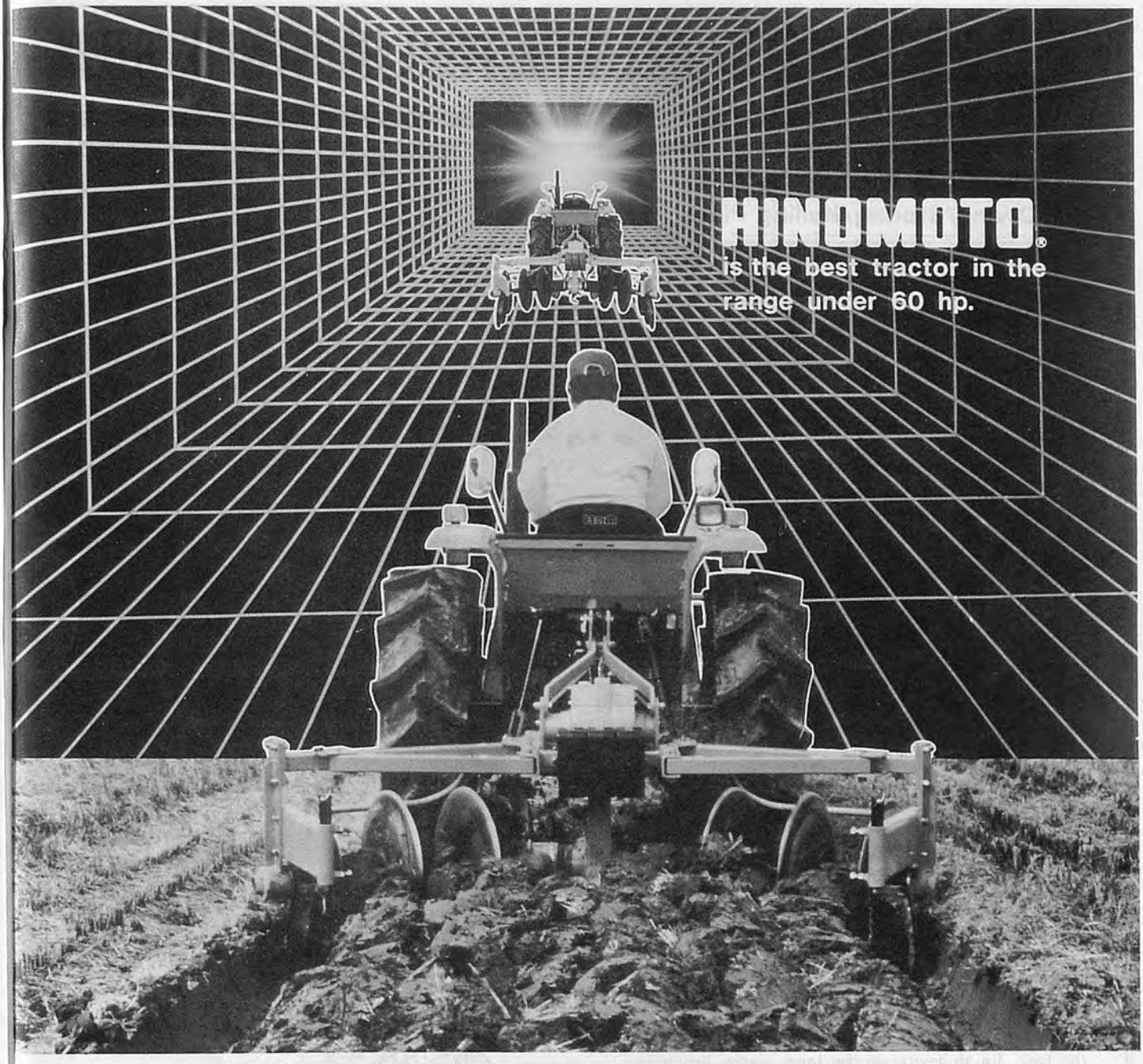
Kubota K75 power tiller

The Basic Necessities Giant

KUBOTA

Kubota, Ltd.

HEAD OFFICE: 2-47, Shikitsuhigashi 1-chome, Naniwa-ku, Osaka, Japan
CABLE ADDRESS: IRONKUBOTA OSAKA
TELEX: KUBOTA AJ65251
TOKYO OFFICE: 3, Nihonbashi-Muromachi 3-chome, Chuo-ku, Tokyo, Japan
CABLE ADDRESS: IRONKUBOTA TOKYO
TELEX: 222-3681 KUBOTA J



We promote mechanization for small sized farmers, and are sure to cooperate together.

The countries are far from each other, while it takes long time for the small sized farmers to mechanize the agriculture.

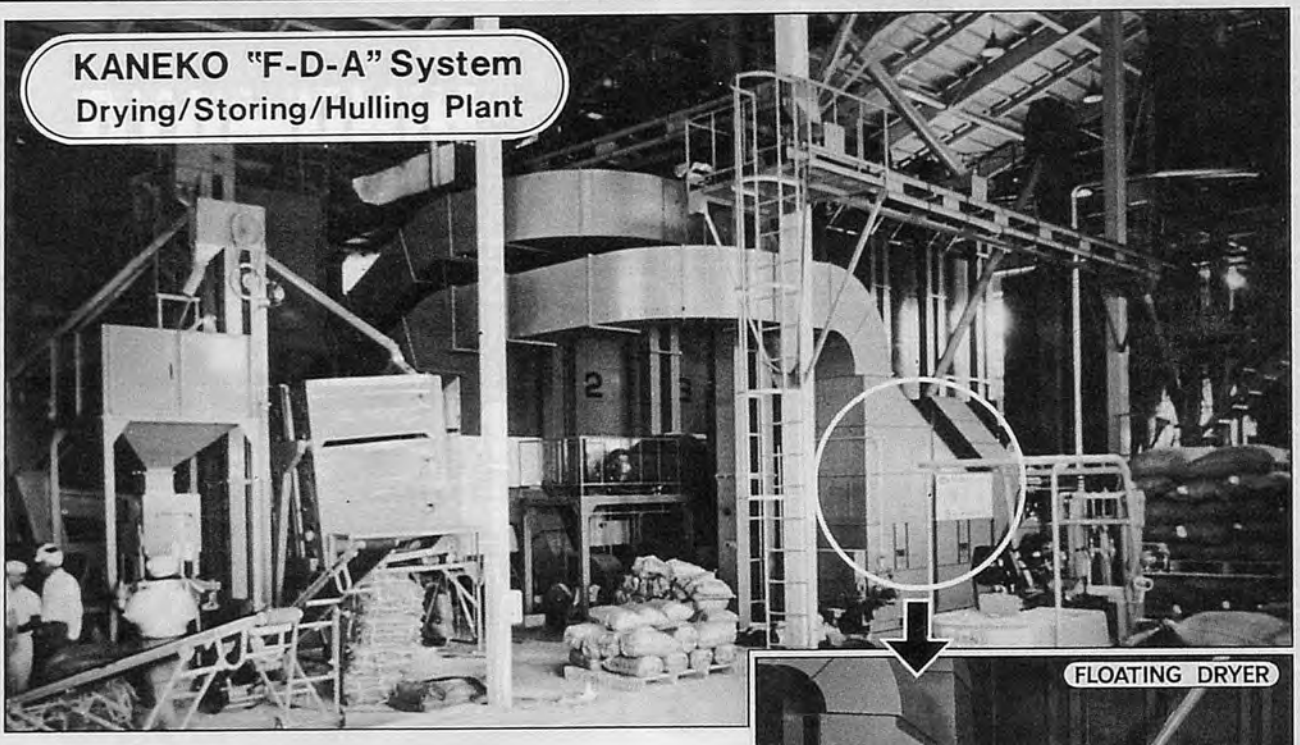
TOYOSHA *does the best to contribute in mechanization of the small sized farmers with sincerity and cooperative relationship.*

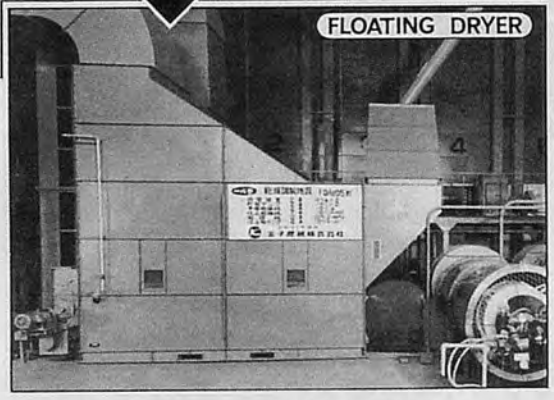
since 1863

TOYOSHA CO.,LTD.

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

KANEKO SELLS THE POST HARVEST SYSTEM





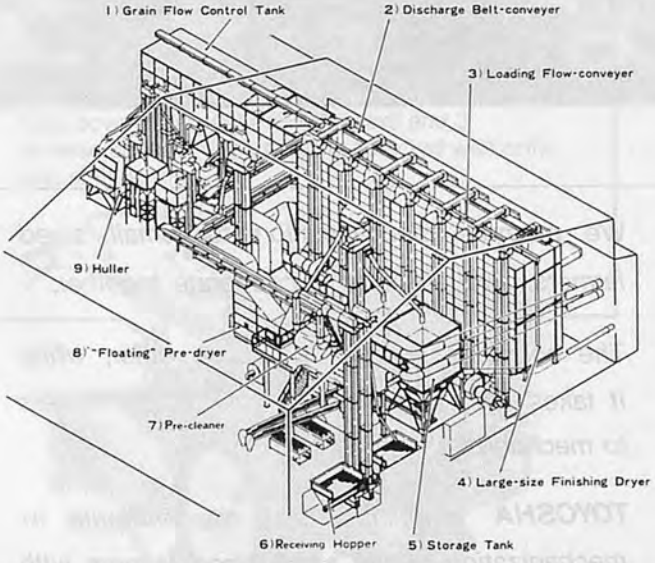
New"F-D-A"system characterized by the FLOATING Dryer, a pre-drying machine, dries paddy and corn of high moisture contents quickly, in large amount, with good quality, and, even more, at low cost.

Firstly, large amount of raw paddy and corn is rapidly pre-dryed in succession by means of the FLOATING Dryer.

Secondly, large amount of paddy and corn pre-dryed by the FLOATING Dryer is given the last finish drying in the large-scale finishing dryer.

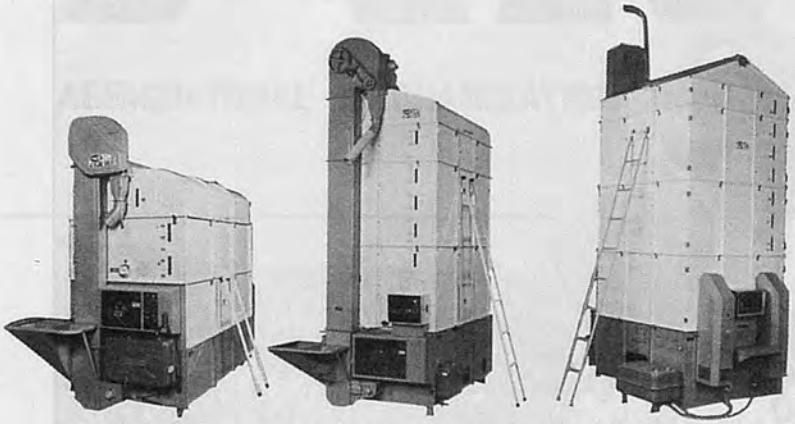
Thus, drying is completed easily and effectively in the"F-D-A" system with the KANEKO originated two-tier drying process empolyed.

*The FLOATING Dryer, both stationary and movable models available now, works efficiently by itself to dry paddy and corn. Movable one can do work at many places on purpose.

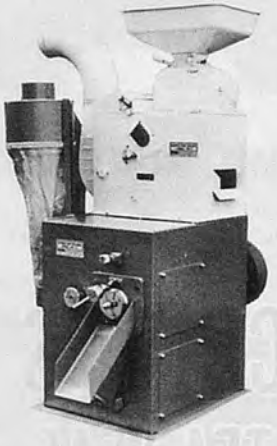


AND SERVES FULL BEFORE-AFTER CONSULTATION

"Supering" Circulating Suction Type Grain Dryer
The circulating type dryer capable of drying raw paddy.

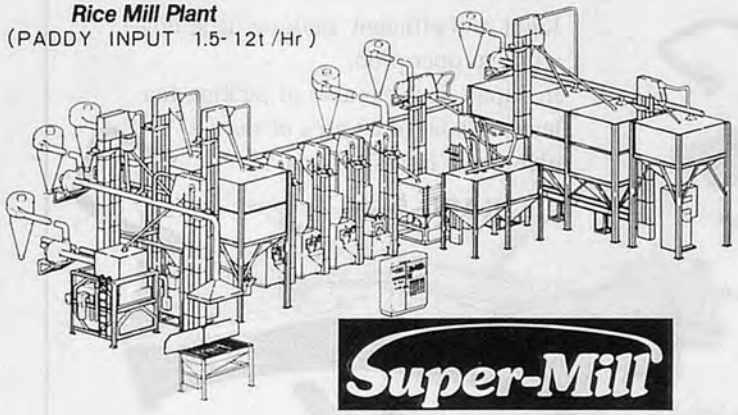


*Model SP-91A *Model SP-281C-X *Model SP-461G
Grain Holding Capacity-Paddy
0.4-0.9t. 0.8-2.8t. 1.5-4.5t.
14 Models from 0.9 to 4.5t. Grain Holding Capacity/Paddy



COMPACT RICE MILL UNIT
model KRM-500
capacity;
650-750kg/h

Rice Mill Plant
(PADDY INPUT 1.5-12t/Hr)



Super-Mill



RICECON System—Rice Conditioning System
is small-size grain drying and conditioning facilities marked by the separate operation of each dryer and a variety of application.

KANEKO, with sixty years of experience to its credit, is a leading manufacturer of a wide variety of drying machines and related equipment and facilities.

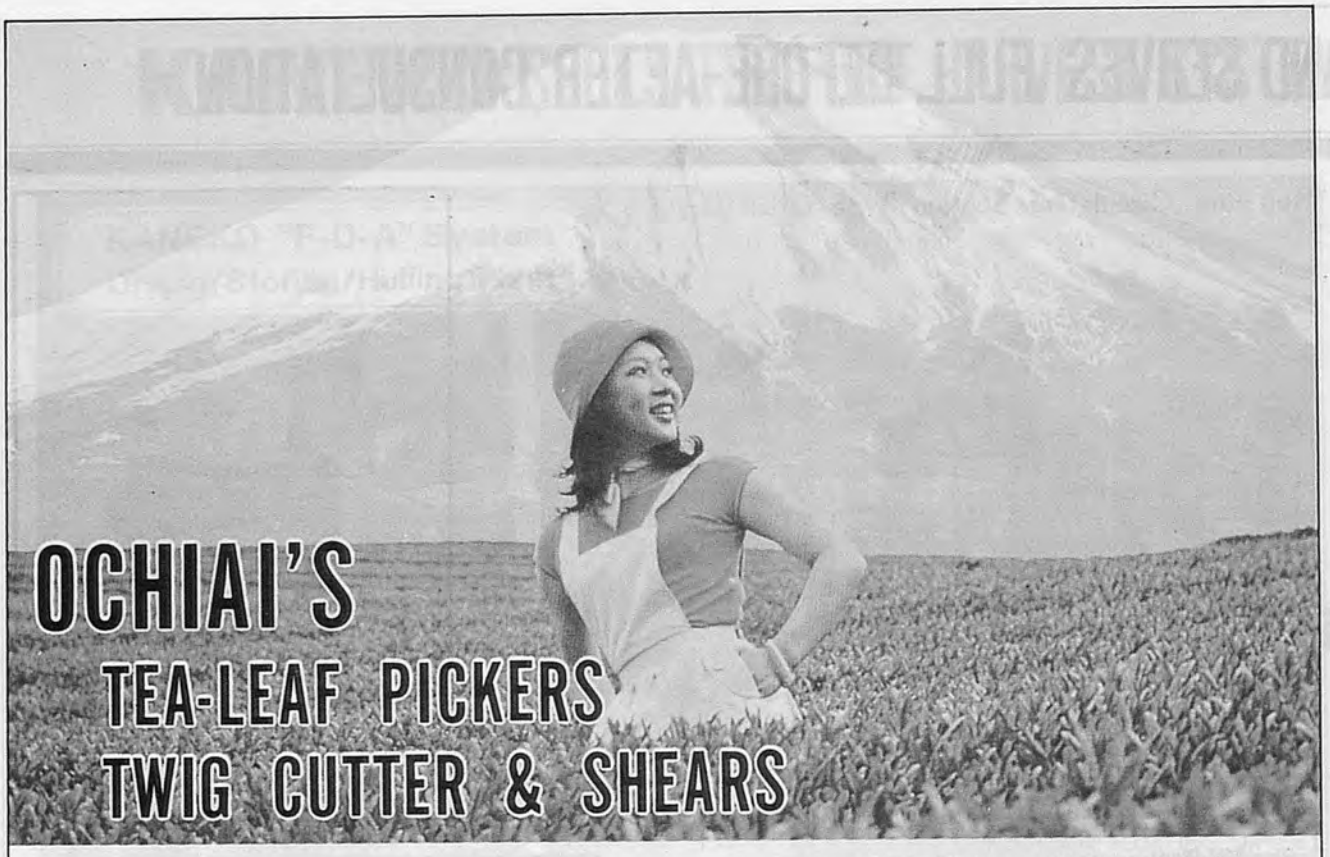
Whether the climate is hot or cold, arid or with plenty of rain, whether the land is at high or low attitude, KANEKO farm products, with their applications of new scientific theories, guarantee the optimum in efficiency and work rationalization wherever used.

KANEKO AGRICULTURAL MACHINERY CO., LTD.

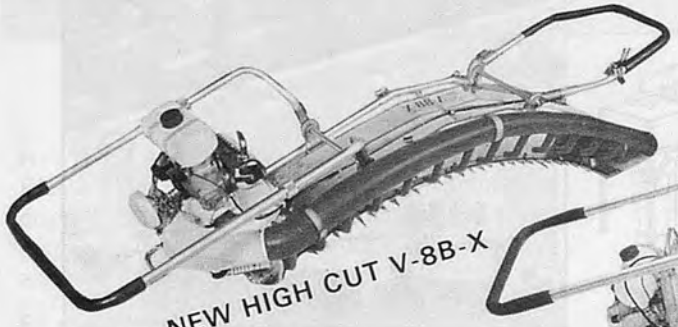
Overseas Division
26-11, Higashinihonbashi 2-chome, Chuo-ku, Tokyo 103 Japan
Phone: (03)862-2459 Cable: AGRI KANEKO Tokyo
Telex: 0265-7165

Headquarters
21-10, Nishi 2-chome, Hanyu, Saitama 348 Japan
Phone: (0485)61-2111 Telex: 2942-462

Catalogue available upon request.



OCHIAI'S
TEA-LEAF PICKERS
TWIG CUTTER & SHEARS



NEW HIGH CUT V-8B-X

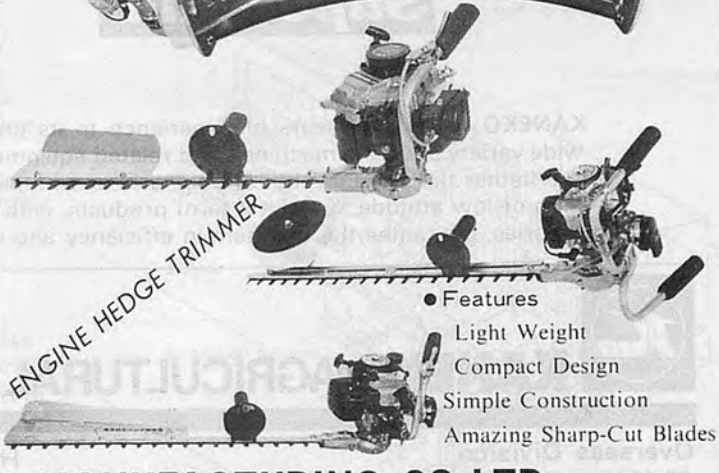
Light and efficient, making little noise while in operation.
In Japan, it is capable of picking tea leaves on 60 to 80 ares of tea plantation in a single day.

KARII-C-8A-1



GUIDE TO OCHIAI

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



ENGINE HEDGE TRIMMER

- Features
  - Light Weight
  - Compact Design
  - Simple Construction
  - Amazing Sharp-Cut Blades

OCHIAI CUTLERY MANUFACTURING CO, LTD.

OCHIAI HAMONO KOGYO CO LTD

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

International specialized medium for agricultural mechanization in developing countries

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.XIV, NO.4, AUTUMN 1983

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
Yoshikuni Kishida, Advisory Director

Contributing Editors and Cooperators

- AFRICA -
Van Lancker, Julien G. (Brundi)
Hanna, George B. (Egypt)
Kandiah, Arumugam (Ethiopia)
Srivastava, K.P. (Ethiopia)
Ampratwun, David Boakye (Ghana)
Chaudhry, Md. Siddique (Libya)
Choudhury, Md. Shahansha-ud-Din (Nigeria)
Igbeka, Joseph C. (Nigeria)
Mittal, Jitendra P. (Nigeria)
Odigboh, E.U. (Nigeria)
Kuyembeh, N.G. (Sierra Leone)
Abdoun, Abdien Hassan (Sudan)
Bedri, Mohamed A. (Sudan)
Saeed, Amir Bakheit (Sudan)
Weerakoon, W.T. (Zambia)

- AMERICAS -
Nääs, Irenilza de Alencar (Brazil)
Phillips, Allan L. (Chile)
Valenzuela, A.A. (Chile)
Mirdha, A.H. (Mexico)
Goyal, Megh Raj (Puerto Rico)
Chancellor, William J. (U.S.A.)
Esmay, Merle L. (U.S.A.)

- ASIA and OCEANIA -
Farouk, Shah M. (Bangladesh)
Roy, Kshirode Chandra (Bangladesh)
Gurung, Manbahadur (Bhutan)
Wang, Wanjun (China)
Chandra, Satish (Fiji)
Michael, A.M. (India)
Verma, S.R. (India)
Soepardjo, Siswadhi (Indonesia)
Sakai, Jun (Japan)
Snobar, Bassan A. (Jordan)
Chung, Chang Joo (Korea)
Andreou, Paris (Lebanon)
Bardaie, Muhamad Zohadie (Malaysia)
Shrestha, Bala Krishna (Nepal)
Chaudhry, Allah Ditta (Pakistan)
Devrajani, Bherulal T. (Pakistan)
Mughal, A.A. (Pakistan)
Lantin, Reynaldo M. (Philippines)
Lee, Chul Choo (Philippines)
Venturina, Ricardo P. (Philippines)
Aziz, M.H. Abdel (Saudi Arabia)
Illangantileke, S. (Sri Lanka)
Kathirkamathamby, Suppiah (Sri Lanka)
Peng, Tien-Song (Taiwan)
Singh, Gajendra (Thailand)

- EUROPE -
Pedersen, T. Touggaard (Denmark)
Pellizzi, Giuseppe (Italy)
Moens, Adrian (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

ADVERTISING
(Tel. 03/291-3672)
Kuniharu Ikeda, Manager (Head Office)
Shuji Kobayashi, 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 © 1983 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 41th issue since the issue, Spring of 1971

Editorial

Development Communication and Farm Mechanization

The relatively new discipline called Development Communication or Devcom, for short, has a distinctly important role to play in the promotion of agricultural mechanization, among other considerations. This role is particularly important in the less developed countries (LDCs) of the world. But Devcom becomes relevant and effective only in its role when there is an efficient communication network that constantly links farm machinery researchers, manufacturers, distributors, policy-makers, the banking community and educational centers, to mention a few. And this network is especially needed in many of the LDCs where the mass media is still in its infancy.

In this regard, the Shin Norinsha Co., Ltd. or Farm Machinery Industrial Research Corp. has been modestly contributing its share in the furtherance of agricultural mechanization by establishing and strengthening the linkage or communication network that updates all parties concerned. For example, the Company has faithfully published for half a century now a weekly in Japanese called *Noki Shimbun* in promoting agricultural mechanization among the Japanese. This humble weekly must have had its early influence on the advancement that Japan has now achieved in modern agricultural mechanization. For another, the AMA, since its debut for more than a decade now, has been reaching out world-wide – also, along the same mission of the *Noki Shimbun* in providing a linkage among all parties interested in agricultural mechanization.

Both Devcom media pledge to carry on their mission for as long as the need for the linkage is felt within Japan and outside. In the same vein, it is hoped that all parties concerned on agricultural mechanization in the LDCs will encourage and utilize Devcom to promote agricultural mechanization for their benefit.

Yoshisuke Kishida
Chief Editor

October, 1983
Tokyo

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol. XIV, No.4, Autumn, 1983

Yoshisuke Kishida	9	Editorial
Yoshiaki Nakamura Haruhiko Murase Sakae Shibusawa	11	Direct Seeding with Coated Rice in Submerged Paddy Field (2)
A.D. Chaudhary	15	Potential of Direct Drilling in Developing Countries
M.A. Choudhary	20	Potential of Direct Drilling in Pakistan
C.J. Baker	25	Some Developments in Direct Drilling Equipment in New Zealand
N.K. Awadhwal G.E. Thierstein	31	Development of Rolling-Type Soil Crust Breaker
Nadeem Amjad David Gee-Clough	35	Field Performance Evaluation of Rice Reaper
A. Chakraverty H.G. More	41	Development and Testing of a Simple Baffle Type Grain Dryer
Surya Nath A.K. Ganguly	45	Experimental Results on Stored Food Products in Different Packaging Materials
Shaukat Khan Sharafeddin M. Sherif Md. S. Chaudhry	51	A Computer Program for Agricultural Machinery Management: Selection of Optimum Farm Size
S.M. Rahman B.C. Basak A.K.M. Habibullah Mesbauddin Ahmed M.R. Biswas	55	Response of Wheat Cultivars to Irrigation and Fertilizer Applications
Sheruddin B. Bukhari Jan Mohammed Baloch Fakir Mohammed Rattar	61	Losses in Wheat Harvesting and Threshing
Gajendra Singh	68	Agricultural Mechanization in Thailand
Hiroyuki Nishimura	75	The Farm Machinery Industry and the Development of Farm Mechanization in Japan
News	81	
New Products	83	
Book Review	84	

★ ★ ★

Index to Advertisers 80
Co-operating Editors 86
Back Issues 88
A Note to AMA Contirbutors 90

Direct Seeding with Coated Rice in Submerged Paddy Field (2)







by

Yoshiaki Nakamura
Professor

Haruhiko Murase
Assistant Professor

Sakae Shibusawa
Assistant Professor

Agricultural Engineering Department, Ishikawa Prefecture College of Agriculture, 33 Suematsu, Nonoichi, Ishikawa-ken, Japan

Abstract

This article describes the technology of the Direct Seeding of Submerged Paddy (DSSP) system reported earlier in this journal. Focus is made on the problems of the system; i) how to develop the coating chemical 'Calper'; ii) how to coat the rice seeds; and iii) how deep the coated seeds should be sown. The construction of the coating machine and the seeding machine are also discussed.

Introduction

The former article outlined the DSSP system which the authors developed in Japan. The DSSP system needs the coating chemical 'Calper' - coated rice seeds and the seeding machine to sow the seeds at desired depth instead of using the rice seedling planter for the conventional type rice cultivation. These are new technical problems for developing the DSSP system. Experiments were conducted in order to develop the system, and the results are summarized in this article.

Note: This paper is the continuation to "Direct Seeding with Coated Rice in Submerged Paddy Field (1) which appeared on the Summer, 1983 issue of AMA.

Development of Coating Chemical 'Calper'

One difference between the DSSP system and the conventional cultivation is the need for the rice seed coated with the Calper dust for the former instead of rice seedling for the latter. Untreated seeds sown beneath the submerged soil cannot grow without enough oxygen supply. The calcium peroxide contained in the Calper dust slowly decomposes with the moisture in the paddy soil and releases oxygen as follows:

$CaCO_2 + H_2O - Ca(OH)_2 + 1/2\ O_2$

Accordingly, the coated Calper dust supplies oxygen to the seed beneath the submerged soil, and the rice plants can absorb oxygen from their stems and leaves just after developing their first leaves. However, the problem has been to coat tightly the rice seeds with the Calper enough to remain on the seed surface. This problem was solved by mixing plaster of Paris in the Calper dust. **Fig. 1** shows the results of the test in mounting or mixing the plaster in the Calper.

The mixing rate of the plaster of Paris was varied and the peel-off rate was measured for each predetermined mixing ratio of the plaster. The coated seeds were dropped down from 1 m high on a steel board of 10 mm thickness. Measuring the weight W_p of the Calper dust peeled off from the coated seeds, the peel-off rate B_a was calculated as follows;

$$B_a = W_p/(W_t.C_r) \times 100^2$$

where

W_t = weight of coated seeds (kg)

C_r = Coating rate (%)

and C_r was obtained as follows:

$$C_r = W_c/W_s \times 100$$

where

W_c = weight of coating material (kg)

W_s = weight of rice seeds (dry weight kg)

From the upper figure in **Fig. 1**,

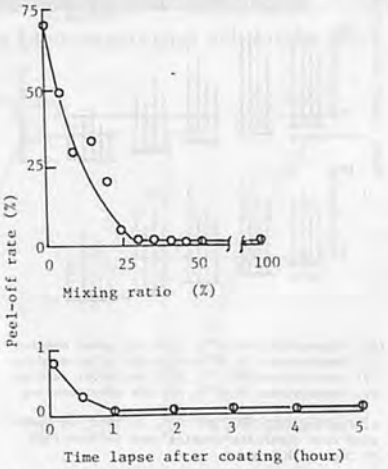


Fig. 1 Plaster of Paris should be contained more than 25% in Calper dust for less peeling-off from coated seeds

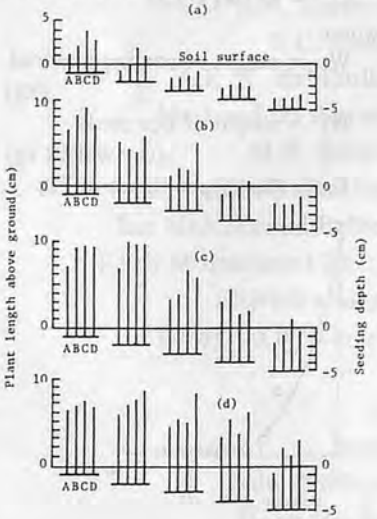
the peel-off rate decreased with the mixing ratio of the plaster of Paris. When that ratio was more than 25%, the coated Calper was scarcely peeled off. From the lower figure (mixing ratio = 25%), the peel-off rate was less than 1% just after coating operation then it decreased with a lapse of time. Above one hour after coating operation, the peel-off rate was almost zero percent.

Accordingly, the plaster of Paris should be mixed more than 25% in the Calper dust and coated seeds should be used after one hour of settling time.

Seeding Conditions for Rice Plant Growing

One of the important technical skills in operating the DSSP system is to determine the coating rate C_r of the Calper dust and seeding depth appropriate for growing the rice plant after germination beneath the submerged paddy soil. Rice seeds can germinate and vegetate only under conditions of adequate temperature, moisture and oxygen. If no foliage emerge above the soil surface, the rice plant cannot develop to seedling stage. Therefore, we conducted the model tests in order to confirm the critical conditions for rice plant growth. The Calper dust used for the tests contained 25% of plaster of Paris and 75% of calcium peroxide.

The results shown in **Fig. 2** prove that the rice plants grew well at shallower seeding depth, higher temperature and higher coating rate. The suitable conditions for rice plant growth in practical operation are the following: (1) seeding depth should be less than 1 cm in lower temperature area (no deeper than 2 cm even in higher temperature area) and (2) coating rate should be above 100%. The coated seeds floated when seeding depth was less than 8 mm. This causes the floating seedling or lodging of rice plant. Therefore, a precise seeding operation is required with respect to seeding depth. One hundred percent-coating rate is recomended in practical operation which is economical in growing the rice plant.



(a); Temperature 10-15°C, 31st day after seeding
(b); Temperature 15-20°C, 21st day after seeding
(c); Temperature 20-25°C, 12th day after seeding
(d); Temperature 25-30°C, 9th day after seeding

A; Coating rate 50%, B; 100%, C; 150%, D; 200%
with each depth the coating rate is from left to right A,B,C and D

Fig. 2 Coating rate of Calper should be more than 100% and seeding depth should be less than 1cm for proper rice plant growth

Coating Machine

Fig. 3 shows the coating machine with a water sprayer, which was constructed by referring to granular machines commonly used in making granular chemical fertilizer. The coating machine consists of a rotating pan, a driving motor, reduction gears and a water sprayer. The pan is 90 cm in diameter and made an angle of 45° to horizontal.

The experiment was conducted in order to confirm how fast to rotate the pan, where to set the water sprayer and where to apply the Calper dust for effective coating. **Fig. 4** shows the effect of the

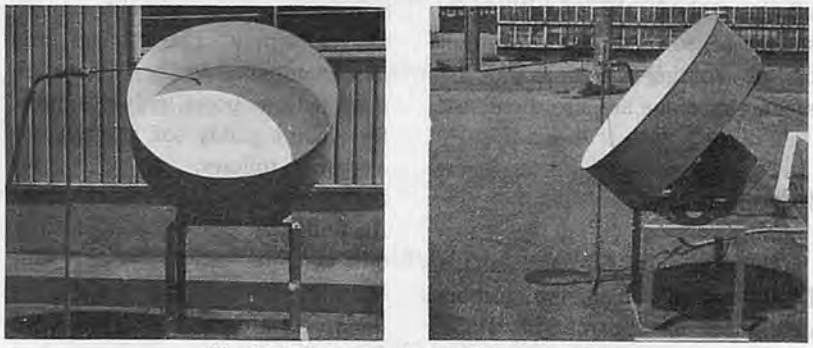


Fig. 3 Coating machine with water sprayer

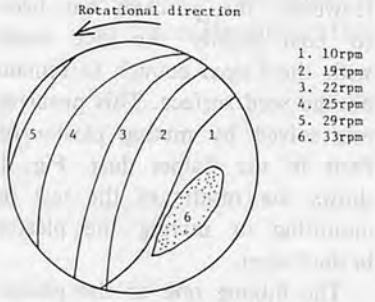
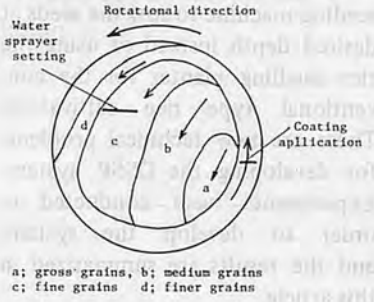


Fig. 4 Moving areas of rice seeds in the pan changed with its revolving speed. The pan revolving speed of 29rpm is favorable for coating operation



a; gross grains, b; medium grains
c; fine grains d; finer grains

arrows in the pan show the moving direcions of grains

Fig. 5 Adequate positions of water sprayer and coating application were located in the pan

speed of the revolving pan on moving areas of seeds. That area was spread well with Calper on that revolution but, not as well when the pan rotated above 29 rpm. Hence, the critical speed of the pan revolution was about 29 rpm for maximum spread on the moving area of the seeds. Therefore, this machine should be used in the range of 25-29 rpm.

The size of grains naturally increased after the Calper dust adhered to them. This coating process of each seed grain progressed with different speed because it had different specific gravity, initial size, frictional coefficient and, so on. Therefore, different grain diameter of coated seeds were made under coating operation, and moving areas of coating seeds were distinguished by their diameter as shown in **Fig. 5**. From this observation, it is clear that smaller grains rose up easily and were distributed in the upper area in the pan. In order to make the coated seeds with equal sizes, water mist should be sprayed more to the smaller sized grains. Hence, the water sprayer was set at the position as shown in **Fig. 5**. The Calper dust should be applied at the critical location.

This machine was able to coat 15 kg of seeds completely for 15 min at a time, when it was operated under the required conditions described above. Fifteen kg of rice seeds is necessary to plant 40-50 areas of paddy field in Japan.

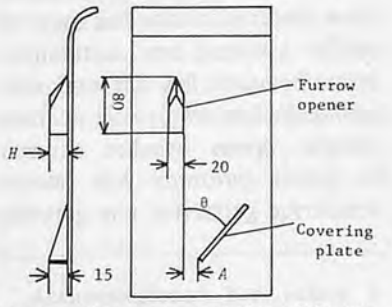


Fig. 6 Experimental device of furrow-opener and soil covering plate for sledge type drill

Seeding Machine for DSSP System

The technology in handling seeding machine is necessary: (1) to sow the seeds in the desired depth and (2) to space the seeds properly so as not to give physical damage to the coated seeds during the operation. The latter may be fairly accomplished by using the roll-type feeding device without agitator. The coated seeds drop by gravity without damage to the coating. But the former technique is necessary for designing a seeding machine. Therefore, some trials were further conducted to solve the problem.

The sledge type furrow opener for sowing the seeds was constructed as shown in **Fig. 6**. The sledge is naturally stable in order for it to slide easily on soft soil in submerged paddy. The height of the furrow opener, the inclined angle θ of soil covering plate and the clearance A between the furrow opener and the soil covering plate were varied in this experiment.

Fig. 7 shows the effect of the clearance A on soil covering operation. The experiment proved that $A = 0$ cm was favorable for soil covering operation, i.e., the covering plate should trace the locus of the furrow opener.

Fig. 8 shows the effect of the inclined angle θ of the soil covering plate on soil covering operation at A=0 cm. The soil covering was calculated in the following manner:

$S_1/Sx100$

where

S_1 = cross sectional area of furrow made by the opener

S = cross sectional area of covered soil by the plate

The results proved that the angle θ should be above 24° at any opener height. When θ was above 30°, covered soil displaced sideward excessively. Hence, θ=24°-30° is recommended.

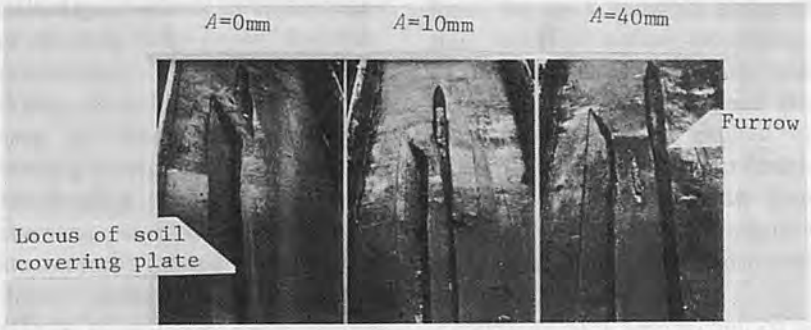


Fig. 7 Effect of clearnce A on soil covering. A=0mm gave good soil covering operation

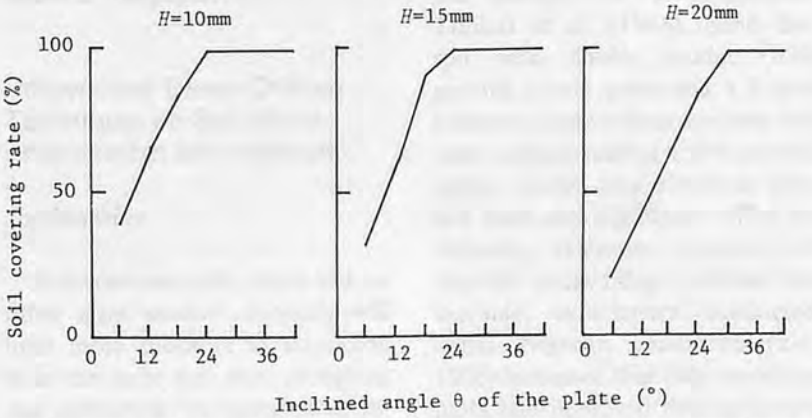


Fig. 8 Effect of inclined angle of soil covering plate on soil covering operation at A=0mm

Table 1. Effect of A, H and θ on Furrow Depth

A (mm)	θ (°)	H (mm)		
		10	15	20
0	5.7	8.4	12.9	16.9
	17.5	8.5	12.6	16.8
	30.0	8.1	12.9	16.9
	44.4	8.3	12.6	16.6
10	5.7	8.5	12.7	16.8
	17.5	8.4	12.8	16.7
	30.0	8.2	12.8	17.0
	44.4	8.3	12.7	16.4
20	5.7	8.4	12.8	16.7
	17.5	8.4	12.9	16.8
	30.0	8.4	12.5	16.6
	44.4	8.3	12.7	16.6

Table 1 shows the effect of the height of furrow opener on furrow depth. This proved that furrow depth was about 85% of the opener height. Accordingly, 12 mm of the opener height is favorable for 1 cm of seeding depth.

Fig. 9 shows an example of nether view of the sledge which is sold in Japan. Its furrow opener and soil covering plate are constructed by referring to the process described above.

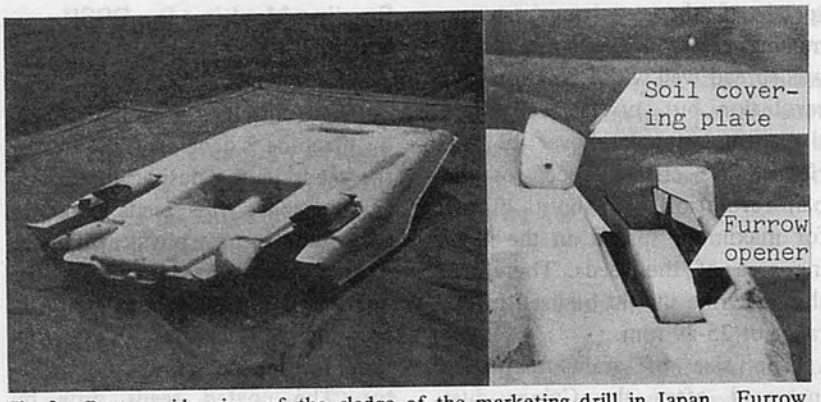


Fig. 9 Bottom-side view of the sledge of the marketing drill in Japan. Furrow opener and soil covering plate are observed

Conclusions

Some trials for the development of the DSSP system provided fundamental data to the mechanization of its cultivation. These are summarized as follows:

The Calper dust should contain 75% of calcium peroxide and 25% of the plaster of Paris. Seeding depth should be about 1 cm and coating rate of the Calper should be 100%. The coating machine which was constructed similar to a granular machine is favorable for coating operation. Sledge type seeding machine with roll-type feeding device of seeds is recomended for the DSSP system. The sledge must be equipped with specially-designed furrow opener and soil coveirng plate.

The authors will appreciate readers' comments and suggestions. And any constructive discussions on the DSSP system will contribute to further outreach of the new technique. ■■

Potential of Direct Drilling in Developing Countries



by
A.D. Chaudhary
Chairman
Dept. Farm Machinery and Power
University of Agriculture
Faisalabad, Pakistan

Introduction

It is now well-known that tillage is not absolutely necessary for crop production. Cultivation can often be made unnecessary by using herbicides to control unwanted weeds, thus substituting chemical energy for mechanical energy hitherto widely used for tillage operations.

The terms "no-till", "no-tillage", "zero-tillage" and "chemical fallow" have been used in the literature. All these terms are synonymous and represent a description of the state of soil which has not been tilled. The term "direct drilling" describes drilling the seed, directly into such untilled ground where the weeds may have been pre-sprayed to reduce competition.

The technique of direct drilling has been claimed to offer many advantages over conventional tillage. These have included: increased trafficability; reduced soil erosion due to wind and water; decreased water evaporation, and increased infiltration into the soil; reduced investment in farm power and equipment due to reduced energy requirements; and improved timing of planting and harvesting operations.

Acknowledgement: The author is thankful to Dr. C.J. Baker of Massey University for help and guidance in the preparation of final draft of this paper.

It has also been considered that direct drilling has uses in areas where conventional cultivation has been difficult or impossible because of rough topography, high rain fall, erosion, stony soils or in low-lying, water-logged conditions (Bramely, 1962).

Crop response to a tillage system depends upon soil characteristics, climatic conditions, and the nature of the crop to be grown. Stand establishment of crops by direct drilling is a function of the efficacy of seed germination and seedling emergence and their interrelationships with the physical, chemical and biological microenvironment created in the soil by direct drilling techniques. The effects of different direct drilling techniques and machines are discussed in this paper.

Influence of Direct Drilling Techniques on Soil Micro-Environment Soil Moisture

Soil Moisture

Soil covered with dead sod or other crop residues normally will hold more moisture at saturation than the same soil after ploughing and cultivation. The presence of undisturbed plant roots, and the greater amount of organic matter in the soil from decayed plant roots, promote the existance of larger pores or openings in the soil. Thus the soil holds large amounts of rainfall. In contrast cultivation tends to destroy plant roots and channels left by decayed roots, which greatly reduces the soil moisture holding capacity.

Soil moisture is normally lost from the root zones by evaporation, runoff of surface water, transpiration of growing plants, and percolation to depths beyond the crop root zone. An expired or killed-off crop residue cover (particularly if this is lying rather than standing) will reduce soil moisture losses from evaporation and runoff (Young, 1973).

Some authors have attempted to quantify these effects in relation to the amount of crop residues. Triplett *et al.* (1968) found that soil with double residue (80% ground cover) promoted a higher moisture content than the same soil with normal residue (50% ground cover). Even crop rotations may not have any significant effect on moisture retention capacity of the soil under tillage systems. For example, experiments conducted under Nigerian conditions (Lal, 1976) indicated that only no-tillage plots had improved their moisture retention capaicty while a crop rotation on tilled plots had no

effect. In irrigated soils crop residues have had considerable influence on water-use efficiency under no-tillage system (Allen *et al.* 1975).

Soil Strength

Bulk density is a weight per unit volume that indicates the amount of soil compaction and is inversely associated with the amount of porosity (where soil porosity is the percentage of bulk volume not occupied by the soil). Porosity is reduced by compaction, which in turn reduces the size and volume of space between soil particles. This restriction reduces air and water movement and limits the voids through which roots can grow. Therefore, two of the factors which have a profound influence on the total seed environment are bulk density and water content of the soil.

Soil mechanical impedance is a phenomenon which affects seeds and seedling emergence in two distinct ways: impedance to the root system and impedance to seedling emergence. Soil conservationists who have been observing no-tillage fields for years have reported a noticeable reduction in compaction. Fields of clay soils in continuous row crop production for nearly a decade showed that the early fears of developing compaction due to prolonged no-tillage may be dismissed. Since the machinery operations of no-tillage are restricted to planting, spraying and harvesting, the opportunities for plough pans or other mechanically-compacted layers to develop are eliminated. In the same way the magnitude of soil-compacting forces arising from seed-bed preparation and cultivation are also limited.

Triplett *et al.* (1968) claimed that residue cover affected soil bulk density and infiltration rates under simulated rainfall of 115 mm/h for one hour. Surface mulches affected the earth worm activity, and as a result of this biological activity, soil bulk density was reduced (lal, 1976).

Soil Erosion and Runoff

Soil erosion by wind and water ultimately dictates land use on farms, but economic pressures have at times strained both land resources and farmers' judgements, causing dust bowls to develop; silting of lower land, lakes and streams; clouds of wind-blown dust; and other undesirable costly effects of erosion all of which have cast doubts on the wisdom of our older clean-cultivation methods.

Prevention of wind erosion may be accomplished by mechanical wind breaks, crop residues, cropping and land use systems, and tillage methods. No-tillage offers a major break-through by leaving crop residues at the soil surface and by lessening disturbance of soil particles during land preparation or cultivation. In no-tillage fields residues from previous crops reduce surface wind velocity and prevent contact of wind with soil, thus preventing rapid loss of soil moisture.

A 1967 Ohio report recorded 318 t/ha of sand movement on prepared land, compared with only 5 t/ha of sand movement in no-tillage grain fields (Young and Phillips, 1973). Further, air pollution from wind erosion and its possible implications to agricultural and urban areas can be reduced by no-tillage systems.

With regard to water erosion, studies have shown that on slopes of up to 15%, no-tillage methods have reduced soil loss to nearly zero when compared with conventional tillage, even where good erosion control management practices were used in conventional system (Lal, 1978). Moreover, the mean water loss was 15% lower under the no-tillage system. The greater the amount of crop residues the less have been the soil losses due to runoff and erosion.

Soil Temperature

Different seeds have different temperature ranges within which they germinate. At very low temperatures and at very high temperatures the germination of all seeds is prevented. Soil heat flow appears to be influenced by bulk density, porosity, moisture content and surface mulch cover. Crop residues on the soil surface will usually reduce soil temperatures when compared to soils without surface cover. Residues remaining from 1 t/ha of corn will reduce the 100-mm soil temperature by about 1°C, or about 0.5°C for each tonne of corn residue (Larson, 1970). Stubbles are effective in retaining snow and affecting soil temperature, because temperature is a function of snow cover and the insulating quality of the snow. In North Dakota the soil temperature has been 10°C warmer under zero-tillage (with rape seed stubble) and never allowed soil temperature to reach −16°C which would be sufficient to kill winter wheat (Stobbe, 1980).

Both crop residues and the nature of the crop canopy affect soil temperature. For example, Lal (1978) observed that under Nigerian conditions close canopy crops such as cow-peas had lower maximum temperatures than maize. This author also claimed that differences due to tillage treatments (no-till and conventional tillage) at 50-mm depth were as high as 11°C for maize, 9°C for soybeans and 6°C for cow peas, two weeks after planting.

Fertilization and Soil Nutrients

Fertilizing no-tillage crops has been done by suprisingly simple methods. There have been contra-

dictory reports of the responses of direct drilled plants and these simple (broadcast) methods of fertilizer application. For example, Young and Phillips (1973) claimed that adequate plant food could be made available to the roots of the no-tillage crops as effectively, more easily, with fully as many economic benefits as in any other tillage system. Furthermore, they felt that problems with fertilizer placement in no-tillage were no more critical than with the other tillage systems. This apparently had proven to be true with phosphate fertilizer, as well as with other plant food nutrients. They felt that fertilizer placement in no-tillage crop appeared to have shaken some well entrenched and cherished theories of many conscientious soils and crop scientists.

Applying plant nutrients was not a problem with no-tillage corn in Ohio soils. Nitrogen applied to the soil surface moved through the profile with soil moisture. Phosphorus and potassium, while largely confined to the site of application were available to growing plants. Mulch cover on the soil surface of untilled soil retained moisture at or near the soil surface, permitting root growth in this zone. These plant roots could apparently use nutrients applied on the soil surface. Band application of fertilizer near the seed provide nutrients for the development of young plants (Larson, 1970). By contrast, more recent reports (Hyde, cited by Baker, 1982) have suggested that separate placement of nitrogeneous fertilizers is more critical under no-tillage system and substantial yield gains have been reported.

Under Nigerian conditions no-tillage crop residues resulted in higher concentrations of C, N, P and exchangeable Ca and K than ploughed plots in the 0-100 mm layer. No-tillage led to the stratification of soil pH in the 0-500 mm profile. The nutrient depletion in conventionally tilled plots has been considered to be mainly due to accelerated soil erosion (Jua *et al.*, 1979). During normal rainy seasons, irrigation may have enhanced leaching of fertilizer, and fertilizer requirement under mulch tillage may generally have been higher than under ploughed plots. For example, during a normal rainy season under mulched tillage treatment, symptoms of N and P deficiency have been observed (Lal, 1978). These symptoms were particularly noticeable in soybeans which, despite denser stands, showed severe P deficiency symptoms and stunted growth. These findings have been confirmed by Syriffuddin (1981) who claimed that in rice fields because of puddling and flooding P became less available to corn plants sown in rice fields after harvest.

The decomposition of crop residues under wet and anaerobic conditions has had adverse effects on root growth and seedling emergence. When straw has been degraded by soil micro-organisms in anaerobic conditions, several fatty acids were produced which restricted the growth of plants. However, these phytotoxin effects could be reduced by coating seeds with chalk, calcium peroxide, which neutralized the organic acid (Lynch *et al.*, 1977).

Direct Drilling Influence on Crop Yields

Higher yields have been one of the important reasons why many growers have changed to 'no-tillage' crop production. Research workers and farmers have often reported increased yields when no-tillage crops were compared with conventional tillage crops although unexplained poor yields have also been reported. Even with the problems encountered, and lack of definitive answers to many problems, the trend has been to increase zero-tillage areas. The situation in North America is illustrated in Table 1.

Table 1 Trends – Zero-tillage Cereals

	Year	Ha
U.S.A.	1973	90 952
	1977	250 716
Canada	1978	20 408
	1979	40 816

Source: D.L. Barnes, 1979 – Trends and Development in Conservation Tillage.

Apparently, where yield increases of 'no-tillage' crops have occurred these have been due to improved timeliness of planting and harvesting; from better soil moisture retention under the mulch of crop residues, therby reducing the weather stresses; from improved soil conditions and; from easier and more efficient harvesting.

Due to the high investment in land and equipment, farmers have adopted no-till double cropping systems as a means of obtaining maximum return on their investment. One of the most common starting points in acceptance of no-till crop production, for many farmers, has been to drill soybeans, grain sorghum or a short season corn variety, no tilled after the wheat harvest. Planting has been made directly behind the combine harvester (Gard and McKibben, 1973). Wheat straw and stubble have provided the mulch for increased water infiltration and reduction of water loss by evaporation, thus providing more water for plant growth as well as lowering the erosion factor. Herbicides have been used to control the weeds. However, crop residues have also been effective, to some extent, in supressing weed growth (Lal, 1976).

The effect of mulching on crop yields is an integrated effect of innumerable factors and it is difficult to attribute the yield increments to any one variable.

However, despite the complexity of the physicochemical and biological influences of crop residues on germination and growth, the residues have been found effective in increasing crop yields. For example, Larson (1970) observed that on a crusting silt loam soil following sod with no-residue cover, corn yields with no-tillage treatments were lower than yields from ploughed plots. However, yields from no-tillage with complete mulch cover were greater than the ploughed plots on the same soil. No-tillage in standing residue may have given higher yields than no-tillage with shredded residue. Furthermore, no-tillage seeding in shredded residue may not have had any advantage for seed germination or growth compared with tilled treatments (Allen *et al.*, 1975).

It is interesting to note that in 1976 (which was a dry U.K. summer) no-tillage out-yielded conventional tillage by 1 t/ha (**Table 2**). It is noteworthy that during wet years these yields may have been reduced due to decomposition of residues.

Table 2 Yield Comparisons for Winter Wheat (NIAE data)

Unit: t/ha

Year	Ploughed 22-cm deep	No-till
1973	6.2	6.0
1974	7.5	6.9
1975	5.2	5.2
1976	3.8	4.8
1977	6.5	6.0

Source: Sharp, L.A. 1979 Some conservation tillage benefits.

Energy Saving in Direct Drilling

Any change in agricultural technology raises obvious questions of economics. What does the new farming technique mean in net income? Are yields better? Will operating costs be reduced? Could labour be reduced? If the new technology is adopted, will management decisions become more critical? Will volume of production be increased? Will unit cost be affected? These questions are a part of the economics of any practice. They must be answered for no-tillage.

It would be misleading to make cost comparisons between conventional tillage and no-tillage systems without recognizing that conventional tillage varies far more from farm to farm than does no-tillage even in terms of numbers of diskings, number of cultivations, etc. Yield increases frequently which results in reduced unit cost of the product. In addition to this type of cost reduction, no-tillage provides other cost advantages.

With less investment in machinery ownership and usage, less labour and fewer field operations are needed, and production costs tend to be lower for no-tillage farmers. This important feature is appreciated even more now by commercial farmers who are faced with shortages of component labour and rising costs of other production items. Some research studies in U.S.A. have shown as much as $152 per ha (1973 prices) profit advantage to no-tillage corn, with a typical per ha advantage of $40. Part of this added profit comes from increased yields and part from lowered costs of production (Young, 1973).

The figures from **Table 3** assembled from the five years crop trial work at Boxworth (U.K.) clearly highlight the benefits of no tillage over English conventional methods (which are based on mould-board ploughing). These results show that not only did no-tillage save 91% in energy inputs and 50% in cultivation costs but it also resulted in an 85% saving in labour. However, these figures did not take into account productivity gained from those extra man hours, the capital freed from unnecessary equipment and the extra productive life gained from tractor investments.

Talbe 3 Input Costs

Item	Plough based (22 cm deep)	No-tillage
Energy inputs (MJ/ha)	3.14 = 100%	9%
Labour (man hours/ha)	3.39 = 100%	15%
Cultivation costs (£/ha)	14.63 = 100%	50%

Source: NIAE

Sherp (1979) quoted Phillips who found that in New Zealand in his four years experience using the no-tillage technique he was able to save 80% of his management time and it was conservatively estimated that his second-hand equipment would have realized a minimum of $NZ5,000. Also, it was not difficult to calculate that the life of a 56-75 kW tractor costing NZ$15 000-25 000 could have been extended by a minimum of 4-5 years. This extra life would become increasingly important as tractor prices continued to rise along with the cost of the energy needed to produce steel. Phillips also found that on his clay loam soils he was saving an average (over 4 years) $26.67/ha on his drilling costs compared with his conventional methods.

Conclusion

This review has indicated that direct drilling (no-tillage) affects the physical, biological and chemical soil micro-environments which themselves determine germination and seedling emergence. It has advantages over conventional tillage systems in terms of fuel and labour saving, low initial investment on agricultural machinery, improving soil physical status and increasing crop yields when properly adopted.

The developed countries are already adopting the no-tillage system increasingly each year. Now

the field is open for its investigation and adaptation by the developing countries in accordiance with their climatic and soil conditions.

REFERENCES

Allen, R.R., Music, J.T.; Wood, F.O.; and Deisec, D.A. (1975). No-tillage seeding of irrigated sorghum double cropped after wheat. Trans. ASAE, 18: 1109-1113.

Baker, C.J. (1982); pers comm. Director, Agri. Machinery Research Div. Massey Univ. Palm North. N.Z.

Bramely, D. (1962) New Development in weed-killer field. N.Z. Weed control Conference proc. 14: 41-47.

Barnes, D.L. (1979) Trends and development in conservation tillage – North America. Proc. Cons. Till. Tech. Sem. Christchurch, N.Z.

Gard, L.E. and McKibben, G.E. (1973) "No-till" crop production proving a most promising conservation measure. Outlook on Agric. 7 (4): 149-154.

Juo, A.S.R. and Lal, R. (1979). Nutrient profile in a tropical Alfesol under conservation tillage systems. S. Sci. 127: 168-173.

Lal, R. (1976). Role of mulching technique in tropical soil and water management. Tech. Bull 1 – Pub. Int. Inst. Trop Agri. Abadan, Nigeria.

Lal, R. (1978) No-tillage effect on soil properties under different crops in Western Nigeria. S. Sci. Soc. Ame. Proc. 40: 762-769.

Larson, W.E. (1970) Problems with no-tillage crops – will it work everywhere? Crop and Soil Magazine 23 (3): 14-20. 14-20.

Lynch, J.M.; Gunn, K.B.; and Harper, S.H.T. (1977). Problems created by crop residues in direct drilled crops. Rep. ARC – Letcombe Lab. 48-56.

Stobe, E.H' (1980). Zero-tillage winter wheat production in Manitoba. Proc. Zero-tillage Workshop – Manitoba, Feb 25-26.

Syarrifuddin, A. and Zandstra, H.G. (1981) Soil fertility, tillage and mulching effects on rainfed maize growth after rice. IRRI Research Paper series No 66: 1-5.

Sherp, L.A. (1979) Some conservation tillage benefits. Proc. Cons. Till. Sem. Christchurch, N.Z.

Triplett, G.B. Jr, Van-Doren, D.M. and Schmidt, B.L. (1968). Effect of corn stover mulch (*Zea maize* L.) on no-tillage corn yield and water infiltration. Agron. J. 60: 238-239.

Young, H.M. (1973) No-tillage farming in U.S.A. – its profit and potential. Outlook on Agri 7 (4): 143-148.

Young, H.M. and Phillips, S.H. (1973). No-tillage farming. Pub. Reiman Assoc. Milwaukee, Wisconsin, U.S.A. ■■

Potential of Direct Drilling in Pakistan



by
M.A. Choudhary
Research Scientist
Agricultural Machinery Research Centre
Massey University
Palmerston North, New Zealand

Abstract

A brief survey of research on tillage aspects being conducted in Pakistan, and the potentials of direct drilling in various soils and agro-climates, is presented. The major areas of direct drilling aspects which need researching in Pakistan are highlighted. Some disadvantages associated with direct drilling are also summarized.

Introduction

It has taken many hundreds of years to evolve the equipment and management skills associated with successful farming by conventional cultivation. Within the last 20 years or so there has been on the scene an entirely new concept – sowing of seeds into previously untilled soil with or without killing the existing vegetation.

In different parts of the world the direct drilling technique has distinct implications. For example, in North America the use of such techniques helps in reducing soil erosion and generally improving soil stability. In western Europe the technique is used mainly to enhance timeliness and the technique is appropriately termed 'direct drilling'. Terms such as no-tillage or zero-tillage are used sometimes in synonymously with least possible soil surface disturbance particularly in the tropics where it is desired not to remove the surface organic matter which improves mulching and reduces excessive soil temperature, harmful to the germinating seeds. (Lal, 1975; McCown 1981).

The potential advantages of direct drilling have been reported by A.D. Chaudhry elsewhere in this publication, and they should apply to Pakistan in common with other developing nations. The weighting of such advantages may vary from place to place depending upon the general topography and climatic factors.

Present Farming Scene in Pakistan

In many developing countries overcultivation, over-stocking and over-grazing have subjected the land to many hazards which have resulted in:

1. Degradation of soil structure and increased soil erosion.
2. Decrease in the soil organic matter, nutrient and soil water-holding capacity.
3. Increased fluctuation in soil temperatures.
4. Change in soil physical properties.

Pakistan is no exception in suffering the consequence of this 'rape' of the soil by continuous farming. This has increased the demand on developing new, generally uncultivable and unproductive lands. This trend is resulting in the loss of natural soil fertility and in huge requirements for manufactured chemical fertilizers. There is urgent need for remedial and managerial measures.

After hundreds of years of traditional farming, Pakistan's agriculture appears to be on the edge of a cross-road. Ever increasing demand to produce more food is leading farmers to desperate measures of further intensifying tillage and in some areas abandoning the longer-duration cash crops like cotton and sugar-cane in favour of wheat and rice for domestic purposes. Traditional ways of harvesting crops by almost complete removal of organic dry matter is also exhausting the soils.

Status of Tillage Research

The available data on tillage shows that no national co-ordinated program has been conducted to understand the problems associated with the use of tillage equipment, either bullock-drawn or tractor pulled. Few isolated studies have been conducted. Sheikh *et al* (1982) at the University of Agriculture, Faisalabad have concluded that the disc harrow (2 passes) gives an increased yield compared with a number of other combinations of

Acknowledgements: This paper has, in part, been extracted from a report submitted to the Government of Pakistan as a result of the author's visit to Pakistan in 1982 under the 'Transfer of Know-how Through Expatriate Nationals' (TOKTEN) program. The United Nations Development Program had funded this visit.

tillage equipment for primary and secondary cultivation. Baz *et al* (1981) at Pakistan Agricultural Research Council, Islamabad have suggested that deep tillage (up to 45 cm) gives increased crop production due to increased water infiltration and moisture conservation in the Pothwar area of Northern Punjab.

Bukhari and Baloch (1982) at Sind University, Tandojam, compared the fuel consumption of primary implements. They have suggested the use of a moldboard plough in combination with a disc harrow on 'soft soils' and a disc plough in combination with a disc harrow on 'hard soils'. Chaudhry *et al* (1982) at the University of Agriculture, Faisalabad, summarised the existing research on farm mechanisation. They concluded that very little research had been conducted on the introduction of tillage implements and their effects on soil characteristics and crop production.

It appears that in all the above studies simple comparisons were made and as yet no detailed information has been presented, particularly on the soil biochemical factors which may undergo changes and have significant effect on crop production when using various tillage methods.

Recently a pilot study was launched at the Agricultural Machinery Institute of PARC (Rahman, Pers. Comm. 1982) to compare the performance of rice crops using various methods of sowing compared with transplanted rice. This study is apparently a prelude to a comprehensive study of comparing tillage methods and their effects on crop production in both dryland and irrigated areas. The study, if properly conducted, could promise to be the first most comprehensive of its kind ever undertaken in Pakistan.

Potential of Direct Drilling in Pakistan

The advantages of using direct drilling compared with conventional tillage methods are well documented. The major soil and climatic factors which might be important in relation to the use of direct drilling in Pakistan are as follows:

Soil Erosivity – Lighter soils with less vegetation and on a slope encourage soil erosion. Cultivated soils are loose and may be more prone to erosion. Under direct drilling, because the soil is less disturbed and has more surface residue and root mat, the soil erosion is reduced. In high intensity rainfall areas this surface and subsurface residue helps increase more infiltration and less water run-off.

Soil Types – Well drained light to medium soils tend to favour the use of direct drilling. In the less drained heavier soils under wetter conditions, the direct drilling might give improved results because of timeliness factor when it may not be possible to till the soil in time for sowing.

Extreme Climate – Large amounts of organic matter and residues on the soil surface reduce soil temperature, and this might be desirable under tropical situations (McCown, 1981). Lower ambient relative humidity in combination with high temperatures increase soil moisture evaporation, particularly from the surface of cultivated soils. In these situations direct drilling may be preferred.

Low Soil Moisture Content at Planting – In soils with critical soil moisture, particularly at planting time, it is important to use methods of seed-bed preparation which help retain soil moisture. It is well understood that when seed is sown directly without cultivation (particularly when a specialist drill is used) better crop establishment may be achieved compared with the tilled soil at a low initial soil moisture.

Soils and Climates in Pakistan

By using the above factors as index, it appears possible to form a 'broad register' of soils and climates which might have potential for improved economic returns using direct drilling techniques. In this way the Pakistan agricultural areas (**Fig. 1**) may be broadly categorised according to the priority for their potential use for crop production by direct drilling.

D.I. Khan and D.G. Khan Divisions

The major rainfed areas of the D.I. Khan and D.G. Khan divisions and the surrouding districts appear to have the highest potential for the introduction of the new techniques. In fact a form of indigenous direct drilling is already being practised in these areas (**Fig. 2**). The significant factors which might favour direct drilling in these areas are; low soil moisture at planting, low rainfall (up to 250 mm annually), potential wind erosion in sandy soils and extremely dry climates. Because of the extreme climate and good crop rotations, the weed problem is not excessive and seed can be sown with the use of little or no herbicide at all.

Quetta Region

There is a huge agricultural area in the Baluchistan province, particularly around Quetta. Traditionally, there are two major farming husbandry types practised in the area i.e. cropping and rangelands. The present pastures have been left to run down because of heavy stocking rates and uncontrolled grazing by the tribal people. These pastures



Fig. 1 Agricultural research centres in Pakistan



Fig. 2 Above: Direct-drilled what (irrigated) and Below: Chickpea (unirrigated). Both crops are sown by traditional bullock-drawn shoe type single-row drill at D.I. Khan

need rejuvenation by resowing and by proper grazing management.

Resowing of these areas on a trial basis by oversowing methods has been a failure (Ahmad, pers. comm. 1982). Low rainfall (350-450 mm annum), low relative humidity and erosive soils are some of the important factors which might favour the use of direct drilling for crop production and pasture renovation in this area. Traditionally, there is some awareness among farmers of the need to conserve soil moisture by bunding, and by minimizing soil cultivation at the sowing time.

Upper Punjab and Lower N.W.F. Province

The major rainfed areas of both the Rawalpindi division and lower N.W.F. province may be classified as having potential for direct drilling. These areas have high intensity, high annual rainfall (up to 1400 mm) which induces soil erosion, particularly in the cultivated soils. However, soil moisture at sowing time and during the plant growth period is very low. The air relative humidity is low and this in combination with high temperatures, particularly during summer crops, induces high moisture evaporation.

Some work on water and soil conservation in this area is already being carried out (Baz *et al.*, 1981). Occasional deep tillage and bunding might be necessary in these areas. In gullied areas, agro-forestry and orchards might be more suitable. There is a tremendous potential for using some kind of conservation tillage techniques for crop establishment in this area.

Irrigated Areas

The irrigated areas in all provinces in Pakistan come under a separate category. In most of these areas double cropping is practised, although the average yield is much below the optimum expected. High cropping pressures in combination with over cultivation and lack of organic matter are adversely affecting the soil structure in these areas. With continuous tine cultivation there appears to be hard pan formation in the sub-soils at the cultivation level.

Fuel, labour and time savings may be significant to warrant the use of this technique in the irrigated areas. Also the long term effects on soil physical factors may be important. There appears to be a definite need to look at the effects of various tillage methods, including direct drilling, on crop production and soil characteristics. The recent study started at the Agricultural Machinery Division of PARC can possibly be extended in this area.

Some of the most important aspects which need research in the early stages of developing farming systems based on the direct drilling techniques are:

Weed Control – In the absence of mechanical methods of removing competing weeds, the direct drilling technique utilizes chemical means. The ICI developed diaquat and paraquat almost 20 years ago.

These herbicides desiccate the existing grasses for a few weeks removing the competition and giving enough time for the sown seeds to germinate and establish into new plants. More recently another herbicide, glyphosate, has come onto the market. This systemic herbicide kills the plant roots and appears to be suitable for most weeds, particularly the perennials like couch grass. These chemicals are known to leave no, or little, toxic residues in the soils as they break down when in contact with the soils. Herbicides may be applied in a complete blanket, for sowing crops, or may be banded when renewing run-down pastures.

These herbicides are, however, expensive and might have to be used selectively in conjuction with proper rotations and with efficient use of crop residues as weed control devices.

Fertilizer Requirement – It is well known that when using some types of direct drilling there is an increased requirement at least in the first few years, of fertilizer application, particularly nitrogen. The amount required will obviously vary from one situation to another depending on the history of previous crops and on the general soil fertility. However, it is not well known why there are enhanced requirements for fertilizers.

Certain theories, like preferential leaching of fertilizers through worm holes, and delayed release of nitrogen in combination with undecayed residues exist. Also, the method of fertilizer application might be important. According to Baker and Afzal (1981) more efficient use of fertilizers might be made by placing it near the seed micro-environment rather than broadcasting it on the soil surface.

There is need to know the rate, time and method of fertilizer application for most cropping systems with direct drilling techniques.

Insects and Pests – It appears that there might be somewhat inadvertent increases in the insect and pest problem with this new technique. Partly, it might be due to increased crop residue left on the soil surface. Also, the mini-seedbeds create good soil physical environments for seed germination which may also favour pest habitats (Choudhary & Baker, 1982). Some allelopathic problems and toxin release from the decaying matter has also been noticed in wet cold soil conditions (Lynch *et al.* 1977).

Crop Rotation – Proper crop rotation is an important aspect in any farming system. This is more so when using direct drilling techniques because of the possible implications on weed control, fertilizer requirements and pest problems. It is possible that crop production in rotation with grass and clover mixtures might be necessary in some places to introduce more residue and organic nitrogen in the badly damaged and compacted soils. Relatively long-term trials are needed on rotations when planning direct drilling research because of its effects on soil physical parameters and general crop production levels.

In-groove Seed Environment – Baker (1976) and Choudhary & Baker (1978, 1980) have shown that different coulter designs significantly affect the seed micro-environment which in turn may determine the seed germination and seedling emergence. This is more important when drilling seed in relatively dry soils with residue cover, where coulter designs determine the ability of the seed grooves to maintain high moisture vapour potential captivity 'MVPC' which affects the seedling emergence (Choudhary & Baker (1981 a,b)). Atmospheric humidity, temperature and the presence of residue affect evaporation from the soil surface and may also determine vapour deficit in the seed micro-environment (Choudhary, 1981).

A well-planned research program needs to clearly define objectives in studying machine and environment effects on the seed micro-environment and long-term soil physical parameters.

Machinery Requirement – Proper drills for seed sowing/fertilizer and pesticide application are considered to be the second most important linkage after weed control when using direct drilling. Most drills being used were, until recently, either conventional drills or those with make-shift modifications. However, more recently a number of drills have become available which are specifically designed for sowing seeds, (some with trash handling) fertilizer and pesticide in direct drilling (Baker *et al.*, 1979a). There is at least one drill which has an optional herbicide spraying unit attached for band spraying (Baker *et al.*, 1979b). At least in one developing country, Nigeria, there is some very interesting and useful manually-operated and bullock-drawn drills developed for their direct drilling program (Lal, pers comm 1981).

Apart from these major aspects, there are other associated areas where further research would be needed. In the long-term more extensive research would be required to determine the suitability of various soils and climates to evolve the most profitable farming system based on the direct drilling technique.

Disadvantages of Direct Drilling

A number of arguments for and against this new technique have been aired from time to time. It is important to take into account the disadvantages as well as the advan-

tages of direct drilling when making decisions in a new area.

Some of the major disadvantages are listed below:

a. Uncertain yields, and as a result slow acceptance by farmers in areas where there are generally favourable agro-climates.
b. There is evidence of possible increases in the pest populations in the seed micro-environment. Hence, control measures are needed at extra cost.
c. Initially there is increased bulk density of surface soils, although continuous use of the technique appears to alleviate this problem.
d. Complete eradication of competition by weeds is still a problem unless herbicides are used leading to less profit margins.
e. Specialist drills are needed, and any one type of drill may not always be suitable for a wide range of situations.
f. Fertilizer placement is still a problem with most drills.
g. New and higher operational and managerial skills are needed.
h. Easily available advisory services may not be at hand when required.

Conclusions

A little coordinate research on tillage aspects is being carried out in Pakistan, although recently there has been an indication of increased interest in this aspect. Conditions exist in Pakistan which favour the use of some form of direct drilling particularly in the low rainfed areas. However, a comprehensive research programme under local conditions would be required to develop and evaluate equipment and management techniques before this technique could be profitably used or recommended.

REFERENCES

Lal, R. 1975: Role of mulching techniques in tropical soil and water management. Technical Bulletin No. 1, International Institute of Tropical Agriculture. Ibadan, Nigeria.

McCown, R.L. 1981. No-till planter evaluation in the wet/dry tropics. Proc. Conservation Technical Seminar, Christchurch, New Zealand.

Phillips, P.S. Personal communications. 1981.

Baker, C.J.; Afzal, C.M. 1981. Some thoughts on fertilizer placement in direct drilling. Conservation Tillage Technical Seminar, Christchurch, New Zealand.

Lynch, J.M.; Gunn, K.B.; Harper, S.H.T. 1977. A preliminary field study of the effects of wheat straw on the establishment and growth of winter oats. Agric. Res. Council, Letcombe Laboratory Annual Report, U.K.

Baker, C.J. 1976. Experiments relating to techniques for direct drilling of seeds into untilled dead turf. Journal of Agric. Engineering Research. 133-44.

Choudhary, M.A.; Baker, C.J. 1977. The interrelationship of drilled seeds and dry soils as a function of sowing techniques under controlled climatic conditions. Proc. International Conference on Energy Conservation in Crop Production, Massey University, New Zealand.

Choudhary, M.A.; Baker, C.J. 1980. Physical effects of direct drilling equipment on undisturbed soil. I. Wheat seedling emergence under controlled climatic conditions. New Zealand Journal of Agric. Research. 23: 489-96.

Choudhary, M.A.; Baker, C.J. 1981a. Physical effects of direct drilling equipment on undisturbed soils. II. Seed groove formation by a 'triple disc' coulter and seedling performance. New Zealand Journal of Agric. Research 24: 183-87.

Choudhary, M.A.; Baker, C.J. 1981b. Physical effects of direct drilling equipment on undisturbed soils. III. Wheat seedling performance and in-groove micro-environment in a dry soil. New Zealand Journal of Agric. Research 14: 189-95.

Choudhary, M.A. 1981. Towards classifying interactions between soil, climate and conservation tillage machines. Proc. Conservation Tillage Technical Seminar, Christchurch, New Zealand, 133-141.

Choudhary, M.A.; Baker, C.J. 1982. Effects of direct drilling coulter design and soil moisture status on emergence of wheat seedlings. Soil and Tillage Research 131-142.

Baker, C.J.; McDonald, J.H.; Seebeck, K. 1979. Development with seed drill coulters for direct drilling. III. An improved chisel coulter with trash handling and fertilizer placement capabilities. Journal of Experimental Agriculture 7, 189-96.

Baker, C.J.; Thom, E.R.; McKain, W.L. 1979. Development with seed drill for direct drilling. IV. Band spraying for suppression of competition during overdrilling. Journal of Experimental Agriculture 7, 441-16.

Sheikh, G.S.; Khalid Pervez; Sial, J.K.; Afzal, M.; Ansari, A.G.; Yasin, M. 1982. A progressive approach towards minimum tillage. Proc. 3rd Annual Convention of the Society of Agric. Engineers, Lahore, Pakistan.

Baz. M. Khan; Shahid Ahmad; Imran Ashraf. 1981. Rain moisture conservation for crop production in the Pothwar area of Pakistan. ed (Pakistan Agricultural Research Council Publication).

Chaudhry, A.D.; Kh. A. Hussain; Khan, A.S. 1982. Comparative study of different mechanised cultivation techniques. (An unpublished report submitted to Agric. Development Bank of Pakistan).

Bukhari, S.B.; Baloch, J.M. 1982. Fuel consumption of tillage implements. Journal Agricultural Mechanisation in Asia, Africa and Latin America. Vol. XIII no. 3 29-22. ■■

Some Developments in Direct Drilling Equipment in New Zealand



by
C.J. Baker
Director
Agricultural Machinery Research Centre
Massey University
Palmerston North, New Zealand

Introduction

Direct drilling is the term used when seeds are drilled directly into uncultivated ("no till", or "zero till") seedbeds, the vegetation on which has been suppressed or killed by herbicides or natural mortality. Where only partial control of resident herbage is sought (such as when new pasture species are introduced) the technique is usually described as overdrilling or sod seeding (Baker, 1972). Both processes require the simultaneous activation of several new techniques which differ in important ways from conventionally tilled seedbeds. Pre-sowing weed control is different from when the soil is tilled (even although post-emergence weed control may be little different). The drilling procedure and equipment are different. Much of the pest control is different; and even the nutrient requirements and management may often be different. For the technique to be successful, knowledge of each of these aspects must be at a high level.

This paper reviews selected works at Massey University, New Zealand, and elsewhere; and attemps to discuss the likely impact of improved machinery on the technique in general.

Impact

The impact of correct drilling procedures is probably roughly equal in importance to correct weed and pest control. Losses of plant population and yield as a result of inadequate pest or weed control have long been recognized, even for no till seedbeds (Sims and Baker 1981) but inadequate drilling techniques or equipment may have just as large an impact on the success of direct drilling (Baker, 1976).

Habitat Conflict

Early work did not highlight the important conflict which was arising between modifying the seedling habitat, by pushing or scraping aside living or dead residue (to help avoid competition or ease machinery operation); and modifying the seed habitat to promote seed germination and seedling emergence (Baker 1981a; Barr, 1980). This conflict may be one of the more important determinants of a successful crop stand, especially when soil or climatic conditions are sub-optimal.

Seedling Emergence Habitat

There is a considerable body of evidence (Baker 1976a; Choudhary & Baker 1980, 1981a,b, 1982) which points to the advantages of retaining the existing dead vegetation or mulch as the main upperstrata covering medium over the drilled seed, in order to insulate the seed groove from drying. This mulch appears to slow down the interchange of soil water vapour with the atmosphere. Even a very dry soil at "wilting point" has an equilibrium relative humidity of approximately 99% (Scotter 1976). When a drill cuts a seed groove in such a soil the initially high humidity of the soil equilibrates with the atmosphere in the groove. Thereafter, however, it is difficult to avoid the humidity decreasing to approach equilibrium with the ambient atmosphere.

In-groove humidity has a relatively small effect on germination (Baker 1976a; Choudhary, 1980) as liquid-phase soil moisture is mostly responsible for imbibing the seed; but it can have a major effect on the survival of the seedlings for the first few days after germination, and until they emerge from the soil. If the in-groove humidity decreases too quickly (even in a reasonably moist soil), seedlings often germinate but die before emerging. The ability of a given seed groove to retain vapour-phase moisture was referred to as "Moisture Vapour Potential Captiv-

ity" (MVPC) by Choudhary and Baker (1981b) who also demonstrated a correlation coefficient of r = 0.75 between this parameter and seedling survival in a dry soil.

Table 1 summarizes 18 related experiments conducted at Massey University under climatic conditions which ranged from full climate-room-control to ambient warm-temperature conditions. The experiments sought to determine the influence of groove shape and covering on seedling emergence (Baker, 1979a).

From the table, the maximum difference attributable to groove shape and covering was 14-fold and differences in the order of 1.5- to 6 fold were common. Even within the common U-shaped groove, the seedling population was increased substantially by refilling the slot with loose soil using a bar harrow developed earlier at Massey University (Baker, 1970). The examples shown in the table illustrate the magnitude of the differences which can be attributed to groove shape and covering. Baker (1976c) had demonstrated a strong correlation (r = 0.97) between the nature of the groove cover (which he graded I to IV according to the amount of loose soil and/or mulch present) and seedling emergence from a dry soil.

It is also noteworthy from the table that the covered V shaped groove was not at any time superior to either of the other two shapes of groove tested (although in the more moist conditions it was often equivalent to them). Similarly in all these experiments the inverted T shaped groove (with its inherent soil plus mulch cover) was at no time inferior to the other two grooves (although it too was only equivalent to them in favourable conditions). The performance of the U shaped groove was almost always intermediate between the disc and inverted T grooves, although it benefited in dry soils from covering by the bar harrow because of the loose surface soil which it generated.

The V and U shaped grooves were also markedly improved by the action of press wheels operating directly on the seeds at the bases of the grooves before covering. None of the groove shapes, however, were improved at all by press wheels operating on the top of the previously covered grooves (Choudhary and Baker, 1980).

It should be appreciated that while the mechanical options for creating V and inverted T shaped grooves are reasonably limited, the U-shaped grooves can be created by a range of openers, including

Table 1 Summary of Effects of Groove Shape and Covering Techniques on Seedling Emergence of Direct Drilled Seeds (In descending order of magnitude)

Reference Reference	Type of Type of Experiment	Soil Soil	Crop Corp	Soil Moisture Status	Maximum & Minimum Treatments	Max: min ratio (Seeding emergence counts)
Choudhary & Baker (1981a)	tillage bin; full climate control	silt loam	wheat	very dry	T/BH V/BH	14:1**
Baker 1976b	field	silt loam	maize	dry	U/BH U	14:1
Baker 1976b	field	silt loam	barley	very dry	U/BH U	9.5:1
Baker 1976b	tillage bin; partial climate control	silt	barley	very dry	T/BH U	6:1
Choudhary & Baker (1980)	tillage bin; full climate control	fine sandy loam	wheat	very dry	T/BH V/BH	5.5:1**
Baker 1976b	tillage bin; partial climate control	fine sandy loam	wheat	dry (21% d.b.)	T/BH V/BH	3:1**
Baker (1971)	field	silt loam	kale	dry	U/BH U	2:1*
Choudhary & Baker (1982)	field	silt loam	wheat	very dry (10.2% d.b.)	T/BH V/BH	1.7:1*
Choudhary & Baker (1981a)	tillage bin, full climate control	fine sandy loam	wheat	adequate (near f.c.)	T/BH V/BH	1.6:1**
Baker (1976b)	field	silt loam	lucern (alfalfa)	dry	U/BH U	1.4:1
Choudhary & Baker (1982)	field	silt loam	wheat	very dry (11.7% d.b.)	T/BH V/BH	1.3:1*
Choudhary & Baker (1982)	field	silt loam	wheat	dry (25.2% d.b.)	T/BH V/BH	1.2:1*
Mai (1979)	field	silt loam	wheat	adequate (near f.c.)	T/BH V/BH	NS
Mai (1979)	field	silt loam	lupin	adequate (near f.c.)	T/BH V/BH	NS
Choudhary & Baker (1982)	field	silt loam	wheat	adequate (28.4% d.b.)	T/BH V/BH	NS
Choudhary & Baker (1982)	field	silt loam	wheat	dry (21.1% d.b.)	T/BH V/BH	NS
Choudhary & Baker (1982)	field	silt loam	wheat	adequate (27.2% d.b)	T/BH V/BH	NS
Choudhary & Baker (1982)	field	silt loam	wheat	very dry (9.7% d.b.)	T/BH V/BH	NS

Key to abbreviations:
* – Significant at 5% level of probability, ** – Signficant at 1% level of probability. Differences relate only to each reported experiment. No comparison is intended amongst ratios listed in the table. t – Only the two extreme treatments are recorded to illustrate the range of responses. Intermediate treatments are not included; U – U-shaped slot usually created by a simple tyne; T – inverted T-shaped slot created by an experimental opener (Baker 1976a, Baker et al. 1979b); V – A neat V-shaped slot resulting from double or triple disc openers with plain discs; BH–Bar harrow covering; (scuffing action on soil surface; Baker, 1970).

hoes, powered rotating heads, twin parallel discs followed by a mouldboard, and others. In the experiments listed above, the only mechanical option used for U shaped grooves was a plain front disc followed by a narrow hoe tool. Care may therefore be necessary in extrapolating these results to include U-shaped grooves created by other mechanical means.

Competition Habitat

Clearly, the retention of dead vegetation close to (and even over) the groove opening, as a barrier to moisture loss, contrasts with recommendations which have sought to remove it; either to reduce the in-row competition for over-drilling (Cross and Glen-day, 1956; Robinson and Cross, 1960); or to simplify passage of the opener. A logical way of achieving both objectives in the absence of blanket spraying, was to kill or suppress the vegetation in situ in a band. This has been achieved by strip spraying (Blackmore 1962; Collins 1970; Baker *et al.* 1979d) or by rolling on with rubber press wheels (Baker, 1982). With spraying, the need to maintain a constant nozzle height and pressure, and to avoid wind was emphasized by Collins (loc cit), while with rolling on of the herbicide these aspects appear to be less of a problem, and any soil which accumulates on the tyres has had surprisingly little affect on the efficacy of the herbicides glyphosate or paraquat.

Wet Soils

Wet soils may be as important as dry soils in determining the limitations of given openers for direct drilling. Aspects of groove formation related to smearing and compaction have been tested at Massey University (Baker and Mai 1982a;b) as have aspects of toxin accumulation by decaying residues at Letcombe Laboratories (U.K.) (Ellis & Lynch 1976; Lynch 1978; Lynch *et al.* 1980).

While different drill openers have been shown to produce different soil compaction effects (Dixon, 1972; Baker and Mai, loc cit) and even to affect the root formation of tap rooted species, there are surprisingly little quantitative data related to seedling survival or crop performance which could be used extensively to nominate preferences amongst drilling or groove covering devices. Where special efforts were made to create V-shaped grooves, with on the one hand a smear, and on the other hand, without a smear (Choudhary and Baker, 1981b) no differences in seed or seedling performance could be found. This contrasted to some extent, with a number of other reports (Cannel and Ellis, 1976; Soane, *et al.*, 1975) and observations of users which had listed smearing as one of the less desirable features of openers which create V-shaped grooves. Choudhary and Baker (1981b), also observed that some smears of this type, when left exposed in an open groove, soon dried to form a super-dry interface zone which may have restricted soil moisture movement to the seed or embryonic seedling.

In relation to the interactions of wet residue-decay, its toxins, and seed germination and seedling performance, in the English cool damp autumn sowing conditions (and possibly elsewhere) it appears that when seeds are in contact with decaying residues, they may be at risk from either competition for oxygen from fungal mycelia and other microbiological activity, or direct contact with fatty acids. Physical separation of seed from the residue has been one combatant, as has the coating or protection of seed by lime or calcium peroxide. What is not known at present is whether or not the English data in a cool temperate climate can be extrapolated to warm temperate conditions, sub-tropical, tropical, arid or semi-arid climates.

"Hair-Pinning"

The commonly used term "hair-pinning" describes straw residue which is pushed doubled-up into the soil in a manner resembling a common hair pin (Erbach, 1978; Baker, 1981b). It is apparently of significance in both wet and dry soils. In wet soils, seeds which rest in a "hair-pin" which is decaying are in danger of damage by the fatty acids present (Lynch *et al.* 1980). In dry soils, seeds suspended in a "hair-pin" are often deprived of sufficient liquid-phase moisture to initiate germination (Baker, loc cit). Both situations are countered by avoiding the formation of "hairpins". Some openers have been designed specifically to avoid contact between seeds and "hairpins" while others have achieved this almost by accident (Baker et al. 1979b).

Trash Clearance

There appears to have been only a few reported studies of trash clearance aspects of drill openers (Baker *et al.* 1979c). Perhaps this has been because openers used in tilled soils had not usually been concerned with trash (except in minimum tillage and even then most of the residue had been either root-anchored or anchored by partial burial and thus provided few guidelines). Machinery researchers and advisors appear to have disagreed amongst themselves about whether or not plant residues should be retained on the surface of no-till seedbeds. Much less has there been agreement on whether such residue that was retained on



Fig. 1 Direct drilled barley utilizing the previous crop residue as a mulch to trap mositure even within the drilled row



Fig. 2 Direct drilled barley in previous crop residue in New Zealand.



Fig. 3 Direct drilled forage brassica crop in New Zealand



Fig. 4 Seed placement in previous crop residue with a chisel coulter



Fig. 5 An example of a prototype field drilling rig utilizing the Massey University technology. Commercial machines range from single-row animal-drawn models to this large broad-area machine

the field, should be retained over the drilled slot, or instead pushed aside to produce "clear strips" during the drilling process.

It appears that many agricultural engineers have opted to push residues aside as a mechanically expedient way of allowing fixed tines to operate. Others have attempted to cut through the trash *in situ* to avoid the need for large opener-clearance zones (and thus seed drill sizes) necessary for pushing it aside (Karonka, 1973, Baker *et al.* 1979c). Yet a further approach has been to chop the residue in situ in a mini-cultivated strip (Dunbar *et al.* 1979).

Little clear consensus appears to have been reached between these different approaches, although the evidence for trash or residue retention on the field (Triplet et al. 1968) and on the drilled groove (Baker 1976, Choudhary and Baker, 1981b) appears to be strong.

Seed Placement

There is a growing body of evidence which suggests that placement of seeds by the openers within the grooves, as well as the maintenance of an accurate depth by the openers themselves, may be of importance (Campbell 1981, Ritchie & Cox, 1981). Certainly small legume seeds appear to demand a narrow tolerance with respect to depth of sowing, and some openers themselves (even when gauged from the ground surface so that they operate at a consistent depth) appear to deposit the seed at irregular vertical and/or lateral positions relative to their below-ground components.

With precision-metered direct drilled crops, the seed is often required to travel down an extended path through the direct drilling opener, due to the robustness and size of its construction. In such situations it may be necessary to provide an additional means of positive seed transfer if the evenly spaced pattern of seed deposit which is expected in tilled soils is to be maintained in untilled soils (Ritchie, 1982).

Fertilizer Placement

It is possible that machine designers have been so pre-occupied with other mechanical problems of making direct drills operate in untilled soils, that they have so far not elevated fertilizer placement high on the design priority list. One of the earliest reports of a special tool for separating seed and fertilizer in direct drilled grooves was by Hyde *et al* (1979). They opted for vertical separation. Soon after Baker *et al* (1979b) reported a device for horizontal separation, and Afzal (1981) studied the effects of the contrasting positions of the fertilizer bands on seed/seedling damage. This favoured slightly the horizontal separation of ammonium sulphate from rape seed, compared with vertical separation.

Perhaps, more importantly, there is a growing amount of data which has highlighted sometimes large differences in crop yield which has been attributable to placement of some fertilizers (usually nitrogen) near the seed at planting (Hyde *et al.*, 1979; Baker and Afzal, 1981). In some cases the

yield increases attributable to fertilizer placement compared with broadcasting under continuous direct drilling have exceeded similar increases from fertilizer placement under continuous tillage regimes.

Conclusions

The first reported development in direct drilling machinery design at Massey University occurred in 1976 (Baker 1976a). Up to, and since that time all research work has followed the simple philosophy of firstly attempting to define the responses of direct drilled seeds and seedlings in relation to various soil micro-environments, especially those that were otherwise considered sub-optimal. Thereafter, machine design specifications could be written to attempt to bring about the more desirable micro-environmental conditions. Even the testing of prototype machines has concentrated more on biological performance than mechanical performance. The latter has become more important as commercial production is approached, and to date a range of five different drill concepts or commercial machines has arisen from this work.

It has been the objective of all of this work to reduce the risk of seed/seedling failure at drilling and thereby to widen the tolerance of any one direct drill to ground and climatic conditions.

A concluding statement in 1976 appears to be as relevant today as it was then (Baker, *loc cit*).

"It is evident that the potential of direct drilling will not be fully realized except in favourable weather and soil conditions which might mask otherwise sub-optimal seed drill design or performance, unless research effort is directed toward the critical phases of seed germination and seedling emergence. An untilled seedbed is not as "forgiving" with respect to the adequacy of seed placement and cover as is cultivated ground, but it often possesses greater potential to promote the establishing plant. It is necessary that machine design schedules should have, as a high priority, methods of utilizing rather than destroying this potential".

REFERENCES

1. Afzal, C.M. 1981. The requirements of dry fertilizer placement in direct drilled crops by an improved chisel coulter. M. Agr. Sc. Thesis, 127 pages.
2. Baker, C.J. 1970. A simple covering harrow for direct drilling. N.Z. Farm. 91 (4), 62-3.
3. Baker, C.J. 1971. Filling up spaces by surface seeding. Proc. 24th N.Z. Weed & Pest Contr. Conf. pp 75-9.
4. Baker, C.J. 1972. Oversowing, overdrilling or direct drilling? N.Z. Farm. 93 (7), 21.
5. Baker, C.J., 1976a. Experiments relating to the techniques of direct drilling of seeds into untilled dead turf. J. Agric. Engng Res. 21 (2), 133-45.
6. Baker, C.J. 1976b. Some effects of cover, seed size and soil moisture status on seedling establishment by direct drilling. N.Z. Jl. Expt. Agric. 5, 47-53.
7. Baker, C.J. 1976c. An investigation into the technique of direct drilling seeds into undisturbed, sprayed pasture, Ph.D Thesis, 186 pages.
8. Baker, C.J. 1979a. Equipment impact and recent developments. Proc. Consvtn Tillage Tech. Sem., 250 pages.
9. Baker, C.J.; McDonald, J.H.; Rix, C.S.; Seebeck, K.; Griffiths, P.M. 1979b. Developments with seed drill coulters for direct drilling: 3. An improved chisel coulter with trash handling and fertilizer placement capabilities. N.Z. Jl. Expl. Agric 7, 189-96.
10. Baker, C.J.; Badger, E.M.; McDonald, J.H.; Rix, C.S. 1979s. Developments with seed drill coulters for direct drilling: 1, Trash handling properties of coulters. N.Z. Jl. Expt. Agr., 7, 175-84.
11. Baker, C.J.; Thom, E.R.; McKain, W.L. 1979d. Developments with seed drill coulters for direct drilling: 4. Band spraying for suppression of competition during overdrilling. N.Z. Jl. Expt. Agric. 7, 411-16.
12. Baker, C.J. 1981a. Techniques of overdrilling for the introduction of improved pasture species in temperate grasslands. Proc. XIV Int. Grasslands Congr. (Kentucky) – in press.
13. Baker, C.J. 1981b. How direct drilling equipment developments in Europe and North America relate to New Zealand. Proc. Consvtn. Tillage Sem. 380 pages: 105-21.
14. Baker, C.J.; Afzal, C.M. 1981. Some thoughts on fertilizer placement in direct drilling. Proc. Consvtn. Tillage Sem. 380 pages: 343-54.
15. Baker, C.J. 1982. Direct drilling; some observations about the state of the art. Proc. N.Z. Min. Agr. Fish. Agr. Engeng Conf. 333 pages: 261-272.
16. Baker, C.J.; Mai, T.V. 1982a. Physical effects of direct drilling equipment on undisturbed soils: 4. Techniques for measuring soil compaction in the vicinity of drilled grooves. N.Z. Jl. Agr. Res. 25, 43-49.
17. Baker, C.J.; Mai, T.V. 1982b. Physical effects of direct drilling equipment on undisturbed soils: 5. Groove compaction and seedling root development. N.Z. Jl. Agr. Res. 25, 51-60.
18. Barr. S.J. 1980. Some factors affecting the success of pasture renovation using overdrilling with band spraying. (unpub. B. Agr. Sc. Hons Thesis, 84 pages).
19. Blackmore, L.W. 1962. Bandspraying: A new overdrilling technique. N.Z. Jl. Agric. 104, 13-19.

20. Campbell, B.D. 1981. Observations of early seedling establishment for overdrilled red clover. Proc. Consvtn. Tillage Sem. 380 pages: 143-163.
21. Cannell, R.Q.; Ellis, F.C. 1976/77. Agr. Res. Council Letcombe Lab. An. Rep.
22. Choudhary, M.A.; Baker, C.J. 1980. Physical effects of direct drilling equipment on undisturbed soils: 1. Wheat seeding emergence from a dry soil under controlled climates. N.Z. Jl. Agr. Res. 23, 489-96.
23. Choudhary, M.A.; Baker, C.J. 1981a. Physical effects of direct drilling equipment on undisturbed soils: 2. Seed groove formation by a "triple disc" coulter and seedling performance. N.Z. Jl. Agr. Res. 24, 183-87.
24. Choudhary, M.A.; Baker, C.J. 1981b. Physical effects of direct drilling equipment on undisturbed soils: 3. Wheat seedling performance and in-groove micro-environment in a dry soil. N.Z. Jl. Agr. Res. 24, 189-95.
25. Choudhary, M.A.; Baker, C.J. 1982. Effects of direct drill coulter design and soil moisture status on emergence of wheat seedlings. Soil & Tillage Res. 2, 131-42.
26. Collins, R.M. 1970. A study of band spraying and direct drilling as a technique for increasing the winter production of pastures. M. Agr. Sc. Thesis, 250 pages.
27. Cross, M.W.; Glenday, A.C. 1956. Reseeding pastures by oversowing and overdrilling. N.Z. Jl. Sc. Tech. 38 (4), 416-30.
28. Dunbar, G.R.; Horrell, R.; Costello, E.J. 1979. Sod seeding trials with a modified rotary hoe. T.G.M.L.I. Review 38.
29. Ellis, F.B., Lynch, J.M. 1976. Problems associated with the persistence of winter cereals. A.R.C. Report - Agr. and Environment (5): 321-28.
30. Erbach, D.C. 1978. Residue cutting furrow opener for no-tillage planting, ASAE Tech. Pap. 78-1014.
31. Hyde. G.M.; Johnson, C.E.; Simpson, J.B.; Payton, D.M. 1979. Grain drill design concepts for Pacific Northwest Conservation farming. ASAE Pap. 79-1525.
32. Karonka, P. 1973. Machinery development for direct drilling, Outlk Agric. 7 (4), 190-195.
33. Lynch, J.M. 1978. Production and phytotoxicity of acetic acid in anaerobic soils containing plant residues. Soil Biol. Biochem. 10: 131-135.
34. Lynch, J.M.: Ellis, F.B.; Harper, S.H.T.; Christian, D.G. 1980. The effect of straw on the establishment and growth of winter cereals. A.R.C. Report - Agr. and Environment (5): 321-28.
35. Mai, T.V. 1979. The effects of drill coulter design on soil physical properties and plant responses in untilled seedbeds. Ph. D Thesis, 350 pages.
36. Ritchie, W.R.; Cox, T.I. 1981. Towards precision sowing in uncultivated ground. Proc. Consvtn. Tillage Sem. 379 pages: 123-132.
37. Robinson, G.S.; Cross, M.W. 1960. Improvement of some New Zeland grassland by oversowing and overdrilling. Proc. VIII Int. Grassld Congr. 764 pages: 402-3.
38. Scotter, D.R. 1976. Liquid and vapour phase transport in soil. Austr. Jl. Soil Res. 14, 33-41.
39. Sims, R.E.H.; Baker, C.J. 1981. Comparisons of four reduced time and energy seedbed preparation systems: Year one of a perennial experiment. N.Z. Jl. Expt. Agric. 9, 299-305.
40. Soane, B.D.; Butson, M.J.; Pidgeon, D. 1975. Soil machine interactions in zero tillage for cereals and raspberries in Scotland. Outlk. Agric. 8, 211.

■■

Development of Rolling-Type Soil Crust Breaker



by
N.K. Awadhwal
Assistant Professor
Department of Agricultural Engineering
G.B. Pant University of Agriculture and Technology
Pantnagar, U.P., India



G.E. Thierstein
Principal Agricultural Engineer
ICRISAT Patancheru P.O.
Andhra Pradesh 502324, India

Abstract

Soil crusting or capping is a serious problem in arid and semi-arid regions; it restricts the emergence of crop seedlings. A mechanical, rolling-type soil crust breaker was designed, developed, and tested in the field. The equipment is of simple construction and breaks the soil crust effectively, improving emergence without any damage to crop seedlings. It can be manually operated as a single-row unit, or a multiple row unit and can be pulled by animal draft power or a small tractor.

Introduction

Soil crusting or capping is a world-wide problem and occurs under a wide range of soil and climatic conditions (Carnes, 1934; Hillel, 1959, 1960; Williams, 1963, Heinonen, 1965; Cary and Evans, 1974; Prihar, 1974; Gupta and Yadav, 1974, 1978). Soil crust offers mechanical resistance to emerging seedlings. If the young seedling lacks the energy to break through the crust, the seedling becomes bent just beneath the crust and dies. Failure of seedling emergence is a common problem in sandy and loamy soils of many arid and semi-arid regions of the world (Miller and Gifford, 1970; Hoogmoed, 1980), where the rapid drying of soil results in faster development of strong soil crust. The crops that are usually affected by crusting are pearl millet (Pennisteum americanum L.), cotton (Gossypium lirulum L.), grain sorghum (Sorghum bicolor L), soybean (Glycine max L.) guar (Cyamopsis tetragonoloba), carrot (Daucus carota L.), and other small grains (Richards, 1953, Hanks and Throp, 1957: Cary, 1967 Chaudhry and Das, 1980; Genard, 1980).

Once crust is formed, it should either be wetted frequently or should be broken mechanically. Moreover, application of water is often impractical because of the limited availability of water in the arid and semi-arid regions and the labour requirement and its cost. Heinonen recommended shallow cultivation to break the crust, which loosens the top soil surface and leaves it open for faster infiltration of water. But shallow cultivation cannot be used over seed rows that are ready for emergence because the cultivator may seriously injure young seedlings just below the soil crust.

So far no equipment is available that can be used by small farmers for breaking the soil crust over the rows of germinated seeds to help seedling emergence.

A piece of equipment called the rolling-type mechanical crust breaker was developed and tested at ICRISAT for breaking the soil crust over the rows of germinated seeds to improve the emergence of seedlings.

Acknowledgement: We gratefully acknowledge the suggestions and help extended by Mr. R.K. Bansal, Agricultual Engineer, and the cooperation of Drs. P. Soman and R.K. Maiti, Cereal Physiologists at ICRISAT, in the field testing of the equipment.

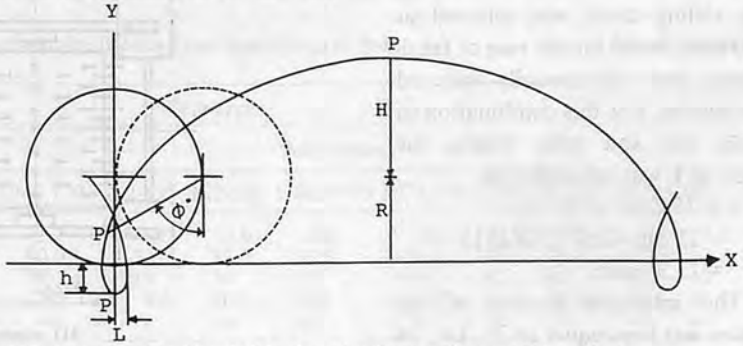


Fig. 1 Trajectory of a spike tip(p) when the drum rolls on a flat surface.

Working Principle

The trajectory of a point P at a distance H from the center of a circle of radius R is described by the following equations when the circle rolls on a straight line:

$$X = R\Phi - H \sin \Phi$$

$$Y = R\Phi - H \cos \Phi$$

where X and Y are coordinates of the point P and r is angle of rotation of the circle from the vertical. In the case of $R < H$, the point will trace a curve called the prolate cycloid, as shown in Fig. 1. Thus if spikes of length h are fixed radially on the surface of a drum of radius R (so, $H = R + h$) and the drum is rolled on the soil surface, then the spike will excavate the top layer of soil to a certain depth. The maximum depth of excavation will be equal to h and the bite length equal to 2L, where L is given by the following equation:

$$L = R \cos^{-1} (R/H) - H \sin (\cos^{-1} R/H)$$

Design and Construction

Small seeds such as pearl millet and cotton are generally planted at a depth of about 30 mm from the soil surface, so the spike length should be less than 30 mm. In a survey of soil crusts at ICRISAT Center, the crust thickness was found to be about 15 to 20 mm. Thus the optimum length of the spike lies between 20 and 30 mm.

An average spike length of 25 mm was selected. The diameter of the rolling drum was selected as 150 mm, based on the ease of fabrication and of manually-operated equipment. For this combination of drum size and spike length, the value of L was calculated as,

$$L = 75 \cos^{-1} (75/25) - 25 \sin (\cos^{-1} [72/25])$$

$$= 11.93 \text{ mm}$$

The inter-row spacing of the spikes was kept equal to 2L, i.e., 24 mm, because this should theoreti-

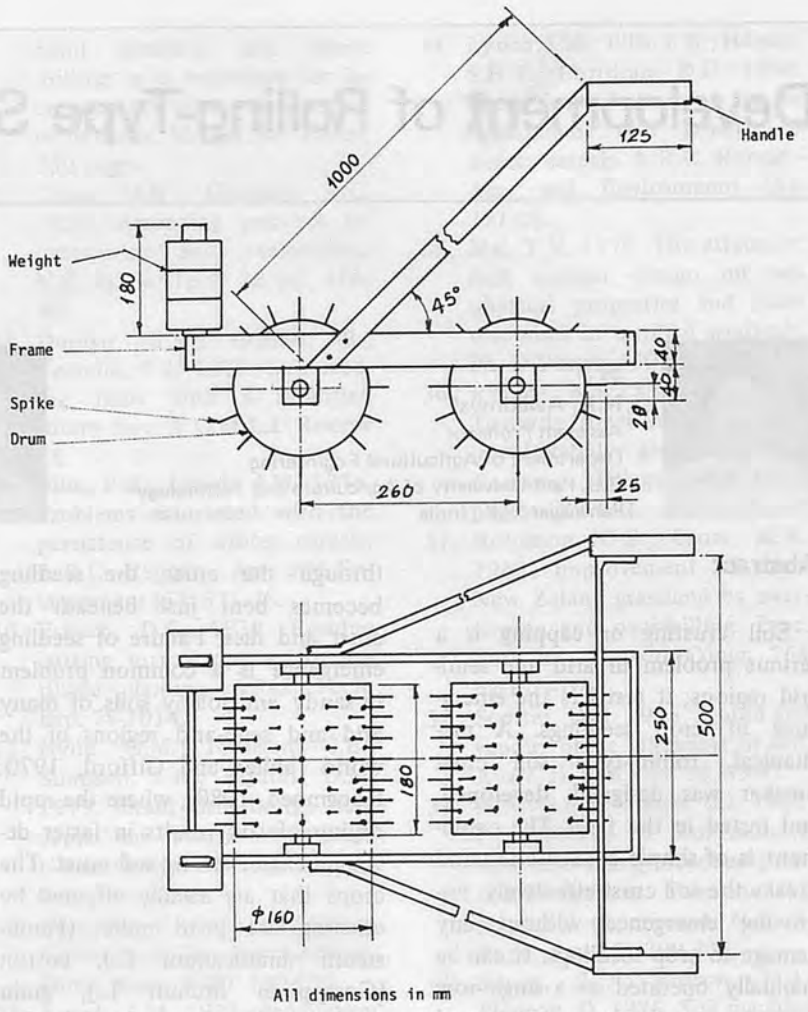


Fig. 2 Rolling type soil crust breaker (manually-operated).

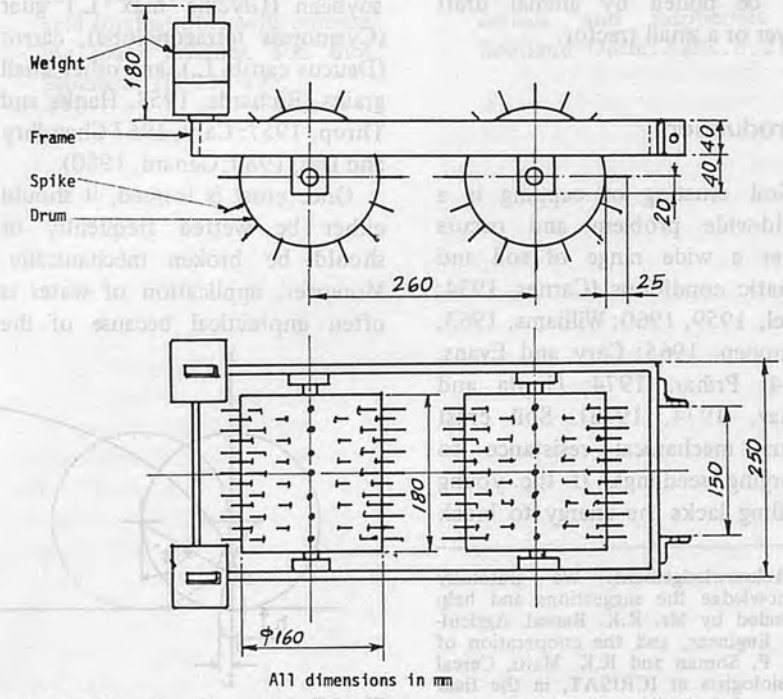


Fig. 3 Rolling type soil crust breaker (attachable to animal-drawn toolbar).

cally leave no crust unbroken at the soil surface. The same distance was selected for spike spacing within rows.

Prototypes of the rolling-type crust breaker were fabricated and mounted on two different types of frames one for manual operation and the other for attachment on the bullock-drawn toolbar, as shown in **Figs. 2** and **3**, respectively. The estimated cost of one crust breaker unit is about Rs.120 ($15).

Performance Evaluation

The performance of the rolling-type crust breaker was evaluated in Alfisol fields with a range of sandy, sandy loam, and sandy clay soils. A split-plot design in five replications with crust and broken crust conditions in main plots and different millet/sorghum genotypes in subplots was repeated three times. The pearl millet and sorghum genotypes were planted manually, and about 35 mm of water was applied by sprinkler from a height of 2 m. This produced a reasonably uniform and hard crust.

On the day prior to the expected emergence the crust surface was dry and its strength, measured with a pocket penetrometer, was in the range of 2.0 to 2.5 kg per cm^2. The average moisture content in the top 10 cm of the soil was 8%, and the soil temperature was in the range of 35 to 37°C. These temperature and moisture conditions were judged to be favorable for emergence.

The rolling-type crust breaker was used to break the soil crust on the seeded rows one day prior to the day of expected emergence. The emergence count was taken one week after breaking the crust. Operation of the manually operated and the bullock-drawn crust breaker is shown in **Figs. 4** and **5**, respectively. The manually-operated crust breaker covers about 0.1 ha/h, and the bullock-drawn tool carrier with three crust-breaker units can cover approximately 0.4 ha/h. The seedling emergence in both the crusted plots and the plots with broken crust were noted.

The data given in **Table 1** indicate that the seedling emergence under crusted condition was very poor and the use of the crust breaker increased seedling emergence significantly when soil moisture was not a limiting factor. The CV values are generally high, possibly due to random selection of seeds for the experiments from the bulk.

Conclusion

The rolling-type crust breaker performed well in experimental fields. It broke the crust over seeded rows without any visible physical injury to the young seedlings just below the crust and improved seedling emergence significantly

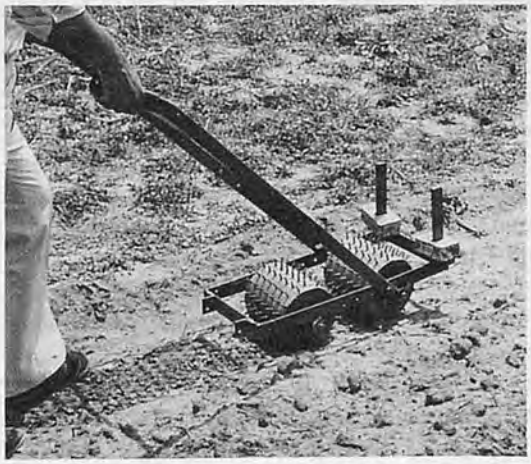


Fig. 4 Manually-operated rolling type soil-crust breaker.



Fig. 5 Bullock-drawn rolling type soil crust breaker.

Table 1 Seedling Emergence under Crusted and Mechanically Broken Crust Conditions of Soil (Unit: Percent)

Treatment	Genotypes												
	Sorghum			Pearl millet									
	IS462-1	IS8129	FS35-1	WC-C-75	ICMS 7703	D2-395	SC2-191	ICMS7703	WC-C-75	D2-99	MEC91	SSC93	WC-C-7
Crust	8.7	37.7	17.3	28.6	1.7	0.0	0.0	0.0	3.3	3.3	1.7	3.4	3.3
Crust broken	45.0	96.3	43.0	43.3	50.0	23.3	55.0	50.0	26.7	45.0	36.7	50.0	33.3
CV %	77	32	14	21	78	119	76	74	93	82	90	60	42
F. value	9.2	22.2	105.5	11.3	17.2	8.5	20.9	22.1	8.5	13.4	12.5	25.8	45.0
Significance	*	**	**	*	**	*	**	**	*	*	*	**	**

* Signficant at 5% ** Significant at 1%

compared to emergence in crusted conditions.

REFERENCES

1. Carnes, A. (1934). Soil crusts-methods of study, their strengh and a method of overcoming their injury to cotton stand. Ag. Eng. 15: 167-169, 171.
2. Cary, J.W. (1967). Punch planting to establish lettuce and carrot under adverse conditions. Agron. J. 59: 406-408.
3. Cary, J.W. and Evans, D.D. (1974). Soil crusts. Tech. Bull. 214 Ag. Exp. Sta. Univ. of Arizona, Tucson, Arizona.
4. Chaudhry, K.G. and Das, D.K. (1980). Seedling emergence of summer legumes through simulated soil crust. J. Indian Soc. Soil Sci. 28: 386-388.
5. Genard, C.J. (1980). Emergence force by cotton seedlings. Agronomy Journal. 72: 473-476.
6. Gupta, J.P. and Yadav, R.C. (1974). Studies on crust formation and its avoidance. Annual Report, 1974. CAZRI, Jodhpur, India.
7. Gupta, J.P. and Yadav, R.C. (1978). Soil crust formation and seedling emergence in relation to rainfall intensity and mode of sowing. J. Indian Soil Sci. Soc. 26 (1): 20-24.
8. Hanks, R.J. and Throp, F.C. (1957). Seedling emergence of wheat, grain sorghum and soyabeans as influenced by the soil crust strength and moisture content. Soil Sci. Soc. Amer. Proc. 21: 357-359.
9. Heinonen, R. (1965). Soil crusting and crust breaking cultivation of cereals, Lantbr Hogsk. Medd. No. 25: 17.
10. Hillel, D. (1959). Studies on loessial crusts. Agri. Res. Sta. Rehvoth Beit Degan, Israel Bull. No. 63.
11. Hillel, D. (1960). Crust formation in loesseal soils. Trans 7th Congr. Soil Sci. Madison (Winsconsin) 1: 330-339.
12. Hoogmoed, W.B. (1980). Development of criteria and method for improving the efficiency of soil management and tillage operations with special reference to arid and semi-arid regions. Report No. 1. Faculty of Agriculture. The Hebrew University of Jerusalem.
13. Miller, D.E. and Gifford, R.O. (1970). Modification of soil crusts for plant growth. In "Soil Crust", Tech. Bull. 214. Agric. Expt. Sta. Univ. Arizona.
14. Prihar, S.S. (1974). Soil crusting in dryland agriculture; Formation, avoidance and manipulation. Proc. Second Annual Meeting AICRPDA, Hyderabad, Jan 1974.
15. Richards, L.A. (1953). Modulus of rupture as an index of crusting of Soil. Soil Sci. Soc. Amer. Proc. 17: 321-323.
16. Williams, W.A. (1963). The emergence force of forage legume seedlings and their response to temperature. Crop Sci. 3: 472-474. ■■

Field Performance Evaluation of Rice Reaper

by

Nadeem Amjad
Head, Testing and Evaluation Section
Agric. Machinery Division
Pakistan Agric. Research Council
Islamabad, Pakistan



David Gee-Clough
Associate Professor
Agric. and Food Engineering Division
Asian Institute of Technology
Bangkok, Thailand

Introduction

Despite the encouraging fact that Asia has good potential for high agricultural yields and the production of crops is increasing due to improved methods of farming, the harvesting techniques employed are still primitive, Asian farmers mostly use hand-sickle for this purpose. Rice harvesting by hand can require about 25% of the total labour requirement of the crop. Depending upon the crop yield, 120 to 250 man-h has been reported for cutting, tying and in-field stacking of one hectare of rice field by using the traditional sickle and up to 240 man-h with the panicle-knife (1,2). In some cases, this high labour requirement has created labour shortages during harvesting, resulting in delayed harvest and consequent field grain losses. Samson et al (3) report that a delayed harvest of 5, 7 and 10 days resulted in yield-losses of 3, 6 and 11%, respectively, for rice. Another important reason for timely harvesting comes from those areas in which a second crop can be grown and the period available for land preparation is short (4, 5).

As a consequence of this realization, development of appropriate crop-harvesting machines such as reapers/windrowers, cutter-binders, etc. was advocated. Japan has made a major contribution in this area, especially by developing small combines. However, these combines have not been readily accepted in many Asian countries. Apart from the machine complexity itself, this has happened mainly because of two reasons. First, the displacement of farm-labour is excessive giving rise to an undesired problem of unemployment. Second, since the threshing operation has already been mechanized in many parts of this region, countries are reluctant to put aside this existing technological achievement. Therefore, rice harvesting machines which could cut and lay the crop in an oriented manner in windrows for collection by permanent farm labour, leaving the threshing operation to be carried out either manually or through existing mechanical means might be more readily acceptable to Asian farmers.

The Chinese Jin Feng vertical conveyor type reaper is a machine which might answer the need for a cereal reaper for small farms in Asia. However, before recommending it to the farmers, it was felt necessary to evaluate its field performance. Hence this study was undertaken with the following main objectives:

1. To measure and evaluate the field performance of a Chinese vertical conveyor type reaper (Model Jin Feng K4G-1.6).
2. To compare the field performance and economics of machine reaping with the conventional method of harvesting.

The following parameters were varied in the field performance tests.

1. Speed of operation; i) Two different forward speeds, ii) Two different cutterbar speeds
2. Time of harvesting; i) At normal crop maturity, ii) One week after normal crop maturity, iii) Two weeks after normal crop maturity
3. Three different cropping densities; Plant spacing: 20 x 20 cm (normal pattern in Thailand)/20 x 30 cm/20 x 40 cm
4. Two different planting systems; i) Transplanting, ii) Broadcasting

Description of the Reaper

Fig. 1 shows a general view of the reaper. The Jin Feng Harvester K4G-1.6 (1.6 m wide header) is a power tiller front mounted attachment, mainly comprising a crop lifting-gathering head, cutterbar, cut-crop supporting pressure springs and crop-conveying lugged endless belts. The conveyor frame is fitted in a plane perpendicular to the cutterbar. The crop is lifted (if lodged) and guided towards the cutterbar



Fig. 1 Jin Feng K4G-1.6 vertical conveyor cereal reaper

Table 1 Conveyor Belt Speed

Unit: cm/sec

Cutterbar speed	Throttle setting		
	Low (850 rpm)	Medium (1585 rpm)	Full (2075 rpm)
Fast	21	39	51
Slow	14	26	34

with the help of continuous, rotating, lugged vee-belts in the crop lifting-gathering head. These are driven by inclined starwheels which are powered by the conveyor drive mechanism. The starwheels hold the crop and feed it to the cutterbar. A pair of flat belt conveyors with lugs mounted on them, operate in the horizontal plane and convey the crop to the right hand side of the operator. A deflector plate helps form the windrow. A pair of pressure springs at each starwheel location keeps the cut crop pressed against the conveyor belts.

The following adjustments are provided on the machine to suit different harvesting conditions;

– Three forward gears and 1 reverse gear each with a high and low range are provided. The manufacturers recommend that harvesting be carried out in low 3rd or high 1st gear.

– Two cutterbar speeds can be used with any forward travel gear by setting a shifting gear to slow or fast shift (see **Table 1**). Speeds of the cutterbar (max. knife velocity) with gear combinations I, II and III (see later), with medium throttle setting were calculated to be 0.94, 1.34 and 1.58 m/sec, respectively.

– Height of the crop stubble can be adjusted to be between 4 and 30 cm by lifting or lowering the whole attachment and the rear wheel.

– Rubber tyres and cage wheels are provided to suit ground conditions at the time of harvest.

Reliability of Transmission and Safety Mechanisms

Power transmission is through gears, belts and pulleys. The first stage power transmission is through gears. All moving parts are well covered and the operator does not have easy access to them while operating the machine. Reliability can only be determined by long term testing but no major breakdowns occurred during the course of these experiments.

Turning Space

i) Turning radius: using brakes & rear wheel – 75.5 cm, using brakes only – 110.0 cm,

ii) Turning space: A circle of 3.9 m radius

Field Tests

Keeping in mind the manufacturer's recommendations, the field speeds at medium throttle setting in low 3rd and high 1st gear were measured in a levelled grassy field. The following gear combinations were then chosen for the field experiments:

Gear combination I: Slow cutterbar speed and low 3rd gear (3.4 km/h)

Gear combination II: Fast cutterbar speed and low 3rd gear (3.4 km/h)

Gear combination III: Fast cutterbar speed and high 1st gear (4.2 km/h)

Actual forward speed was measured during each test.

Methodology

In order to generalize the results and avoid intervarietal differences, only one rice variety, RD-7 (highly susceptible to shatter at maturity), was grown in the experimental plots. Some of the settings of the machine, such as the cutting height of 5 cm above ground level and medium throttle setting, were kept constant throughout the experiments.

To prevent the harvester pressing down the crop a 3.5 m x 3.5 m square was cut by hand in each corner of the field. In addition, a strip 0.2 m wide was cut on each side of the field to prevent the tines from being broken when the crop-lifter assembly tines directly hit the ground. After the machine began to work and had harvested about 3 or 4 m width, this cut crop then was taken out of the headlands so as to facilitate turning of the reaper.

For the tests to determine optimum gear combination on the basis of grain losses incurred, the reaper was driven for a total of 15 effective passes along the width of each test-plot (50 m x 40.5 m). There were 5 replication for each gear combination, each performed randomly over the test area.

The field capacity tests were performed in two different plots but of equal size and shape i e, 43 m x 23 m, at two different harvesting dates (at maturity and 8 days after maturity). In the first test gear combination I was used, and gear combination II was selected for the 2nd test. Field performance of the reaper was directly compared with the conventional method (manual harvesting using sickle) in terms of field grain losses, labour requirement and economics of operation. Only the normal planting density (20 cm x 20 cm) was selected for these tests. A total of 94 different tests were performed.

For each harvesting test, different field grain losses i e, pre-harvest, uncut, shattering, cutterbar, conveying (windrowing) and gathering/bundling were measured (1). Cutterbar losses were defined to be the sum of the uncut and shattering losses minus the pre-harvest

loss. Total machine loss was defined to be the sum of the cutterbar and conveying losses. Total harvesting loss was defined to be the sum of the total machine and gathering/ bundling losses. All the crop samples collected during experimentation were threshed manually in the laboratory under closely controlled conditions to avoid threshing loss.

For the field capacity tests, the harvested area was measured. For the case of manual harvesting only the total time to harvest the specified area was recorded, but for machine reaping, individual times lost due to clearing/clogging, adjustments and repairs were also taken into account.

Results and Discussion

The data collected during field-tests was analyzed for the reaper performance in terms of field grain loss occurrence, using a computer. The results obtained were analyzed using the statistical t-test for comparison of two groups by making use of the computer program package BMDP-3D (6).

Reaper Performance at Harvest

Performance of the reaper was evaluated by reaping the normal density crop at maturity, 7 days after and 14 days after normal crop maturity period.

The effects of date of harvesting and gear combination on machine performance are shown in **Figs. 2A and 2B**. These experiments were all carried out in transplanted plots with a plant spacing of 20 cm x 20 cm. **Fig. 2A** shows that total machine loss increased regularly as harvesting date was delayed further. Gear combination I always had higher losses than the other gear combinations and this was mostly due to a higher percentage of uncut loss. Because of the low cutterbar speed the machine had a tendency to "ride over" the crop without cutting it in several parts of the field. This was completely remedied by changing to high cutterbar speed (combinations II and III). Shattering and conveying losses were of similar magnitude. Both increased regularly as harvesting date was delayed further and both were similar for each gear combination, ranging from about 1% at maturity to about 3% at 14 days after maturity.

Gathering and bundling losses ranged from about 1% at maturity to about 2% at 14 days after maturity and the total harvesting loss for each gear combination is shown in **Fig. 2B**. The conclusions which can be drawn from **Fig. 2B** are that, in order to avoid unacceptably high harvesting losses, the crop must be harvested at maturity and the high cutterbar speed must always be used. When these conditions were met the total harvesting loss was about 3% which is quite acceptable for a shatter-prone variety such as RD-7.

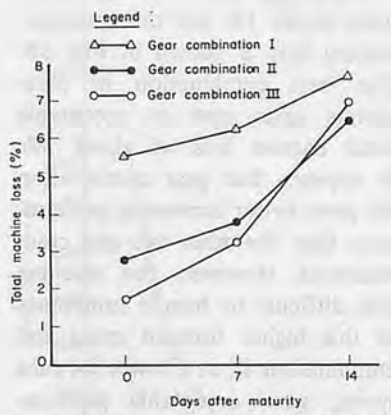


Fig. 2A Total machine loss and time of harvest

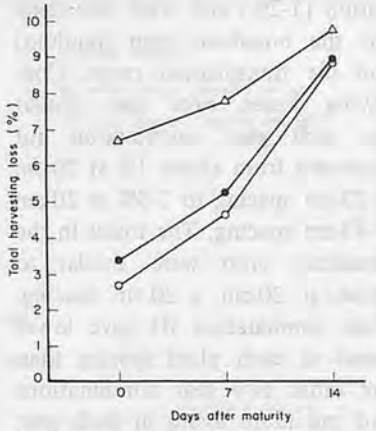


Fig. 2B Total harvesting loss and time of harvest

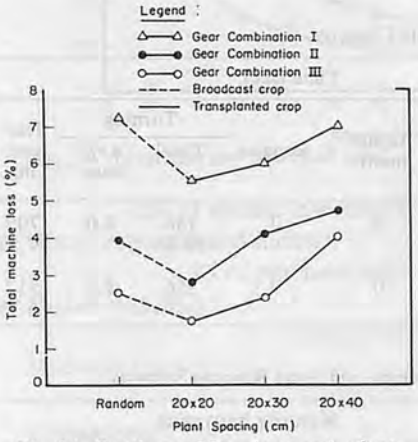


Fig. 3A Total machine loss and plant spacing

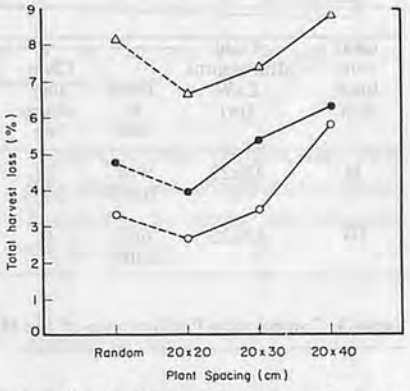


Fig. 3B Total harvesting loss and plant spacing

Effect of Crop Density and Planting System

The effects of crop density, planting system and gear combination on machine performance are shown in **Figs. 3A and 3B**. These experiments were all carried out when the crop was at maturity. **Fig. 3A** shows that gear combination I again gave much higher losses than the other two gear combinations and this was again mainly due to a higher percentage of uncut loss. Shattering losses were similar for each gear combi-

nation (1-2%) and were the same for the broadcast crop (random) and the transplanted crops. Conveying losses were also similar for each gear combination but increased from about 1% at 20 cm x 20 cm spacing to 2-3% at 20 cm x 40 cm spacing. The losses in the broadcast crop were similar to those at 20 cm x 20 cm spacing. Gear combination III gave lower losses at each plant spacing than the other two gear combinations and minimum losses in each gear combination always occurred at 20 cm x 20 cm spacing.

Gathering and bundling losses were about 1% and the total harvesting loss is shown in **Fig. 3B**. The best combination of parameters again gave an acceptable total harvest loss of about 3%. It appears that gear combination III gives better harvesting performance than the other two gear combinations. However, the machine was difficult to handle sometimes at this higher forward speed and combination II, at a lower forward speed, gave acceptable performance. In order to minimize harvesting losses with this machine, therefore, gear combinations II or III should be used and the crop should either be broadcast or transplanted at 20 cm x 20 cm spacing or less

Comparison between Machine Reaping and Hand Reaping Systems

Table 2 shows the speed, field capacity and efficiency of the reaper when operating with two gear combinations i e, II & III, for harvesting the normal density crop (20 x 20 cm).

In a rectangular field of 43 m x 23 m the machine had a field efficiency of 76% and an effective field capacity of 0.43 ha/h when used with gear combination II. With gear combination III these figures became 70% and 0.47 ha/h respectively.

Table 3 gives the comparative performance of the machine and hand reaping systems at two dates of harvesting. The total harvesting loss was significantly less with the hand reaping system

Table 2 Various Times in Harvesting, and Field Capacity

Gear combination	Field dimensions LxW (m)	Time (sec)							Travel speed (km/h)	Field capacity (ha/h)		Field eff. (%)
		Total in field	Clearing/ clogging	Adjustments	Repairs	Turning Total	Turning Avg/ turn	Harvesting		Theo.	Effec.	
II	43x23	915 100%	20 2.2%	0	0	186 20.3%	6.0	709 77.5%	3.6	0.57	0.43	76
III	43x23	668 100%	0	0	0	156 23.3%	5.2	512 76.7%	4.2	0.67	0.47	70

Table 3 Comparative Performance of the Machine and Hand Reaping Systems

Field grain losses (%)	Maturity harvesting			8 days delayed harvesting		
	Machine reaping gear combination II	(t-value)	Hand reaping	Machine reaping gear combination III	(t-value)	Hand reaping
Uncut	0.5	(3.70)	0.0	0.3	(2.52)	0.0
Cutterbar (sickle)*	1.8	(1.37)	1.4	1.5	(−1.64)	2.0
Conveying (dropping)	1.2	(4.68)	0.8	1.6	(3.09)	1.1
Gathering and bundling (bundling)	1.1	(2.97)	0.7	1.6	(2.01)	1.2
Total harvesting	4.1	(3.16)	2.9	4.7	(1.17)	4.3

* Names in parentheses refer to the comparable losses incurred with the hand reaping system
** t-values at 18 degrees of freedom: – level of significance (%), t-values; 10%/1.73, 5%/2.10, 1%/2.88, 0.1%/3.92.

Table 4 Labour Requirement for Rice Harvesting by Machine and Hand Reaping Systems

System of crop reaping	Labour requirement (man-h/ha)		
	Trial 1	Trial 2	Average
Machine harvesting			
a) Reaping	7.1	6.0	6.5
b) Gathering, bundling and transporting crop to one corner of the field	28.3	29.8	29.1
Total	35.4	35.8	35.6
Hand harvesting			
a) Reaping	139.5	105.7	122.6
b) Gathering, bundling and transporting to one corner of the field	17.9	11.5	14.7
Total	157.4	117.2	137.3

at maturity harvest but not for 8 days delayed harvest. The harvesting loss increased significantly as harvesting was delayed with hand reaping but the effect of delayed harvesting on machine reaping was partly offset by using the more efficient gear combination III. At both harvesting dates, losses with machine reaping were of the same order as those with hand reaping which is a very encouraging result.

Table 4 gives the labour requirement for harvesting 1 ha of rice using the two reaping systems. Two persons were engaged for the machine reaping (one of them performed supplementary field operations). The operational labour requirement in the case of machine reaping was inclusive of the labour required to carry out the preliminary hand harvesting needed in the field. For the hand reaping, three women labourers were employed. It can be seen from Table 4 that the labour requirement for machine reaping was only 5% of that required for hand reaping. However, longer time was required for gathering, bundling and transporting the machine cut crop and the total harvesting labour requirement for machine harvesting was 26% of that required for hand harvesting.

The costs of operation for each reaping system were estimated based on the following information. These figures are representative figures for Thailand in 1982:

Tiller cost with engine:
(US) $1,175

Header cost:
$ 435

Useful life of the power tiller:
8 years
6000 h (750 h/year)

Useful life of the header:
7 years
2100 h (300 h/year)

Salvage value:
10% of the purchase price

Annual interest rate:
15% of average investment

Taxes, insurance and shelter:
3% of purchase price

Labour wage rate:
$3.00/8 h

Fuel cost (diesel):
$0.32/l

Lubrication:
20% of fuel cost

Repair & maintenance cost:

a) for power tiller:
1% of purchase price/100 h

b) for header:
7% of purchase price/100 h

Estimated costs of the reaper were determined at its optimum operating conditions, i.e., field capacity, 0.45 ha/h; labour requirement, 6.5 man-h/ha; and fuel consumption, 3.3 l/ha.

The relationship between the total cost per ha and annual harvested area is shown in Fig. 4. For single cropping, the break-even area for machine use in Thailand is 8.6 ha, and for double-cropping 4.3 ha. Given that the average farm size in Thailand is 3.2 ha (7) it appears that this machine could profitably be used by a farmer reaping his own crop and performing a contracting operation for his neighbours. Total time required to reap 8.6 ha is only 19 h. Therefore, the prospects for timely harvesting by using the machine are very good.

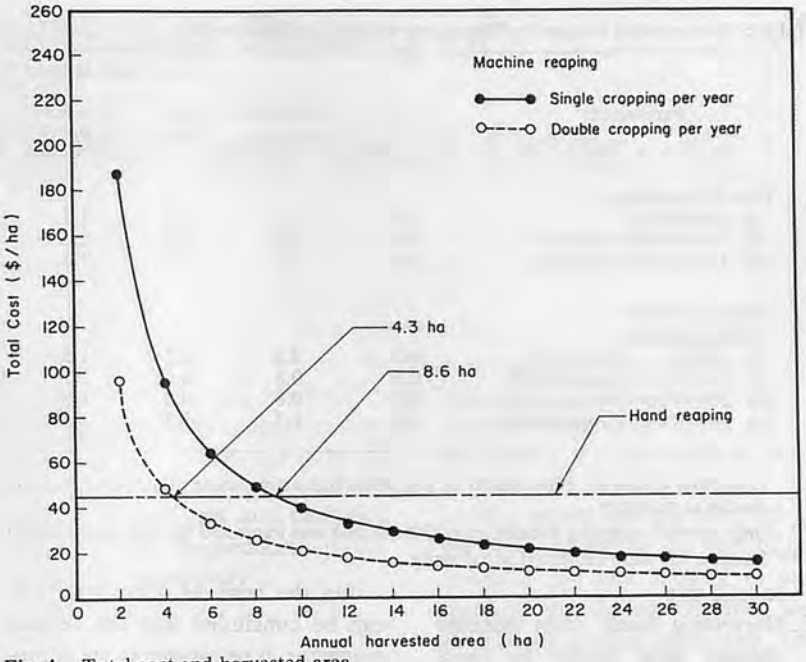


Fig. 4 Total cost and harvested area

Conclusions

1. Optimum machine performance was obtained with gear combination III. This not only minimized the harvesting losses but also maximized the work rate. Table 5 summarises the reaper performance in terms of field grain losses using gear combination III.
2. Harvesting losses increased rapidly as harvesting date was delayed.
3. Harvesting losses were lowest with a broadcast crop and a transplanted crop with 20 cm x 20 cm spacing. Increasing the plant spacing increased the harvesting losses.
4. The effective field capacity of the reaper was 0.43 ha/h using gear combination II and 0.47 ha/h when operating in gear combination III, with 76% and 70% field efficiencies respectively, in two similar fields (43

Table 5 Summarized Reaper Performance for Gear Combination III

Parameters	Grain losses as percent of total product*							Crop yield (t/ha)
	Uncut	Machine shatter	Cutter-bar	Convey-ing	Total machine	Gather/ bundle	Total harvest	
Time of harvesting; **								
i) at maturity	0.0	0.6	0.6	1.1	1.7	1.0	2.7	2.9
ii) 7 days after maturity	0.0	1.4	1.4	2.0	3.4	1.4	4.8	3.1
iii) 14 days after maturity	0.0	3.3	3.3	3.8	7.1	1.9	9.0	2.1
Cropping density; *** (plant spacing)								
i) random (broadcast)	0.3	0.9	1.2	1.3	2.5	0.9	3.3	4.4
ii) 20x20 cm (transplanted)	0.0	0.6	0.6	1.1	1.7	1.0	2.7	2.9
iii) 20x30 cm (transplanted)	0.0	0.8	0.8	1.6	2.4	1.1	3.5	2.1
iv) 20x40 cm (transplanted)	0.0	1.3	1.3	2.8	4.1	1.8	5.9	2.0

* These loss values are expected to be less when harvesting some other variety, as the variety harvested (RD-7) was susceptible to shatter at maturity.

** Only normal cropping density crop (20x20 cm) was harvested for this part of research.

*** These crops were harvested at maturity.

m x 23 m).

5. Harvesting losses from machine reaping were similar to those from hand reaping the same crop.
6. Reaping by machine required only 6.5 man-h/ha compared to 122.6 man-h/ha required for hand-reaping. The machine-reaped crop, however, required more time for gathering, bundling and transporting than did the hand-reaped crop. The total labour requirement for machine harvesting was 35.6 man-h/ha compared to 137.3 man-h/ha for hand harvesting.
7. At the present wage levels in Thailand, machine reaping has a break-even area of 8.6 ha and 4.3 ha for single and double cropping per year, respectively. Keeping in mind that the average farm holding in Thailand is 3.2 ha it appears that the machine could profitably be used in Thailand either by a farmer owner/contractor or by contractor alone.

On the basis of these results, it can be concluded that the vertical conveyor type reaper is an appropriate machine suitable for the farming conditions of Thailand and could, therefore, be adopted by Thai farmers to minimize harvesting costs, improve timeliness and overcome labour shortages at the peak demand period of harvesting. It seems likely that machine reapers of this kind could be useful in many other Asian countries in addition to Thailand.

REFERENCES

1. Amjad, Nadeem (1982), Field Performance Evaluation of a Cereal Reaper, M. Engg. Thesis, Asian Institute of Technology, Bangkok.
2. Stout, B.A., (1966), Equipment for Rice Production, United Nations Food and Agriculture Organization, Agricultural Development Paper No. 84.
3. Samson, B. and Duff, B. (1973), The pattern and magnitude of field grain losses in paddy production, International Rice Research Institute Saturday Seminar Paper, July 7.
4. United Nations Food and Agricultural Organization (1976), Mechanization of Rice Production: India-Nigeria-Senegal, An Industrial Coordinated Research Project (1970-76).
5. Khan, A.U. (1971), Harvesting and threshing of paddy, Paper presented at the International Rice Research Conference, held at International Rice Research Institute (IRRI), Los Banos, Philippines (IRRI Paper No. 71-05), April 19-21.
6. University of California at Los Angeles (1978), Biomedical Computer Program (BMDP)-P series, School of Medicine, Department of Biomathematics.
7. Boonit, Anusorn (1971), The present and future agricultural mechanization in Thailand, Agricultural Mechanization in Asia. Vol. I, 113-117. ■■

Development and Testing of a Simple Baffle Type Grain Dryer

by
A. Chakraverty
Assistant Professor
Post Harvest Technology Centre, I.I.T.
Kharagpur, India

H.G. More
Scientist
C.I.A.E., Bhopal
M.P., India

Abstract

A simple baffle type grain dryer of 100 kg holding capacity has been developed and tested at the Post Harvest Technology Centre, I.I.T., Kharagpur, India. The dryer was tested with both raw and parboiled paddy. The average heating efficiencies, namely, heat utilization factor (H.U.F.) and total heat efficiency (T.H.E.) were 0.84 and 0.72, respectively. The head yields obtained from the raw and parboiled paddy dried continuously in the baffle dryer corresponding to 60° and 70°C air temperatures were 46% and 67.5%, respectively. The head yields of the control raw and paddy samples were 52.8 and 72.8%, respectively. The drying performance of the dryer was found to be good.

Introduction

Inspite of its popularity in India, the L.S.U. dryer, it is reported, fails to produce uniformly dried parboiled paddy of high quality in many cases. In view of this, an attempt was made to develop a simple baffle dryer for uniform drying of grains. The major objectives of this study were: i) To design and fabricate a simple baffle type dryer of 100 kg holding capacity and (ii) to test the performance of the dryer with raw and parboiled paddy at air temperature of 60° and 70°C, respectively.

Materials and Methods

The baffle dryer designed at PHTC consists of three sections, namely; over head storage bin, drying chamber fitted with baffles and discharging hopper. Details of the dryer are shown in Fig. 1.

The paddy sample was fed to the dryer up to the top level of the overhead bin and allowed to pass through the drying chamber and discharging hopper by gravity. The grain came in contact with a cross flow of hot air and was mixed while flowing down through the drying chamber in a zig-zag path. The grain was recirculated until its moisture content was brought to the desired level.

A sample of 100 kg clean Jaya

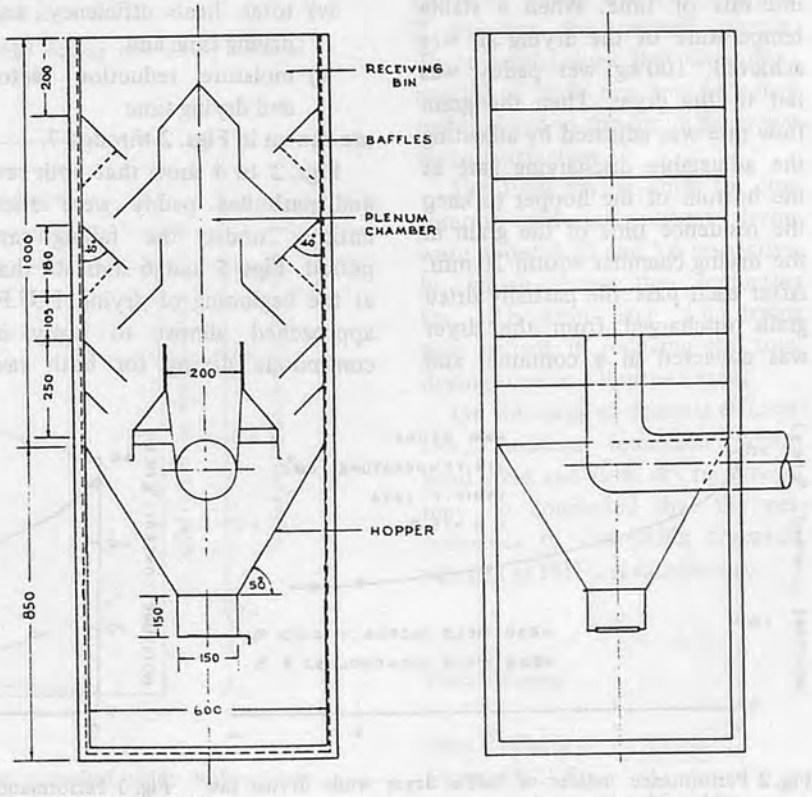


Fig. 1 Baffle type dryer.

variety of raw paddy was spread uniformly on the ground and subjected to a spray of water for sometime by means of a sprayer. During spraying the sample was intermittently stirred for thorough mixing. Then the sample in thin layer was kept for about 16 h to equilibrate moisture throughout the grain kernel.

The moisture content of paddy was raised to about 22%. The wet paddy was then steamed for 5 min at a pressure of 2 kg/cm^2.

Moisture contents of the samples were measured by both universal moisture meter and oven drying method.

To determine the performance of the baffle dryer, a number of drying tests were conducted with the baffle dryer for raw and parboiled paddy at air temperature of 60° and 70°C, respectively. A minimum air flow rate of 6 m^3/min was maintained for all experiments. The dry bulb and the wet bulb temperatures of drying air and exhaust air was noted at regular intervals of time. When a stable temperature of the drying air was achieved, 100 kg wet paddy was fed to the dryer. Then the grain flow rate was adjusted by adjusting the adjustable discharging gate at the bottom of the hopper to keep the residence time of the grain in the drying chamber within 20 min. After each pass, the partially dried grain discharged from the dryer was collected in a container and recirculated to the overhead bin of the dryer manually. The recirculation of grain was continued until the samples were dried to the desired moisture level.

Few samples were dried continuously by continuous circulation of paddy to the dryer till they were dried to 14% moisture content. Other samples were dried to the same moisture content in a few passes by circulating them in the dryer for one hour in each pass and then tempered for about 12 h after each pass.

There were two replications of each experiment at any temperature level.

Results and Discussion

The relationships, namely;

i) moisture content and drying time;
ii) heat utilisation factor and drying time;
iii) coefficient of performance and drying time;
iv) total heat efficiency and drying time and
v) moisture reduction factor and drying time

are shown in **Figs.** 2 through 7.

Figs. 2 to 4 show that both raw and parboiled paddy were dried entirely under the falling rate period. **Figs.** 5 and 6 indicate that at the beginning of drying, H.U.F. approached almost to unity in continuous drying for both raw and parboiled paddy. Subsequently H.U.F. fell gradually. The amount of heat supplied to the drying air was constant for the whole drying experiment, but the amount of heat utilised decreased as exhaust air temperature was increased with the progress of drying time. Some amount of heat was used for heating the grain and a considerable amount of heat was lost with the exhaust air also. This may be the reason for falling of H.U.F. with the progress of drying time. For intermittent drying the H.U.F. was almost unity at the beginning of the first pass and then decreased gradually as time elapsed. But H.U.F. was always augmented at the beginning of the subsequent passes due to the effects of tempering after each pass. The average H.U.F. for the baffle dryer was found to be 0.84 which indicated its very high heat utilisation efficiency.

Coefficient of performance (C.O.P.) vs drying time are plotted in **Figs. 5** to 7. The C.O.P. started with a small value and then increased gradually. The small value of C.O.P. at the beginning of drying was due to the fact that the exhaust air temperature became almost equal to the ambient air temperature. The average value of C.O.P. for the baffle dryer was about 0.15 which revealed high efficiency of the dryer.

The total heat efficiency decreased with the progress of drying

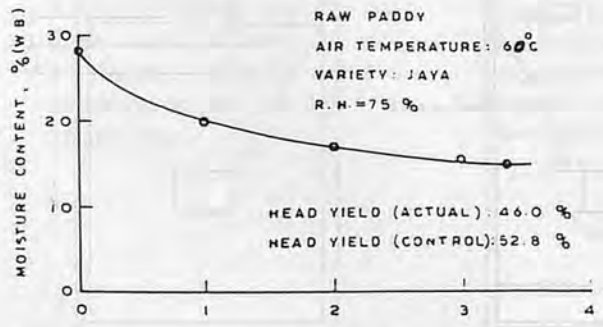


Fig. 2 Performance indices of baffle dryer while drying raw paddy without tempering.

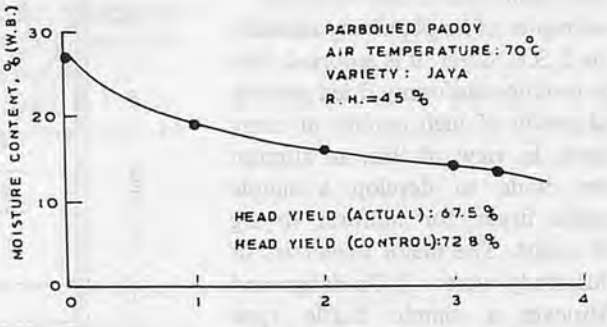


Fig. 3 Performance indices of baffle dryer with parboiled paddy without tempering.

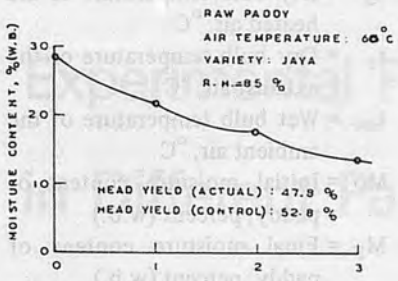


Fig. 4 Performance indices of baffle dryer while drying raw paddy with tempering.

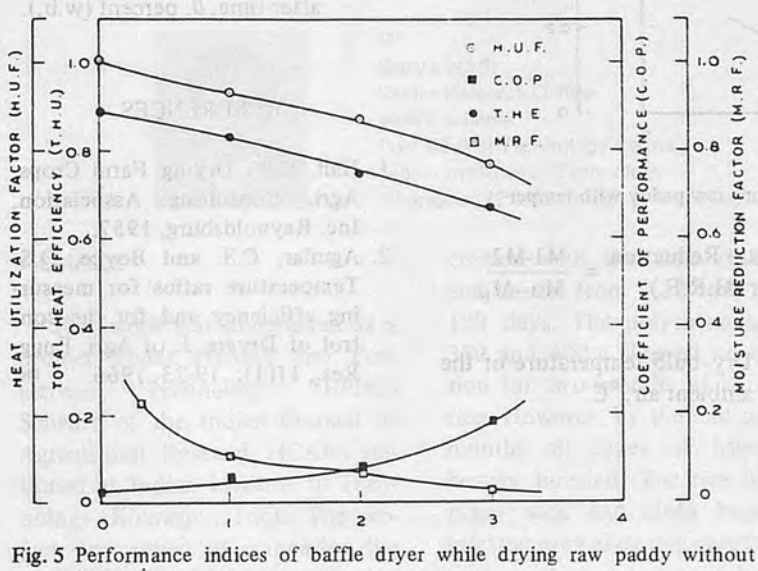


Fig. 5 Performance indices of baffle dryer while drying raw paddy without tempering

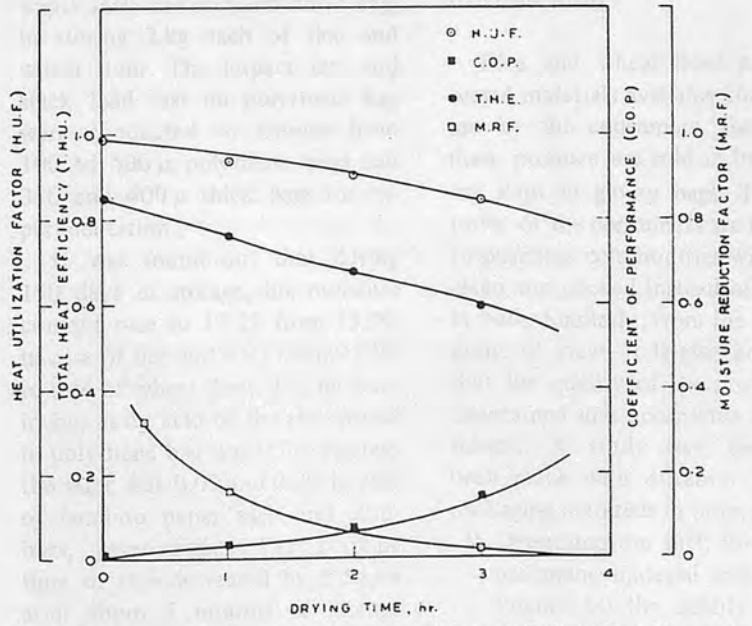


Fig. 6 Performance indices of baffle dryer with parboiled paddy without tempering.

time. By defination, T.H.E. is always smaller than H.U.F. at any time. The average value of T.H.E. for baffle dryer was found to be 0.72 which was quite high indicating higher efficiency.

Figs. 5 and 6 show that in continuous drying, moisture reduction factor (M.R.F.) decreased with the increase of drying time. In intermittent drying (Fig. 7), tempering for 12 h had significant effect on M.R.F. The values of M.R.F. were always augmented by tempering after each drying pass. The decreasing trend in M.R.F. is due to the decreasing moisture gradient between the centre and surface of the grain. The average M.R.F. for the baffle dryer was found to be 0.16 which was quite satisfactory. It indicates higher efficiency of drying.

As regards the milling quality of the samples, head yields obtained from continuous and intermittent drying of raw paddy at 60°C are 46% and 47.8% against 52.8% for the control sample. Head yield obtained from continuous drying of parboiled paddy was 67.5% against 72.8% for the control sample. These results show that the milling quality of both raw and parboiled paddy dried in the baffle dryer was quite satisfactory.

The total drying times for continuous and intermittent drying were about 3.25 and 3 h respectively, which shows that tempering for 12 h after each 1 h drying pass helped in reducing the total drying time to a limited extent.

On the basis of thermal efficiencies, moisture reduction factor, head yield and total drying time, it may be concluded that the performance of the baffle dryer developed at PHTC is satisfactory.

Definitions

$$\text{Heat Utilisation Factor (H.U.F.)} = \frac{t_d - t_e}{t_d - t_a}$$

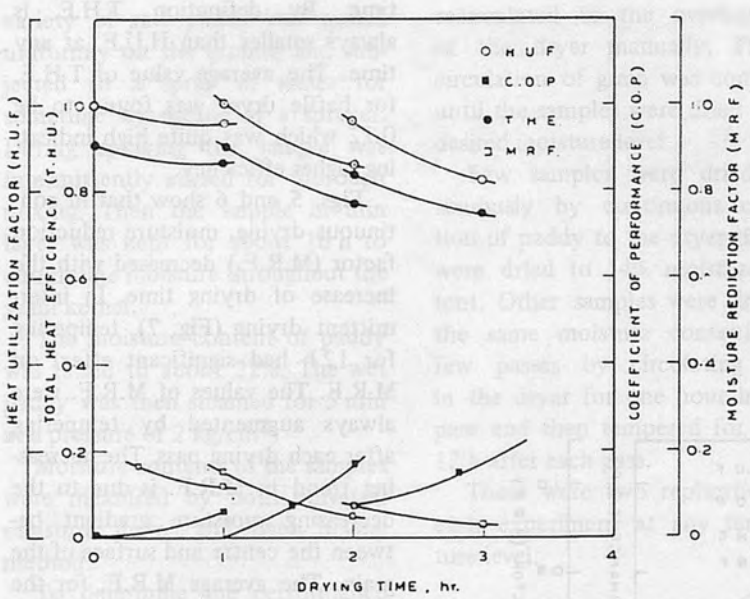


Fig. 7 Performance indices of baffle dryer while drying raw paddy with tempering.

Coefficient of performance (C.O.P.) $= \frac{t_e - t_a}{t_d - t_a}$

Total Heat Efficiency (T.H.E) $= \frac{t_d - t_e}{t_d - t_{aw}}$

Moisture Reduction Factor (M.R.F.) $= \frac{M1\text{-}M2}{Mo - M_F}$

Where

t_a = Dry bulb temperature of the ambient air, °C

t_d = Dry bulb temperature of the heated air, °C

t_e = Dry bulb temperature of the exhaust air, °C

t_{aw} = Wet bulb temperature of the ambient air, °C

Mo = Initial moisture content of paddy, percent (w.b.)

M_F = Final moisture content of paddy, percent (w.b.)

M1 = Moisture content of paddy before time, θ, percent (w.b.)

M2 = Moisture content of paddy after time, θ, percent (w.b.).

REFERENCES

1. Hall, C.W. Drying Farm Crops. Agri. Consulting Association, Inc. Reynoldsburg, 1957.
2. Aguilar, C.S. and Boyce, D.S. Temperature ratios for measuring efficiency and for the control of Dryers. J. of Agri. Engg. Res., 11(1): 19-23, 1966. ■■

Experimental Results on Stored Food Products in Different Packaging Materials



by
Surya Nath
Senior Research Officer
HPHT Scheme
Post Harvest Technology Centre
Indian Institute of Technology
Kharagpur 721302, India

A.K. Ganguly
Senior Research Assistant
HPHT Scheme
Post Harvest Technology Centre
Indian Institute of Technology
Kharagpur 731302, India

Abstract

This work was undertaken as a project under Harvest and Post Harvest Technology (HPHT) Scheme of the Indian Council of Agricultural Research (ICAR) stationed at Indian Institute of Technology, Kharagpur, India. The project was aimed at comparing the performance of three packaging materials: polythene bag, bamboo paper sack and markeen cloth bags in storing 2 kg each of rice and wheat flour. The impact test and stack load test on polythene bag were conducted to choose from 100 to 400 μ polythene bags and 350 and 400 μ thick bags for experimentation.

It was found out that during 150 days of storage, the moisture content rose to 13.21 from 13.0% in case of rice and 9.92 from 9.81% in case of wheat flour. The increase in free fatty acid of the rice stored in polythene bag was 0.3% whereas the same was 0.09 and 0.2% in case of bamboo paper sack and cloth bags, respectively. The cooking time of rice decreased by 1.5 min after about 5 months of storage irrespective of type of bags used. Similarly, the swelling index increased with the time of storage and varied from 0.32 to 0.5 after 120 days. The polythene bags of 350 and 400 μ showed no infestation for two months of storage of rice. However, by the end of three months all types of bags were heavily infested. The rice filled in paper sack and cloth bags were infested even after one month.

Introduction

Rice and wheat flour are processed materials available for direct use by the consumers. Generally, these produce are sold in bulk and are kept in gunny bags. The majority of the consumers are inclined to purchase commodities which are clean and packed instead of buying in bulk. Similarly, from the traders' point of view, it is also necessary that the quality of the product be maintained and acceptable to consumers. A study has, therefore, been made with different type of packaging materials in order to:

i) Determine the shelf life of the packaging material and its influence on the quality of the commodity under room temperature, and
ii) Find the economics of the use of the packaging materials.

In the study rice and wheat flour were stored in polythene bags, bamboo paper sacks and markeen cloth bags. The polythene bags were available in different sizes and thickness and, hence, an impact test and stack load test were performed in order to select the most suitable materials. Observations were made on the different aspects of the bag materials and quality of stored products every 15 days during the storage period of 150 days. It was found out that polythlene bags (400 μ) are most suited both for wheat flour and rice storage. Bamboo paper sacks are not suited for any of the product beyond 30 days. However, cloth bags could be used for up to 90 days depending on cleanliness of the storage space.

Experimental Procedure

Quality Tests of Polyethylene Bags

These bags with thickness ranging from 100 μ to 400 μ were chosen for suitability tests. An impact test and stack load test judged

Table 1 Bursting Point of Different Thickness of Bags

Polythene bags	Number of Drops				
	1	2	3	4	5
100 microns	*	–	–	–	–
150 "	*	–	–	–	–
200 "	**	*	–	–	–
250 "	**	**	*	–	–
300 "	**	**	**	**	*
350 "	**	**	**	**	**
400 "	**	**	**	**	**

* Bag bursts. ** Bag remains intact.

Table 2 Rupture Point of Different Thickness of Bag

Polythene bags	Load (kg)				
	10	15	20	25	30
100 microns	**	**	*	–	–
150 "	**	**	*	–	–
200 "	**	**	**	*	–
250 "	**	**	**	**	*
300 "	**	**	**	**	*
350 "	**	**	**	**	**
400 "	**	**	**	**	**

* Bag ruptures ** Bag remains intact

the quality of a particular gauge bag for packaging the products.

Impact test – Ten bags with thickness 100, 150, 200, 250, 300, 350 and 400 μ were taken for test. The bags were filled in the usual way with rice and wheat flour and then sealed. Each bag was dropped 5 times on plane cemented floor from a height of 1.25 m and the bursting of the bag was noted.

Table 1 shows that 350 μ and 400 μ thick polythene bags withstood even 5 drops from a height of 1.25 m. Hence these were chosen for the study.

Stack load test – Ten bags with thickness 100, 150, 200, 250, 300, 350 and 400 μ were filled with raw rice and wheat flour and sealed. Each bag was placed on a smooth plate. On the top surface of the bag, another smooth plate was placed. It was then loaded with 10, 15, 20, 25 and 30 kg dead load and the rupture of the bag was noted.

Table 2 shows that all the bags, excepting the 350 and 400 microns thickness, failed below 30 kg stack load. Hence, the 350 and 400 microns size bags were selected for the experiment.

Storage of Rice and Wheat Flour

Two kg of rice and wheat flour were stored in polythene bags, bamboo paper sack and markeen cloth bag for 150 days. All bags were properly sealed after filling. The bags were kept on a wooden table. The place of storage and the bags were disinfected before storage. The samples were drawn from the bags for quality test at an interval of 15 days. All the bags were thrice replicated. The bags were immediately sealed after the samples were drawn out. The following observations were taken and are presented in a tabular form:

i) Moisture content of the stored product commodity – oven dry method was used to find the moisture contents.
ii) Temperature of the commodity in the bag, °C – dial type thermometer was used.
iii) Damage to packaging materials by insects.
iv) Insect infestation.
v) Cooking quality of rice (cooking time and swelling

Table 3 Moisture Content of Rice during Storage Period

No. of days	Polythene Bags		Bamboo paper sack	Markeen cloth bag
	350 μ	400 μ		
0	13.00	13.00	13.00	13.00
15	13.00	13.00	13.14	13.21
30	13.00	13.00	13.22	13.31
45	13.10	13.00	13.28	13.52
60	13.10	13.10	13.56	13.75
75	13.10	13.10	13.87	13.92
90	13.08	13.10	14.23	14.24
105	13.13	13.11	14.28	14.46
120	13.16	13.12	14.31	14.61
135	13.17	13.16	14.42	14.74
150	13.21	13.21	14.60	14.80

Table 4 Temperature of Rice inside the Bag during Storage Period

No. of days	Polythene Bags		Bamboo paper sack	Markeen cloth bag
	350 μ	400 μ		
0	30.8	30.8	30.8	30.8
15	30.8	30.8	30.7	30.9
30	31.0	31.0	31.0	31.0
45	31.1	31.1	31.2	31.2
60	31.1	31.1	31.1	31.1
75	31.0	31.0	31.1	31.1
90	30.6	30.7	30.7	30.8
105	31.7	31.5	31.6	31.8
120	31.8	31.8	31.8	31.7
135	31.5	31.7	31.7	31.6

Table 5 Moisture Content of Wheat Flour during Storage Period

No. of days	Polythene Bags		Bamboo paper sack	Markeen cloth bag
	350 μ	400 μ		
0	9.81	9.81	9.81	9.81
15	9.81	9.81	10.06	10.31
30	9.82	9.82	10.62	10.87
45	9.82	9.82	10.81	11.22
60	9.84	9.83	11.31	11.68
75	9.85	9.84	11.66	11.87
90	9.85	9.85	12.46	12.87
105	9.86	9.85	***	***
120	9.86	9.86	–	–
135	9.90	9.91	–	–
150	9.91	9.92	–	–
165	9.91	9.92	–	–
180	9.92	9.94	–	–

*** Experimentation stopped due to spoilage.

index)

In order to cook rice, water-bath technique was used maintaining a temperature of 99±1°C, whereas the initial temperature of water added to the rice was about 80°C.

vi) Free fatty acid (FFA) development was determined by the solvent-extraction method and used the INCU SHAKER.

Results and Discussions

Moisture Content

Tables 3 and 5 show the moisture content during the storage period with very little variation in both rice and wheat flour for the polythene bags: 0.21 and 0.11%, respectively. The polythene is highly moisture proof. For rice, the moisture rise was about 1.6 and 1.8%, respectively, for bamboo-paper sack and markeen cloth bag. The rise of moisture in the case of the flour was 2.65 and 3.06 respectively, for the bamboo paper sack and cloth bag. The rise in moisture content was due to rise in humidity of the atmosphere in the rainy season. Bamboo paper cloth bag being less impervious to moisture, moisture migration was eminent. The rise was little higher in case of wheat flour compared to rice, since wheat flour is more hygroscopic than rice. The condition of the rice and wheat flour in different packag-

Table 6 Temperature of Wheat Flour inside the Bag during Storage Period

No. of days	Polythene Bags		Bamboo paper sack	Markeen cloth bag
	350 μ	400 μ		
0	30.8	30.8	30.8	30.8
15	30.7	30.8	30.9	30.8
30	31.0	31.0	31.1	31.1
45	31.1	31.0	31.0	31.0
60	31.1	31.2	31.1	31.1
75	31.0	31.0	31.1	31.0
90	30.8	30.9	31.0	30.9
105	31.6	31.5	***	***
120	31.8	31.7	–	–
135	31.6	31.6	–	–
150	31.6	31.5	–	–
165	31.5	31.4	–	–
180	31.5	31.5	–	–

***: Experimentation stopped due to spoilage.

Table 7 Free Fatty Acid of Rice During Storage Period

No. of days	Polythene Bags		Bamboo paper sack	Markeen cloth bag
	350 μ	400 μ		
0	0.32	0.32	0.32	0.32
15	0.32	0.32	0.33	0.34
30	0.33	0.32	0.34	0.36
45	0.33	0.33	0.35	0.37
60	0.36	0.37	0.41	0.42
75	0.41	0.40	***	0.42
90	0.43	0.42	–	0.43
105	0.46	0.47	–	0.46
120	0.51	0.51	–	0.52
135	0.56	0.57	–	0.52
150	0.58	0.58	–	***
165	0.58	0.59	–	–
180	0.62	0.61	–	–

***: Experimentation stopped due to spoilage

Table 8 Free Fatty Acid of Wheat Flour During Storage Period

No. of days	Polythene Bags		Bamboo paper sack	Markeen cloth bag
	350 μ	400 μ		
0	1.12	1.12	1.12	1.12
15	1.15	1.17	2.87	3.92
30	1.67	1.68	3.62	5.69
45	1.79	1.76	8.75	8.86
60	1.82	1.81	10.91	9.82
75	2.17	2.38	***	11.16
90	2.31	2.46	–	13.25
105	3.74	2.75	–	15.62
120	4.61	3.01	–	***
135	8.62	8.91	–	–
150	12.62	11.52	–	–
165	13.19	13.22	–	–
180	14.21	14.17	–	–

***: Experimentation stopped due to spoilage



Fig. 1 Storage of raw rice in different type of bags.



Fig. 2 Storage of wheat flour in different type of bags.

ing materials are shown in Figs. 1 and 2.

Temperature Variation

The temperature variations inside the bag of all types was not very significant as it was more or less equal to the atmospheric temperature.

Free Fatty Acid

Tables 7 and 8 show that the FFA increased with the storage time. For rice stored in polythene sack, the increase was 0.3% in bamboo paper sack 0.09% and in cloth bags, 0.2%. This was, of course, dependent upon the storage period. The increase in FFA may be due to the deterioration of the bran layer present on the surface of the rice grain as well as insect and fungal activities that developed during the storage period. The increase in FFA for the wheat flour stored in polythene sack was 13.09% (after 180 days), 0.79% (after 60

Table 9 Cooking Time of Rice with Storage Period (unit: min.)

No. of days	Polythene Bag 350 μ	Polythene Bag 400 μ	Bamboo paper bag	Markeen cloth bag
0	26.51	26.53	26.51	26.52
15	26.41	26.41	26.39	26.41
30	26.21	26.19	26.21	26.31
45	25.76	25.74	25.82	25.76
60	25.21	25.20	25.47	25.31
75	25.17	25.16	***	25.21
90	25.10	25.16	–	25.15
105	25.06	25.00	–	25.12
120	25.06	25.06	–	25.11
135	***	25.00	–	25.08
150	–	25.01	–	25.07
165	–	***	–	***
180	–	–	–	–

***: Experimentation stopped due to spoilage

Table 10 Swelling Index of Riee with Storage Period

No. of days	Polythene Bag 350 μ	Polythene Bag 400 μ	Bamboo paper bag	Markeen cloth bag
0	3.16	3.16	3.17	3.16
15	3.26	3.28	3.29	3.31
30	3.35	3.35	3.34	3.34
45	3.38	3.37	3.38	3.39
60	3.41	3.42	3.41	3.41
75	3.42	3.43	***	3.41
90	3.44	3.46	–	3.43
105	3.46	3.49	–	3.45
120	3.48	3.52	–	3.47
135	***	3.64	–	3.58
150	–	3.74	–	3.72
165	–	***	–	***
180	–	–	–	–

***: Experimentation stopped due to spoilage

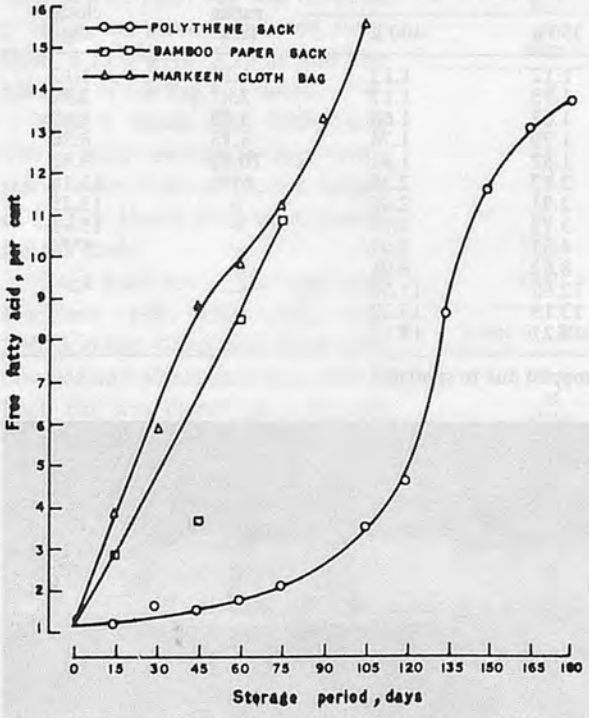


Fig. 3 Variation in FFA of raw rice with storage period for different packaging material.

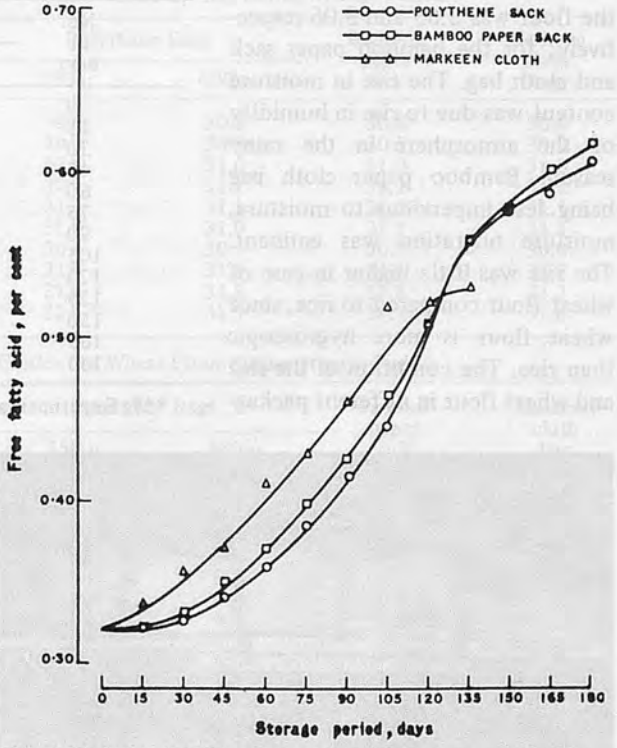


Fig. 4 Variation in FFA of wheat flour with storage period for different packaging materials.

Table 11 Rate of Infestation and Condition of Bag with Storage Period and Cost of Packaging Material per Quintal of Storage

Days of storage	Packaging Materials			
	Polythene bag		Bamboo paper bag	Markeen cloth bag
	350 μ	400 μ		
Rice				
0	No infestation	No infestation	No infestation	No infestation
30	No infestation	No infestation	Moderate to little heavy infestation	No infestation
60	Infestation traced, sack	No infestation	Very heavy infestation with the bag completely bored	No infestation
90	Moderate to heavy infestation	No infestation	–	No infestation
120	Heavy infestation with bag completely bored	Infestation traced with bag little damaged	–	Heavy infestation
150	–	Heavy infestation with bag completely damaged	–	Heavy infestation with fungal attack. Bad odour with bitter taste
Wheat Flour				
0	No infestation	No infestation	No infestation	No infestation
30	No infestation	No infestation	Infestation traced and was moderate	Infestation traced
60	No infestation	No infestation	Heavy infestation with fungal attack, bitter in taste with bad odour	Moderate infestation with very little fungal attack
90	No infestation	No infestation	–	Heavy infestation with heavy fungal attack bad odour with bitter taste
120	Infestation traced	No infestation	–	–
150	Very little infestation	Infestation traced	–	–
180	Infested a little heavier with bitter taste	Infestation is moderate, slightly bitter in taste	–	–
Cost	Rs. 9.00	Rs. 9.00	Rs. 1.60	Rs. 12.00

days) in case of bamboo paper sack and 14.50% (after 105 days) in case of cloth bag. The increase in FFA was due to the deterioration of the bran already present along with the wheat flour and to the fungal and insect growth. The rate of increase in FFA was more prominent for the wheat flour due to the presence of the bran in the wheat flour.

Cooking time and swelling index – **Table 9** shows that cooking time decreases with the storage period in all types of bags. The time is reduced by 1.5 min after about 5 months of storage. The reduction in cooking time is due to the bondage between the starch molecules which gets weaker with the storage time. It also helps in easy intake of water. **Table 10** shows that the swelling index increases with the storage period ranging from 0.32 to 0.56 between 120 and 150 days of storage.

Infestation – **Table 11** shows the infestation rate in different storage materials. In case of rice packed in ploythene sack, infestation started after 60 days of storage. In 350 μ thick polythene sack, the infestation became very heavy after 120 days and the cereal became completely useless. This bag can be used for a period up to 90 days only. Rice stored in 400 μ thick polythene bags developed infestation after 120 days and was heavily infested after 150 days. This bag can be used safely up to 120 days. Rice cannot be stored in bamboo paper sack for more than 30 days since the bag is completely spoiled by the insects thereby affecting the rice. Infestation started after 120 days of storage of rice in markeen cloth bag and became heavy between 120 and 150 days. This is was due to fungal attack in rice after 140 days of storage. The development of fungus was mainly due to high humidity.

Infestation in wheat flour stored in polythene sack (350 μ thick) was traced after 120 days of storage.

It became very heavy between 150 and 180 days of storage when the FFA was above 10% (Table 8) which is beyond human tolerance limit. In case of wheat flour stored in polythene sack (400 μ thick) the infestation was traced after 130 days and became heavy between 150 and 180 days when the FFA observed was higher than the human tolerance limit. In the case of wheat flour stored in bamboo paper sack the infestation started after 40th day and became severe by 60th day of storage. There was fungal attack also. It helped the FFA to rise higher than the human tolerance limit. Similar trend was observed in case of wheat flour stored in cloth bag.

Conclusion

1. Rice can be stored in polythene sack (400 μ thick) for about 90 days.
2. Rice can be safely stored in cloth bag for a maximum of 70 days.
3. Bamboo paper sack is not fit for storage of rice longer than 30 days.
4. Wheat flour can be stored in polythene sack for a maximum of 90 days.
5. Wheat flour should not be stored either in bamboo paper sack and cloth bag for a period longer than a month.

REFERENCES

1. Annual report, 1980. Harvest and Post Harvest Technology (ICAR) Scheme, I.I.T., Kharagpur-721302, India.
2. Hunnel, S.M., Nowlin, J.F., 1972. Solvent Extractive Rice Milling. Rice Chemistry and Technology. Chapter 8, D.F. Houston, ed. American Association Cereal Chemistry, St. Paul, Minn. U.S.A.
3. Rao, B.P., Ahmed, S.A., Rao, S.D.T., 1967. Factors Affecting the Free Fatty Acids Changes in Rice Bran. Indian Oil and Soap J. 32(7): 203-210.
4. Sidhom, E.I., El-taby Shenate, A.M., Mohasseb, Z.S., 1975. Effect of Storage Conditions on the Formation of Free Fatty Acids in Rice Bran. Alexandria J. Agri. Res. 23(1): 101-107. ■■

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)

A Computer Program for Agricultural Machinery Management: Selection of Optimum Farm Size



by

Shaukat Khan
Assistant Lecturer
Dept. of Agricultural Engineering
University of Alfateh
Tripoli, Libya



Md.S. Chaudhry
Assistant Professor
Dept. of Agricultural Engineering
University of Alfateh
Tripoli, Libya



Sharafeddin M. Sherif
Head and Associate Professor
Dept. of Agricultural Engineering
University of Alfateh
Tripoli, Libya

Abstract

A computer program has been written, in FORTRAN-IV language, to determine the optimum farm size for a known cropping pattern and a set of farm machinery consisting of tractor(s) and tractor-drawn implements. This program also gives, for each farm size, the minimum power requirement and the minimum size of each equipment for economical agricultural production along with other decision variables like average cost of operating farm equipment per hectare, annual hours of use for each equipment, fuel and oil requirements and the cost of individual farm operation.

For a typical cropping pattern data, the results indicate that the minimum power requirement and the minimum size of each implement, especially for very small farms, are much less than the power available from tractor(s) and the nominal size of each implement, respectively. Also the cost of operating these implements for very small farm is extremely high. With the increase in farm size, the operating cost decreases till the minimum power requirement and the minimum size of each emplement approach to the power available from given tractor(s) and the nominal size of each implement, respectively. Hence the optimum farm size is obtained.

For larger farms, multiple units of these farm machines are required to fulfil this condition of optimality whereas the minimum average cost of operation remains nearly constant.

Introduction

During the last few decades, the means of agricultural production have changed drastically. The cost of labour and machinery use for various farm operations constitutes about more than 50% of overall production cost. In recent years, as farming has become more and more business oriented, the economists, engineers and policy makers have shown increasingly great interest in the efficient selection and utilization of farm equipment to ensure maximum profits (2).

Many scientists and research workers have studied the economics of using the farm implements while others have related the cost of operating an implement as a function of its size, annual fixed cost and hours of use, size of tractor and other parameters like timeliness of operation, etc. Hunt (4) developed the least cost equations for minimum power requirement and minimum size of an implement that give economical agricultural production.

Among other decision variables, matching of farm equipment to farm needs, i.e., the decision – "Whether the farm size is sufficient and cropping pattern is such that

it is justified to purchase and own the available farm equipment for economical production" – is a complex task (5). The least cost algebraic equations that define the optimum machinery system are of low order but contain so many variables that computation by hand, especially for repeated farm sizes, is practically impossible (3). Therefore, a computer program, in FORTRAN-IV language, is written to help decide:

1. For a given cropping pattern and avialable farm machinery, what is the optimum farm size, or;
2. For a known cropping pattern and farm size, what is the minimum power requirement and the minimum size of farm equipment that will give the economical agricultural production?

In addition to this, for each farm size, the program also calculates the cost of every individual farm operation, average cost of all operations per hectare as well as per hour, initial investment, annual hours of use for each implement and oil and fuel quantity, etc.

To calculate the fixed cost percentage (FC%) of a farm machine, the provision has been made to include either the interest on investment or the bank service charges according to the region/country where the program is being used.

The Computer Program

As on a modern farm, majority of the farm operations are carried out either with a tractor and/or tractor-drawn implements. Only such field operations are included to form the basis for the selection of optimum farm size or farm equipment. Hunt's least cost equations and other standard equations (1) have been used in the Program to compute various

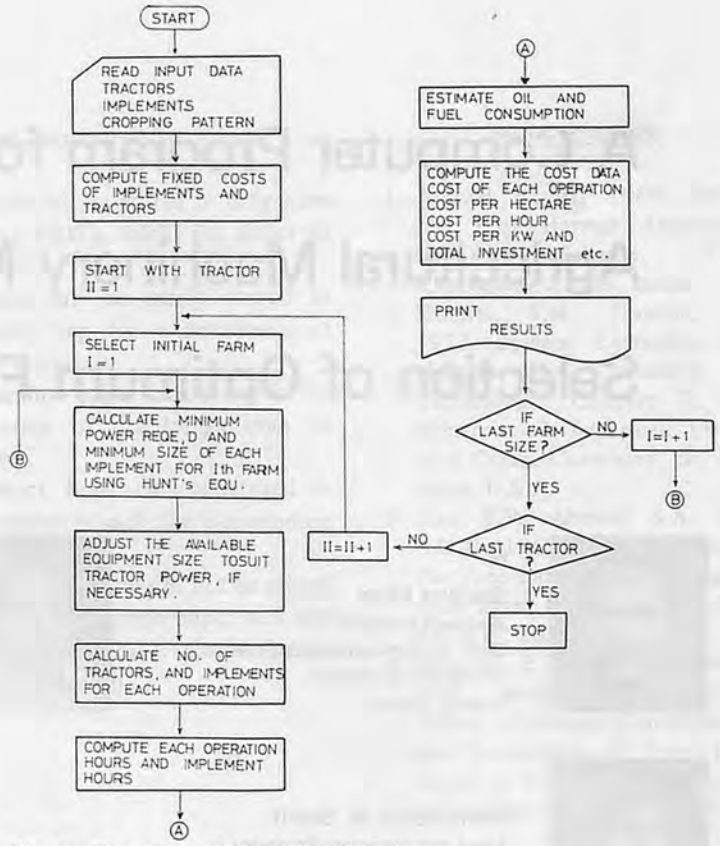


Fig. 1 Flow chart of main computer program

Table 1. List of Input-output Variables Used in the Program

Variables	Description
I. INPUT DATA	
A. Constants	
IRICOD	Irrigation code, 1: for irrigated and 0: for rainfed
NCROP	Number of crops to produce
NTRMOD	Number of tractor models recommended
NMBRIM	Number of farm implements for field operations
NMBRPR	Number of processing activities
NMBRTR	Number of transport activities
BNKSER	Bank service charges, decimal
BNKINT	Bank interest rate, decimal
XLABOR	Labour charges for tractor driver/operator, money($)/hr
TLABOR	Labour charges for transport activity, $/hr
PLABOR	Labour charges for processing activity, $/hr
XLFTR	Load factor for tractor, decimal
FTYPE	Fuel type, 1: diesel and 2: petrol
EPRICE	Fuel price, $/L
OPRICE	Oil price, $/L
RMTR	Repair and maintenance factor for tractor
ALIMT	Upper limit for the farm size
B. Tractors	
A(I)	Name of ith Model of Tractor, I = 1, 2, 3, ... , NTRMOD
PURTR(I)	Purchase price of ith Tractor
PWR(I)	Rated power of ith Tractor
SALVTR(I)	Salvage value of ith Tractor
LIFET(I)	Expected life of ith Tractor
C. Implements	
IMPCOD(I)	Implement code, integer and I = 1, 2, 3, ..., NMBRIM
PURI(I)	Purchase price of ith implement
WAVL(I)	Width of ith implement available/recommended
RMI(I)	Repair and maintenance factor for ith implement
LIFEI(I)	Expected life of ith implement
SALVI(I)	Salvage value of ith implement
XNOPS(I)	Field charges for ith implement
D. Cropping pattern	
PCAREA(I)	Percent area under ith crop, I = 1, 2, 3, ..., NCROP
Y(I)	Expected yield of ith crop, tons/ha
V(I)	Expected sale price of ith crop produce, $/ton
DISCR(I)	Distance, if ith crop produce is to be transported
RCR(I)	A factor for ith crop used in the least cost equation
NMBROP(I)	Number of operations necessary to grow ith crop

E. Field Operation

IMPLX(I)	Implement code used for ith operation, I = 1, 2, 3, ..., N where N = NMBROP(I) + N and initial N = 0
SPEED(I)	Permissible speed at which ith operation can be carried out
EFFIC(I)	Field efficiency for ith operation, decimal
FFACTR(I)	Force factor for ith operation, kW hr/ha
TPOWRD(I)	Code for ith operation: 1 for tractor, 0 for other source
TIMLI(I)	Timeliness loss factor, 1/day
SC(I)	Constant: 2 for premature or delayed schedules, 4 for balanced
XTIMES(I)	Number of times the Area of ith operation is divided
U(I)	Fractional utilization of total time, decimal
H(I)	Expected working hours per day, hrs/day
ROP(I)	A factor for ith operation used in the least cost equation

F. Processing activities

ESTPR(I)	Estimated number of tractors needed for ith processing activity, I = 1, 2, 3, ..., NMBRPR
GPR(I)	Force factor for ith activity
TONSPR(I)	Quantity of the material handled for ith activity
RPR(I)	Factor for ith activity used in the least cost equation

G. Transport activities

ESTTR(I)	Estimated number of tractors needed for ith transport activity, I = 1, 2, 3, ..., NMBRTR
DISTR(I)	Distance for ith activity, km
TONSTR(I)	Quantity of material for ith transport activity
RTR(I)	Factor for ith activity used in the least cost equation

II. OUTPUT DATA

A. GENERAL

TAREA(I)	Total area for ith farm size, I = 1, 2, 3, ...
PWRMAX(I)	Minimum power required for ith farm, kW
XNTRS(I)	Number of tractors for ith farm
HOPT(I)	Total operation hours for ith farm
HTRT(I)	Total tractor hours for ith farm
TFUEL(I)	Fuel required for ith farm, L
TOIL(I)	Oil required for ith farm, L
SMCOST(I)	Base investment for ith farm, $

B. IMPLEMENTS

WC(I,K)	Calculated optimum width for ith farm size and kth implement code
WMAX(K)	Width of kth implement matching to the available tractor power if WVAL(K) is too large
XNIMPS(I,K)	Number of kth coded implement for ith farm size
HIMP(I,K)	Operation hours for kth coded implement for ith farm size
SUMAC(K)	Total acreage covered by kth coded implement

C. FIELD OPERATIONS

IMPLX(J)	Implement code used for jth operation, J = 1, 2, 3, ... N
HOP(I,J)	Operation hours for jth operation and ith farm size
FUEL(I,J)	Quantity of fuel needed for jth operation and ith farm size, L
OIL(I,J)	Quantity of oil needed for jth operation and ith farm size, L
Q(I,J)	Power available for jth operation and ith farm size
XNTRSN(I,J)	Number of tractors required for jth operation and ith farm size
CSTPHR(I,J)	Cost for jth operation and ith farm size, $/hr
CSTPKW(I,J)	Cost for jth operation and ith farm size, $/kW
CSTPHA(I,J)	Cost for jth operation and ith farm size, $/ha
COSTIO(I,J)	Total cost for jth operation and ith farm size

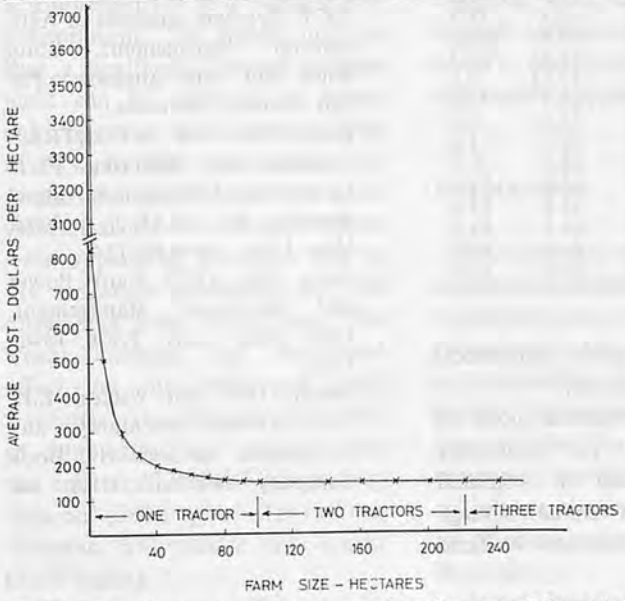


Fig. 2 Overall average cost for operating given set of farm machinery at different farms.

parameters. A flow chart, depicting step by step calculations, is shown in **Fig. 1** and the Fortran Program is available with the authors. A list of input-output data variables and constants is also given in **Table 1**. Although the program was written in FORTRAN language, a WATFIV complier was used on an IBM-370 computer at the University of Alfateh, Tripoli, Libya.

Sample Print-Out

The program was run for a typical cropping pattern, farm equipment and 65-kW tractor (3) and the results were obtained for various farm sizes ranging from 1 to 240 ha. **Fig. 2** is a graph of overall average cost for different farm sizes. The average cost for very small farms (1 - 5 ha.) is extremely high and it decreases rapidly in the beginning (up to 60 ha) and reaches a minimum value of about $.150 for a farm size of 100 ha. For larger farms, the average minimum cost remains nearly the same but the number of tractors and/or farm implements increase accordingly.

For each farm size, decision variables like average cost per hour, cost of individual farm operations, minimum power requirement, annual hours of use for each implement and oil and fuel quantity were calculated (**Tables 2** and **3**).

Conclusion

This program can be used, in general, on regional level when a specific cropping pattern, normally available farm equipment and other information like soil conditions and market prices for agricultural commodities are known. Therefore, it is of greater interest and importance for government

Table 2 Average Cost, Oil and Fuel, Minimum Power, Total Operation Hours, and Number of Tractors for Different Farm Sizes

Farm size	Average cost		Oil	Fuel	Minimum power req'd	Total operation hours	No. of tractors
(ha)	($/ha)	($/ha)	(ℓ)	(ℓ)	(kW)	(h)	
1	3739	929	0.24	139.7	15.7	4.0	1
2	1923	478	0.48	279.4	16.4	8.1	1
3	1318	327	0.75	419.1	17.0	12.1	1
4	1016	253	0.96	558.8	17.6	16.1	1
5	835	208	1.21	698.6	18.2	20.1	1
10	472	117	2.42	1397.1	21.0	42.2	1
15	352	88	3.62	2095.7	23.6	60.4	1
20	292	73	4.83	2794.2	26.1	80.5	1
25	256	64	6.04	3492.8	28.5	100.6	1
30	233	58	7.24	4191.3	30.8	120.7	1
35	216	54	8.45	4889:9	33.1	140.8	1
40	204	51	9.66	5588.4	35.3	160.9	1
50	187	47	12.07	6985.6	39.6	201.2	1
60	176	44	14.49	8382.7	43.8	241.4	1
70	169	42	16.91	9779.8	47.9	281.6	1
80	164	41	19.32	11176.9	52.0	321.8	1
90	160	40	21.74	12574.0	56.0	362.1	1
100	157	39	24.16	13971.1	59.9	402.3	1
120	156	39	28.98	16765.3	83.63	482.8	2
140	154	38	33.80	19559.6	92.2	563.3	2
160	153	38	38.54	22353.8	100.6	638.6	2
180	153	38	43.35	25148.0	106.8	718.4	2
200	151	39	46.64	26836.8	116.9	761.6	2
220	152	40	51.31	29520.4	125.0	837.7	2
240	145	55	49.90	32204.2	150.0	634.5	3

Table 3. Individual Field Operation Hours and Costs for a Typical Farm Size of 110 ha

Field operation	Implement code	Operation hours	Operation cost	Average cost	
				$/h	$/ha
Grain corn chisel	3	90.01	2974.8	33.1	64.4
Grain corn field cultivator	4	12.07	535.0	44.3	11.6
Grain corn rotary hoe	7	6.58	334.5	50.8	7.2
Grain corn row planter	8	21.64	1036.4	47.9	22.4
Grain corn row cultivator	11	19.25	744.1	38.7	16.1
Grain corn sprayer	12	6.42	474.9	74.0	10.3
Silage corn chisel	3	8.57	235.5	27.5	53.5
Silage corn field cultivator	4	1.15	50.7	44.1	11.5
Silage corn rotary hoe	7	0.63	27.9	44.5	6.3
Silage corn forage harvestor	5	18.02	787.1	43.7	178.9
Silage corn row planter	8	2.06	92.2	44.8	21.0
Silage corn row cultivator	11	1.83	58.1	31.7	13.2
Silage corn sprayer	12	0.61	26.7	43.61	6.1
Soybean moldboard plow	1	111.06	3363.4	30.3	72.8
Soybean chopper & disk	2	46.46	1766.4	38.02	38.2
Soybean field cultivator	4	12.07	533.9	44.3	11.6
Soybean rotary hoe	7	6.58	317.3	48.2	6.9
Soybean row planter	8	21.64	1008.3	46.6	21.8
Soybean row cultivator	11	19.25	688.5	35.8	14.9
Hay baler	6	16.18	1076.0	66.5	81.5
Hay mower and conditioner	9	12.34	532.1	43.1	40.3
Hay rake	10	8.15	412.1	50.6	31.2

officials, policy makers, managers of agricultural farms and agricultural machinery hiring stations and others as compared to an ordinary farmer. On the basis of the results obtained from typical data, the following conclusions can are drawn:

1. For a given machinery system, there exists a minimum farm size that gives economical agricultural production.

2. The operational cost of farm equipment for producing different crops can be estimated as a function of annual acreage or hours of annual use for farm equipment.

3. Functional relationships or graphs of decision variables like annual operation hours, minimum power required, oil and fuel quantities and average cost of operating farm machines can be established for various farm sizes.

Limitations

For the sake of simplicity and because most of the farm operations are carried out either by a tractor or a tractor and tractor-drawn implements, only such operations are included in the program to form the basis for the criteria of selecting the optimum farm size and other calculations. The operations that consume electric or other forms of energy are not taken into account for calculating the minimum power requirement, minimum size of each farm equipment and operating costs, etc.

REFERENCES

1. Anonymous. 1982. Agricultural Machinery Management Data (D230.3). Agricultural Engineering Yearbook. ASAE., Michigan, USA.
2. Dent, J.B. and Anderson, J.R. 1971. Systems Analysis in Agricultural Management. John Wiley and Sons Australasia Pty Ltd. Sydney, Australia.
3. Hunt, D.R. 1966. A FORTRAN Program for Selecting Farm Equipment. Fifty nineth Annual Meeting of ASAE., Amherst Mass. USA. Paper 66-154.
4. Hunt, D.R. 1977. Farm Power and Machinery Management. Iowa State Univ. Press. Iowa, USA.
5. Smith, H.P. and Wilkes, L.H. 1976. Farm Machinery and Equipment. McGraw Hill Book Company, New York, USA. ■■

Response of Wheat Cultivars to Irrigation and Fertilizer Applications







by

S.M. Rahman
Senior Scientific Officer

B.C. Basak
Scientific Officer

A.K.M. Habibullah
Principal Scientific Officer

Institute of Nuclear Agriculture, P.O. Box 4, Mymensingh, Bangladesh



Mesbauddin Ahmed
Assistant Professor
Irrigation and Water Management
Agri-Varsity
Mymensingh, Bangladesh

M.R. Biswas
Professor
Irrigation and Water Management
Agri-Varsity
Mymensingh, Bangladesh

Abstract

The major objective of this study was to characterize the relationship between the yield of four wheat cultivars and the irrigation regimes under low and high levels of NPK fertilizer application in a climatic region where irrigation is supplementary to growing season precipitation. The results indicate that a significant increase in grain yield can be achieved for wheat cultivars with the increased level of NPK fertilizer application. The results also show that the grain yield of all the four wheat cultivars were apparently increased due to the irrigation treatments but the differences were insignificant. The wheat cultivars had significant effect on the yield and yield attributes. The highest grain yield of 3935 kg/ha was obtained with the cultivar 'Sonalika' followed by 'Inia 66' (3638 kg/ha). The cultivar 'Norteno 67' yielded the lowest (3375 kg/ha).

The water use efficiency for both irrigation and total water decreased with the increase in number of irrigations under both fertilizer levels without affecting the wheat yield. This, however, does not mean that irrigation water is not required for optimum yield. Soil water depletion, in general, increased with decreasing amount of irrgation. The data clearly show that irrigation water use efficiency was strongly influenced by the seasonal rainfall distribution and number of irrigations applied.

Introduction

Consumption of wheat products increased considerably since its introduction and presently it constitutes 20% of the staple cereal food in Bangladesh. This and the low inputs (including irrigation) per unit of land for wheat have encouraged the Bangladesh farmers to initiate more wheat cultivation in place of other Rabi crops and Boro rice.

Most studies on the water requirements (one of the costly inputs) of wheat crop have laid stress on scheduling of irrigations to maintain optimum soil water regimes uniformly throughout the crop growth (Dastane *et al.*, 1970; Hukkeri & Pandey, 1977). When water resources are limited, it is essential to schedule irrigations at critical growth stages (Lehane and Stable, 1962; Petel *et al* 1971: Razzaque, 1977; Rafey *et al*, 1978) to maximize the water use efficiency. Bangladesh farmers cannot use an optimum level of fertilizer for their crops because of economic reasons, although the application of fertilizer is a prerequisite for an economic yield to be obtained by cultivation of HYV wheat under both rainfed and irrigated condition.

The objectives of the present investigation were, therefore, (i) to study the response of four wheat cultivars to irrigation at critical growth stages under low and high levels of NPK fertilizer application and (ii) to evaluate the effects of different irrigation regimes on the water use efficiency

and soil water depletion pattern.

Materials and Methods

The experiment was conducted during the wheat growing season of 1979-80 at the Regional Agricultural Research Station, Ishurdi, Pabna. The soil, a calcareous brown flood-plain loam developed in the Ganges river alluvium, is classified as a "calcaric fluvisol". The pH of the soil is 8.3. The field capacity and the bulk density values at 0-15 and 15-30 cm of soil depth were 29.6 and 39.9% by volume and 1.16 and 1.37 g/cm^3, respectively.

A split-split-plot design was followed in the experiment having two fertilizer treatments in the main plots, four irrigation treatments in the sub-plots and four wheat cultivars in the sub-sub-plots with three replications each. The treatments are summarised in **Table 1**. The amount of the irrigation water applied at a particular growth stage was calculated on the basis of deficit from predetermined field capacity level of soil water content of 60 cm depth. The field capacity was determined following the method of Burrows and Kirkham (1958) using a neutron moisture meter.

The blocks, main plots and sub-plots were separated from each other by 3 m, 3 m and 2 m buffer zones, respectively, to prevent movement of water from plot to plot. The sub-sub-plots (4 m x 3 m size) within one irrigation sub-plot were separated from each other by a 30 cm imaginary buffer zone to avoid any border effect. One-third of nitrogen, and full dose of phosphorus and potassium fertilizers in the form of urea, triple super phosphate and muriate of potash, respectively, were applied before sowing and mixed with the top 15 cm soil. The rest of the nitrogen fertilizer was equally splitted into two halves and applied as top dressing at tillering and booting stages. A pre-sowing light irrigation was given to wet the dry soil surface and also to augment the stored soil water. The wheat cultivars (*Triticum aestivum* L.) were sown on November 17, 1979. Spacings of 25 cm between rows and 5 cm between plants were maintained. One overhead tank equipped with a glass manometer was installed at a central position in the field for supplying measured quantity of irrigation water to the treatment plots individually. Overhead sprinklers were used for irrigating the plots uniformly. Aluminium access tubes were placed in each irrigation sub-plot up to 1.5 m depths to measure soil water content with a neutron moisture meter (a Troxler model No. 1255 having 100mci Am-Be fast neutron source). Changes in the soil water contents in 15 cm increments in 0-120 cm soil profile of the irrigation sub-plots were measured at weekly intervals and also before and after each irrigation. Periodic gravimetric samplings were also carried out for check comparisons.

Water use efficiency (WUE) was calculated as described by Cassel et al (1978). A change with time in the soil water content at a particular depth gave soil water depletion (SWD) for that depth and time. The soil water depletion of each depth interval was calculated and integrated over the whole profile to ascertain the total depletion during a particular time period under consideration. The number of effective tillers, plant height, panicle length and number of grains per panicles were recorded before the harvest. The plants were harvested at maturity, and grain and straw weights were recorded on sun dry basis. The weight of 1000 grain was also recorded. Statistical analysis were done following the Duncan's Multiple Range test.

Table 1 Description of Treatments

Main plot treatments (fertilizer levels):

F_1 – NPX fertilizer application @ 60 kg N, 40 kg P_2O_5 and 20 kg K_2O/ha.
F_2 – NPK fertilizer application @ 120 kg N, 80 kg P_2O_5 and 40 kg K_2O/ha.

Sub-plot treatments (irrigation regimes):

W_0 – No irrigation
W_1 – One irrigation during tillering stage (24–26 days after sowing)
W_2 – Two irrigations during tillering stage and boting stage (54–56 days after sowing).
W_3 – Three irrigations during tillering stage, booting stage and grain filling stage (80–85 after sowing).

Sub-sub-plot treatments (wheat cultivars):

V_1 – Sonalika
V_2 – Jupateco 73
V_3 – Inia 66
V_4 – Norteno 67

Results and Discussion

Rainfall and Irrigation

A summary of the meterological data for the growing season along with the amounts of irrigation water applied is presented in **Table 2**.

Yield and Yield Attributes

The general effects of fertilizer levels, irrigation regimes and cultivars on the wheat yield and yield attributes are summarized in **Table 3**. Significant increase in grain and straw yields of all the wheat cultivars was observed when NPX fertilizer level was doubled from 60 kg N, 40 kg P_2O_5 and 20 kg

Table 2 Meteorological Parameters and the Amounts of Irrigation Water Applied during the Cropping Season 1979–80 in Ishurdi, Pabna

Month/ (day)	Av. Temp. Max. °C	Av. Temp. Min. °C	Rainfall cm	Av. 24h Wind Vel. km/h	Av. Sunshine hours	Av. Pan evaporation mm/day
Nov. (28,30)	30.9	20.3	5.23	1.8	6.3	2.9
Dec. (1)	25.7	14.1	1.70	2.6	7.7	2.2
Jan. (2)	24.2	11.9	2.97	2.4	7.6	2.2
Feb. (16, 29)	28.4	13.8	0.36	2.6	7.5	3.0
March (1, 9)	33.8	19.8	3.00	4.6	7.6	4.9
April (10)	38.7	23.8	–	5.3	8.6	6.2

Irrigation water applied — Unit: cm

Treatment		T*	B	GF	Total
F_1	W_0 –	–	–	–	–
	W_1 –	2.01	–	–	2.01
	W_2 –	2.28	5.03	–	7.31
	W_3 –	2.20	4.25	7.87	14.32
F_2	W_0 –	–	–	–	–
	W_1 –	1.92	–	–	1.92
	W_2 –	2.23	5.27	–	7.50
	W_3 –	1.44	4.56	6.84	12.84

*T=Tillering, B=Booting, GF=Gain filling stage.

Table 3 Effects of Fertilizer Levels, Irrigation Regimes and Cultivars on the Wheat Yield and Yield Attributes

Source	Grain yield kg/ha	Straw yield kg/ha	1 000 grain weight g	No. of tillers/ hill	Plant height cm	Panicle length cm	No. of grains per panicle
Fertilizer levels:							
F_1	3241b*	4918b	41.48a	5.6a	96.3a	7.9a	38.2a
F_2	4019a	5686a	41.05a	6.2a	99.9a	8.2a	38.1a
Irrigation regimes:							
W_0	3380a	4885a	41.65a	5.2a	95.6a	7.7a	37.9a
W_1	3669a	5573a	41.54a	6.4a	98.9a	8.4a	38.7a
W_2	3647a	5169a	41.06a	6.0a	99.0a	8.0a	38.0a
W_3	3826a	5582a	40.94a	6.2a	98.9a	8.2a	38.0a
Cultivars:							
V_1	3935a	5343a	48.93a	7.6a	98.1ab	8.2a	32.2b
V_2	3574bc	5186a	35.19d	5.6b	92.8c	7.5b	40.2a
V_3	3638b	5345a	39.98c	5.1b	100.4a	8.1a	40.6a
V_4	3375c	5334a	41.10b	5.4b	101.1a	8.4a	39.5a

* Means followed by the same letter within a main effect column are not significantly different at 5% level by Duncan multiple range test.

K_2O/ha (F_1) to 120 kg N, 80 kg P_2O_5 and 40 kg K_2O/ha (F_2). The mean grain yield was increased by 24% from 3241 to 4019 kg/ha. The results also indicate that the grain yield, straw yield and other yield attributes of all the four wheat cultivars were increased somewhat due to various irrigation treatments but the differences were not significant. The results thus obtained is in contrast to those obtained from previous experiments in the same area, when two irrigations, totalling 9.5 cm were applied at tillering and booting stages with precipitaiton of only 4.15 cm (Rahman, *et al.* 1981). The precipitation of 13.26 cm received during the cropping season was rather high.

The cultivars of wheat obviously had significant effect on the yield and yield attributes. The highest grain yield (3935 kg/ha) was obtained with the cultivar 'Sonalika' (V_1) followed by 'Inia 66' (V_3) having grain yield of 3638 kg/ha. Of course, there was no significant difference in grain yield of 'Inia 66' and 'Jupateco 73' (V_2). The cultivar 'Norteno 67' (V_4) yielded the lowest. The interactions between fertilizer levels, irrigation regimes, and cultivars influencing grain yield were found to be non-significant. The fertilizer x irrigation, the fertilizer x cultivar and the irrigation x cultivar interactions showed that neither of the fertilizer level could significantly increase the grain yield of wheat due to any irrigation treatment nor, of any cultivar.

In the case of straw yield of different cultivars, no significant differences was observed. It was also observed that the 1000 grain weight of 'Sonalika' wheat was significantly higher than that of other cultivars. Similar trend was observed in case of other yield attributes except the number of grains per panicle which was more in other three cultivars. The highest yield attributes, in general, have contributed to the highest grain yield of the cultivar 'Sonalika'. The wheat cultivars are very flexible with respect to yield and yield attributes (Briggle and Vogel, 1980).

Water Use Efficiency (WUE)

The effects of fertilizer levels and irrigation regimes on grain

Table 4 Effects of Fertilizer Levels and Irrigation Regimes on the Grain Yield, Total Water and Water Use Efficiency

Treatments		Grain yield (Fert. x irrig.) kg/ha	Precipitation cm	Soil water depletion* cm	Irrigation water cm	Total water cm	Water use efficiency: Irrigation water kg/ha/cm	Water use efficiency: Total water kg/ha/cm
F_1	W_0	3 012	13.26	13.34	–	26.60	–	113.23
	W_1	3 371	13.26	15.19	2.01	30.46	93.01	110.67
	W_2	3 410	13.26	13.37	7.31	33.94	54.22	100.47
	W_3	3 173	13.26	13.50	14.32	41.08	11.12	77.24
F_2	W_0	3 749	13.26	15.03	–	28.29	–	132.52
	W_1	3 967	13.26	16.42	1.92	31.60	65.86	125.54
	W_2	3 884	13.26	13.99	7.50	34.75	20.90	111.77
	W_3	4 479	13.26	14.98	12.84	41.08	57.08	109.03

*To 120 cm soil depth.

yield, total water and water use efficiency (WUE) are presented in Table 4. As the soil water measurements were made from the irrigation sub-plots, the grain yield presented here are the means of fertilizer x irrigation interactions. Total water which may also be called as the evapo-transpiration was computed indirectly using the water balance equation of Rose (1966) assuming the drainage component equal to zero. Practically, the total water is the sum of irrigation, rainfall and net soil-water depletion. The quantity of irrigation water varied according to the frequency of irrigation, the maximum being in the W_3 treatments (of both the fertilizer levels) where three irrigations were given at three growth stages. Total water was almost the same in both the fertilizer levels.

The water utilization by the crop is generally described in terms of water use efficiency (WUE). The WUE for irrigation is defined here as the yield difference between irrigated and non-irrigated treatments divided by the irrigation water minus the difference in soil water depletion between non-irrigated and irrigated treatments. The WUE for total water, on the other hand, is defined as the ratio of the grain yield to the total water use (which is not corrected for drainage loss). The WUE for both irrigation and total water decreased with the increase in number of irrigations under both fertilizer levels. However, the yields were not significantly affected due to irrigation treatments in either of the fertilizer levels. The WUE for irrigation water of W_2 treatment under F_2 was considerably low (20.90 kg/ha/cm). As there was no significant difference between grain yield of W_0 and W_2 treatments, this might have contributed to the low WUE value for the treatment. Higher WUE values for total water were observed in the irrigation treatments receiving 120 kg N, 80 kg P_2O_5 and 40 kg K_2O/ha compared to those receiving just half of the above NPK fertilizer dose. The highest WUE for total water was, however, obtained when no irrigation was applied. But this does not mean that irrigation is not required for optimum yields. The WUE values for the irrigation water observed by Rahman et al. (1981) were higher even when two irrigations were given at tillering and booting stages with precipitation of only 4.15 cm. The 13.26 cm of precipitation which was distributed during the vegetative period of the growing season resulted in the lower WUE values. Cassel *et al.* (1978), Sepaskhah (1978), Jain and Jain (1979), Follet *et al.* (1978) all found that WUE is strongly influenced by rainfall distribution and also the number of irrigations applied. The WUE as used in this context, provides some valuable insight into the efficiency of water resource use as well as optimum production of yield (Bauder *et al*, 1978). The results from the

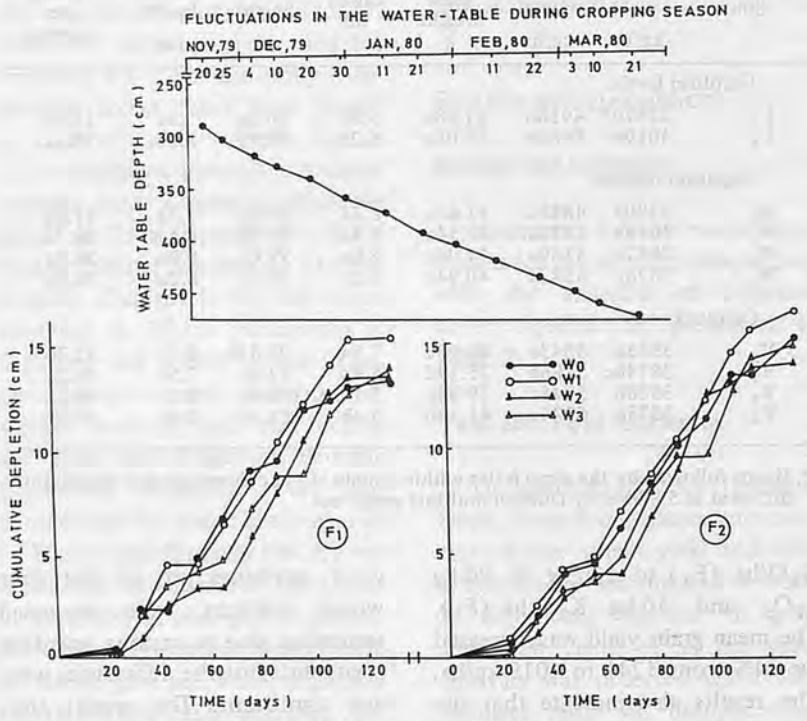


Fig. 1 Water-table fluctuation during the cropping season.

study generally demonstrate that the amount of yield produced per unit of water use increased with the increase in the availability of soil water.

Soil-water Depletion and Change in Soil Water Content

Fig. 1 depicts the cumulative soil-water depletion (SWD) along with the fluctuations in the water table for a period of 117 days from the 8th day after sowing to harvest of the crop. Soil water depletion, in general, was greater in the F_2 treatment where higher level of NPK fertilizer was used. Water depletion in treatments of high fertilizer level increased due to absorption of more soil water and its subsequent transpiration. Maximum SWD occured in the W_1 treatments which received only one irrigation during tillering stage (followed by precipitation in later period). The W_2 and W_3 treatments received considerable amount of irrigation water in the later periods also, in addition to precipitation resulting in less SWD. Soil water depletion in all the irrigation treatments started to increase sharply after 65-70 days when day temperature also started rising immediately after winter. The same can also be confirmed from the water table which fluctuated between 2.9 m and 4.7 m during the cropping season (Fig. 1).

Changes in water content of the different soil layers during the growing season in the various irrigation treatments are plotted in Figs. 2A and 2B. The differences in soil water contents in the soil profile are quite apparent. The water content considerably decreased with time at the top soil layers upto 60 cm depth in all the irrigation treatments. It, however, remained almost static at the lower depth up to 65-70 days, thereafter started decreasing.

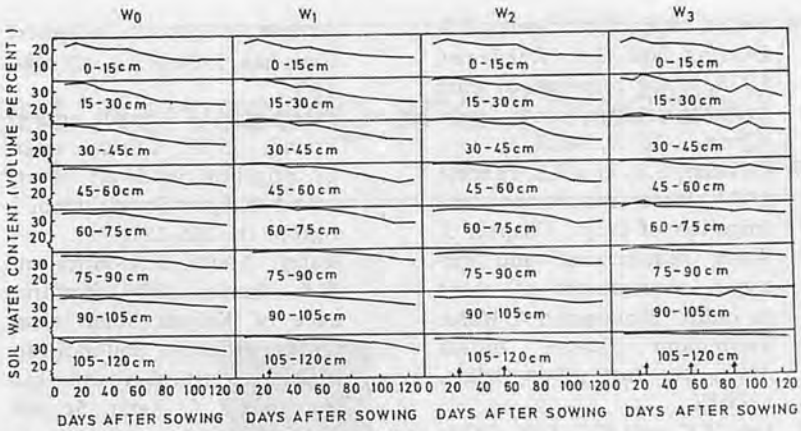


Fig. 2A Water content change in the soil layers.

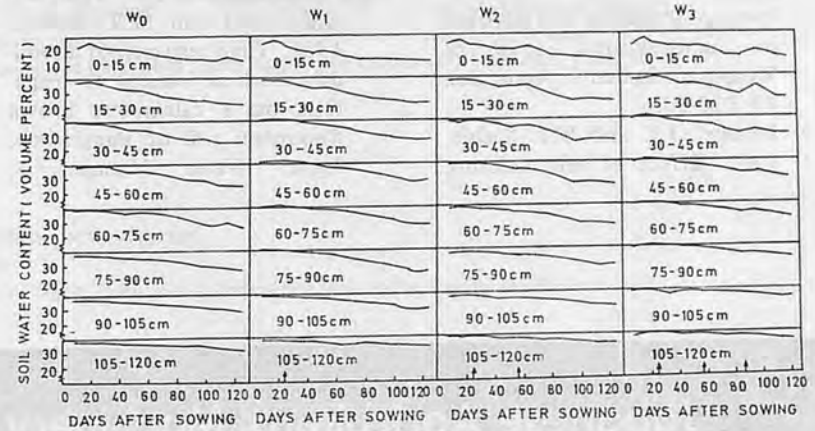


Fig. 2B Water content change in the soil layers.

No significant difference in the water extraction pattern was observed due to the different fertilizer levels although the treatment receiving higher NPK fertilizer level had apparently higher SWD. The decrease in the soil water content was greater in W_0, W_1 and W_2 treatments whereas it was less in W_3 treatment. The irrigation at later stages replenished the water extracted from the top soil and hence little change in water content in this treatment. The sharp decrease in soil water content in all the irrigation treatments after 65-70 days is likely due to the increase in the day temperature as well as the higher evapo-transpiration.

REFERENCES

1. Bauder, J.W., A. Bauer, J.M. Ramirez and D.K. Cassel, 1978. Alfalfa water use and production on dry land and irrigated sandly loam. Agron. J. 70, 95-99.
2. Briggle, L.W. and O.A. Vogel, 1978. Breeding short stature disease resistant wheats in the United States. Euphytica Suppl. 1, 107-130.
3. Burrows, W.C. and Don Kirkham, 1958. Measurement of field capacity with a neutron meter. Soil Sci. Soc. Am. proc. 22, 103-105.
4. Cassel, D.K., Armand Bauer and A.D. Whited, 1978. Management of irrigated soybean on a moderately coarse textured soil in the upper mid west. Agron. J. 70, 100-104.
5. Dastane, N.G., M. Singh, S.B. Hukkeri and V.K. Vamadevan, 1970. Review of work done on water requirements of crops in India, Navbharat Prakshan, Pune, 106 p.

6. Follet, R.F., L.C. Benz, E.J. Doering and G.A. Reichman, 1978. Yield response of corn to irrigation on sandy soils. Agron. J. 70, 823-828.
7. Hukkeri, S.B. and S.L. Pandey, 1977. Water requirement and irrigation of crops. Chapter 5, Water requirement and irrigation management of crops in India. Monograph 4, Water Technology Centre, Indian Agric. Res. Instt., New Delhi - 110012.
8. Jain, T.C. and K.C. Jain, 1979. Response of dwarf barley to levels of irrigation and nitrogen in light-textured soils of Rajasthan. Indian J. Agric. Sci. 49, 330-335.
9. Lehane, J.J. and W.J. Stable, 1962. Effect of soil moisture tension on growth of wheat. Canadian J. Soil Sci. 42, 180-187.
10. Patel, C.S., V. Singh and D. Prasad, 1971. Critical stages of irrigation in dwarf variety wheat 'Kalyan Sona' Indian J. Agron. 16, 265-267.
11. Rafey, Abdul, B.N. Mitra and H.K. Pande, 1978. Performance of Kalyan Sona wheat under different soil-moisture regimes at critical growth phasses. Indian J. Agric. Sc. 48, 736-741.
12. Rahman, S.M., S.U. Talukder, A.K. Kaul and M.R. Biswas, 1981. Yield response of a semi-dwarf wheat variety to irrigation on a calcareous brown floodplain soil of Bangladesh. Agric. Water Manage. 3, 217,225.
13. Razzaque, A. 1977. Review of ten years of modern wheat research in Bangladesh. Workshop on ten years of modern rice and wheat cultivation in Bangladesh, 1977. BRRI, Joydebpur, Dacca, 60-83.
14. Rose, C.W. 1966. Agric. Physics, Pergamon Press, N.Y. 226 p.
15. Sepaskhah, A.R. 1978. Time and frequency of irrigation in relation growth stages of barley. Agron. J. 70, 731-734.
16. Singh, N.T., A.C. Vig, Rachhpal Singh and M.R. Chaudhury, 1979. Influence of different levels of irrigation and nitrogen on yield and nutrient uptake by wheat. Agron. J. 71, 401-404. ■■

Japanese Agricultural Machinery Catalogue '83

This bi-annual Catalogue is published in odd-numbered years. This 1983 edition introduces the latest models and designs of Japanese agricultural machines, equipment and facilities in 154 color and black/white photographs in 36 pages. Detailed specifications of each product are provided in 220 pages. It lists 300 leading machinery manufacturers in a directory that is conveniently indexed by trade and brand names of the product.

Other features in Japanese include recent breakthroughs and innovations incorporated in the design and functions of the new models.

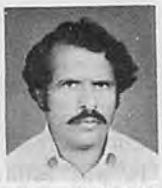
The catalogue measures 18 cm x 25.6 cm, in limp cover and sells for ¥6,800 (sea mail) and ¥7,800 (air mail).

SHIN-NORINSHA CO., LTD.

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

Losses in Wheat Harvesting and Threshing





by
Sheruddin B. Bukhari
Associate Professor
Jan Mohammed Baloch
Assistant Professor
Farm Power and Machinery, Sind Agriculture University, Tandojam, Pakistan



Fakir Mohammed Rattar
Lecturer
Faculty of Agric. Engg., Sind Agriculture University, Tandojam, Pakistan

Introduction

Wheat is the most important food crop in Pakistan. The cultivated area covered by wheat is increasing rapidly. Wheat production meets about 78% of the total food grain requirements and contributes to nearly 82% of the total protein needs obtained from cereals alone. The bulk of wheat produced is still grown on small farms and harvested by manual labour. Generally, all areas concerned with wheat production practise all the methods of harvesting and threshing. In most of the areas harvesting is done manually with the use of a sickle. Threshing is done by animal treading or flailing by hand or power-operated threshers. Recently, the combine harvesters have been introduced in the country.

The problem of grain losses in crops has received attention in developing countries. The urgency of increasing food grain availability, finding food grain substitutes, and greater emphasis on the efficiency of resource use in farming, necessitates the minimization of losses in wheat because of its possible contributions to improve returns to the farmer by higher yields and increasing food self-sufficiency prospects. The benefits of high production of wheat can be utilized by minimizing the losses in wheat from production to consumption. Grain losses may be classified into preharvest, harvest, and machine losses. Preharvest losses occur before the harvest starts because of birds, wind, rain or other environmental factors. The harvest losses are those which occur during harvesting and transport of harvested crop to the threshing yard. Machine losses are those that occur because of mechanical thresher or combine which is not adjusted and operated properly.

Machine losses during the harvest operation can constitute the one single greatest problem. An expert machine operator will hold the machine losses to a minimum by operating the properly adjusted machine at optimum harvest time of the crop. It is important to identify where harvest and threshing losses are occuring because once identified measures can be taken to eliminate or minimize the losses. The object of the study is to determine the wheat grain losses during different methods of harvesting and threshing.

Literature Reviewed

The traditional methods of seed separation from the stalks are uneconomical, time-consuming and laborious. The development of mechanical threshers and combine harvesters for the purpose clearly has an edge over conventional methods and have reduced the drudgery of work to a greater extent. The literature related to grain losses during harvesting and threshing wheat is referred to below.

Moshabbir and Khan (1981) found that an average total grain losses estimated from the study of 7 makes of threshers was 1.2% of the grain throughput. In the case

of traditional threshing the grain loss of 0.1% was obtained in one case whereas negligible loss was recorded in two other experiments.

Devrajani (1981) investigated that the total wheat grain losses were 3.6%, 10.58% and 19% for combine, thresher and traditional harvesting, threshing, cleaning operations, respectively.

Iqbal *et al* (1980) concluded that the percent harvesting losses in wheat increases as harvesting is delayed after the ripening of the crop. The harvesting losses increased linearly with time after ripening of grain, that is, from 3% in the first week to 7% in the third week. Grain losses from the conventional winnowing operations were as high as 10% but decreased in a non-linear fashion with distance becoming negligible beyond a distance of 2.5m. Grain losses from locally produced mechanical threshers ranged from 2 to 6%.

Choudhry (1979) found that the grain losses in bullock threshing, mechanical threshing, tractor threshing and combine harvester amounted to 3.11, 2.68, 2.01 and 1.2%, respectively. The maximum losses were for bullock threshing and minimum for combine harvester. It was estimated that as an average 2.65% of the potential production of wheat was lost during harvesting, threshing and winnowing operations for all modes. In the Punjab, the quantum of wheat losses was estimated around 151 000 t in 1974-75 valued to Rs. 147.9 million ($14.9 million) which is of major economic importance for a poor and food deficit country like Pakistan.

Tripathi (1979) reported the post-harvest losses estimated by the expert committee that the losses of good grain occured at processing, threshing yard, transport and storage were 0.92, 1.68, 0.15 and 6.58%, respectively.

Brown and Vasey (1967) reported 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 end losses were 2, 1.5, 1.5 to 4%, respectively. The average total machine loss in bushels/acre was 1.5. The average shatter, comb and rear end losses were 0.5, 0.4 and 0.4 to 1 bushels per acre, respectively.



Fig. 1 Bundling and transport of harvested wheat crop by a worker.

Conventional Method

Manual Harvesting

Manual harvesting of wheat with hand sickle is common. Three different sites on farms were selected for harvesting the wheat with this method. The harvested wheat crop was left in small heaps of 5 to 10 kg each depending on the



Fig. 2 Transport of harvested wheat crop on bullock cart.



Fig. 3 Transport of harvested wheat crop on tractor trailer.

density and height of the crop. After the harvest, bundles of wheat stalk of 30 to 35 kg were made. The bundles of wheat were transported to the caked mud threshing yard (**Figs. 1-3**). The process was replicated three times on all three locations selected for the study.

Field Losses

Harvesting losses – Three plots of 25 square feet on each location were randomly selected from the wheat area for estimating the field losses. Each plot was manually harvested with sickle. The ears, shedded loose grains left on the ground were collected, threshed and weighed.

Bundling losses – The grain losses in the process of collecting and bundling the small heaps of harvested crop were determined in the field. The harvested crop was placed in small heaps before making bundles of 30 to 35 kg each. From randomly selected area of 25 square feet (2.3225 m^2) at three sites, the ears and grains fallen while carrying and bundling the harvested wheat were collected, threshed and weighed. The bundling loss per ha and in percent was calculated.

Transport losses – The bundles were transported on the heads of carriers to the threshing site. During transport, the ears and grains falling on the ground of five randomly selected bundles of wheat were collected, threshed and weighed. The total number of bundles per hectare were also recorded. The procedure was repeated for three selected plots. The total losses were recorded and total grain loss per hectare was also calculated.

Threshing by Bullocks

The harvested 30 bundles of wheat were placed on the threshing yard and treaded by bullocks under long twings of thorny trees interwoven with wheat straw locally as "phala." The threshed material was manually winnowed (**Fig. 4**).



Fig. 4 Wheat threshing by bullock and manual winnowing and cleaning of grain from threshed material.

Threshing losses – Threshing losses were measured after the wheat threshing operation was over. Five spots of 100 sq. feet each were randomly selected from the entire threshing yard. The ears and grains scattered during the operation were collected and weighed. The soil of the randomly selected spots of the threshing floor was dug to 7.5 cm. deep and the grain seeds included in the area were collected and weighed. The total grain losses during threshing operation were found. Percent grain loss and mean grain loss per unit area was also calculated.

Winnowing and cleaning operation – The winnowing operation was performed manually. Cleaning was done by using the broom which separated the pieces of straw and straw nodes unthreshed ear pieces from the grain.

Winnowing and cleaning losses – The grain remained in the straw and unthreshed ear pieces were collected, re-threshed and weighed. The grain loss in straw was measured from a distance of 0 to 8 feet. Three samples of 1 kg each were randomly taken from each group. The group made for the purpose were 0 to 2 feet, 2 to 4 feet, 4 to 6 feet, 6 to 8 feet.

Mechanical Method

Mechanical Threshing

Five mechanical threshers of different makes on eight farms were selected for the study. All the threshers were powered through tractor power pulley. The manually-harvested wheat crop was threshed by the mechanical threshers.

Grain losses – The blower and unthreshed ear loss were measured and recorded. Two cloth bags were used for collecting the straw and unthreshed ear tips. The first bag was laid down near the straw outlet for collecting the unthreshed ear pieces and second for collecting the straw which contains the grains thrown by the fan of a thresher. The thresher was operated at intervals of 15 minutes and grain loss measurements were made.

Combine Harvester

The combine is rarely used in Pakistan. Four experiments were conducted with tractor operated JF-70 combine harvester (**Fig. 5**). It has a 5.91 feet wide header and 27 inches wide raspbar cylinder having 18 inches diameter. A wheat field was selected at four places to



Fig. 5 PTO-operated JF-70 combine harvester.

carry the experiment of combining wheat and determining the grain loss. The average height of the wheat plants ranged from 40 to 54 inches. The weather at the time of harvest was warm. The average straw moisture content was 12.48%. The cutter bar, cylinder, rake and shoe losses occured during combining operation were measured and recorded.

Cutter bar losses – In order to determine the cutter bar losses, a canvas cloth was used to collect the required material along an area of 40 feet long on the forward line of travel. The shattered heads and seeds were collected, threshed and weighed from five plots of 5 x 5 feet each, randomly selected at two sites.

Cylinder losses – The cylinder losses were measured by collecting the unthreshed heads from the straw discharged from straw outlet on the canvas used for this purpose. Three samples weighing 1 kg each were randomly taken to determine the cylinder loss. The unthreshed heads were rethreshed and grains were weighed. By determining the grain straw ratio in the sample, the grain loss in total quantity of straw was calculated and the grain loss per unit area, percent loss on through put (yield) basis was also calculated.

Rack losses – In order to measure the effect of feeding rate, a canvas was used to collect the material discharged from the walkers over a measured area. The walker loss was determined by sorting out the loose grains from 1 kg straw and weighing the loose grains obtained from the straw collected for this purpose.

Shoe losses – In order to determine the shoe losses, a canvas was used to collect the material discharged from the shoe over the measured area. The canvas contained collected chaff and free seed from the shoe as well as unthreshed seeds and weighed. This procedure was repeated 10 times on two sites for the same treatment.

Quality of Wheat

The quality of wheat in terms of minimum impurities contained in the clean threshed wheat by conventional method, threshers and combine harvesters were determined by taking out four samples of clean threshed wheat each weighing 200 g. From each sample of threshed grain, impurities such as unthreshed ear tips, nodes of stem, clods, straw, leaves, fine dust, weed seeds, etc. were sorted out and weighed. Hence the percentage of impurities in threshed grain was calculated.

Experimental Results and Discussion

The ultimate purpose of any harvesting and threshing operation is to recover the seed free from straw with a minimum of grain losses, external grain damage and internal injury to the grain. The systems studied for determining the wheat grain losses are discussed under the following headings.

Effect of Delayed Harvesting on Grain Losses

This refers to the effect of harvesting time and date on shattering grain losses. Grains and ears tend to shed as the crop slightly over-ripens due to delays in harvesting which calls for the use of reapers and combine harvesters to speed up the operation and to avoid heavy grain losses. Further, the delays either in harvesting or threshing are subject to natural hazards like weather, rain, heavy winds etc. which may deteriorate the quality of grain in addition to quantitative losses. **Table 1** shows the effect of harvesting time on shattering grain losses in wheat harvested by sickle. It is clear from the data that for the crop harvested in the early

Table 1 Effect of Harvest Time on Grain Losses in Wheat

Time of Harvest hr	Grain Losses per Hectare (percent)					
	1	2	3	4	5	Average
Up to 0800	2.10	2.90	2.73	2.48	2.21	2.28
0800–1000	2.32	2.83	2.08	2.66	2.41	2.43
1000–1200	2.52	2.95	2.31	2.83	2.55	2.63
1200–1600	2.84	2.27	2.66	3.01	3.02	2.99

Table 2 Effect of Delayed Harvesting on Shattering Grain Losses in Wheat

Harvest Date	Shattering Loss/m²		Grain Yield/m²	Shattering Grain Losses	
	No. of ears	Weight of grains (g)	(kg)	kg/ha	Percent
19.4	–	–	0.35	–	–
20.4	–	–	0.34	–	–
21.4	–	–	0.33	–	–
22.4	3	4.50	0.32	45.00	1.41
23.4	7	8.50	0.38	85.00	2.24
24.4	8	9.25	0.40	92.50	2.31
25.4	9	10.25	0.24	102.50	3.85
26.4	10	11.50	0.26	115.00	4.42
27.4	11	12.00	0.26	120.00	4.61
28.4	12	12.50	0.26	125.00	4.80

morning hours, the grain losses are minimum as compared to the crop harvested in late hours. This is because the crop is more moist in morning hours than in late hours. The average grain losses recorded in the crop harvested up to 0800, 0800 to 1000, 1000 to 1200 and 1200 to 1600 h were 2.28, 2.43, 2.63, and 2.99%, respectively.

Further the crop was harvested at different dates after the crop was ripe. For this study, the harvest was carried out from April 19 to April 28. **Table 2** shows the effect of delayed harvesting on shattering grain losses in wheat. On first three dates, April 19, 20 and 21, the grain losses were zero, this was due to the reasons that the harvesting operation was carried out immediately after the crop ripened. The average shedding grain losses incurred during harvest of wheat on April 22, 23, 24, 25, 26, 27, and 28 were 1.41, 2.24, 2.31, 3.85, 2.42, 4.61 and 4.80%, respectively. The losses increased as the harvest was delayed.

Conventional Method

The conventional method of harvesting and threshing requires five operations to complete the system: harvesting, bundling, transport, threshing, winnowing and cleaning the grain. The harvesting and threshing losses of grains by conventional method are shown in **Table 3**: highest on farm-1 and lowest on farm-3. The average harvesting losses on the area studied was 3.67%. Bundling losses incurred are highest on farm-3 and lowest on farm-1: the average being 3.98%. The transport losses are minimum amongst all the operations: highest for farm-1 and lowest for farm-3. The average transport losses was 0.24%. Threshing losses by conventional method varied from 1 to 1.47%. The highest threshing losses were for farm-1 and lowest for farm-2. The average grain losses calculated were 1.18%. The winnowing losses recorded for the material of the area studied were highest for farm-1 and lowest for farm-3. The average winnowing grain losses was 2.46%. The winnowing grain losses decreased with an increase in distance from the start of the straw. The ghundi (stem and ear pieces) losses incurred in the final operation of cleaning the grains were highest in the material of farm-3 and lowest in the material of farm-1. The average grain losses obtained from cleaning the discorded "ghundi" were 4.53%. In the conventional method of harvesting and threshing wheat, the total grain losses estimated were highest on farm-2 and lowest on farm-3. The total average losses were 16.07%.

Mechanical Method

The methods followed were i) threshing by threshers operated by tractors whereas other operations were performed by manual labour; and ii) tractor operated combines.

Threshers

The performance of the threshers studied were of five makes: Sartaj, Itfaque, Ghazi, Beco, and National. The grain losses observed during the study of these threshers were categorized into "ghundi" and blower losses. The grain loss incurred by various stationery threshers is given in **Table 4**. The total average grain losses recorded during the study of Beco, Sartaj, Itfaque, Ghazi and National threshers were 4.33%, 4.52%, 4.70%, 4.73% and 4.81%, respectively.

The total grain losses of harvesting and threshing were also estimated. The harvesting, bundling and transport operations were manual. The grain losses of 7.89% incurred during these operations were added to obtain the total grain loss by using the mechanical threshers. The

Table 3 Grain Losses Recorded in Wheat by Conventional Method of Harvesting and Threshing Operation.

Source of Grain Losses	Grain Losses						Average Grain Losses	
	Farm-1		Farm-2		Farm-3			
	Total kg	Percent	Total kg	Percent	Total kg	Percent	Total kg	Percent
Harvesting	102.92	3.85	100.21	3.64	121.94	3.53	108.36	3.67
Bundling	112.25	4.20	116.92	4.25	121.92	3.50	116.80	3.98
Transport	7.70	0.29	7.09	0.26	5.54	0.16	6.78	0.24
Threshing	39.20	1.47	27.67	1.00	37.32	1.08	34.73	1.18
Winnowing/ separation	67.35	2.52	68.29	2.48	82.51	2.38	72.72	2.46
Ghundi cleaning	105.59	3.95	131.73	4.79	167.96	4.86	135.09	4.53
Total	435.01	16.28	451.91	16.44	536.49	15.51	474.48	16.07

Table 4 Grain Losses Incurred by Various Mechanical Threshers

Type of Thresher	Year of Purchase	Through-put	Output				Grain Losses					
			Grain		Straw		Ghundi		Blower		Total	
		kg	Qty. kg	%	Qty. kg	%	Qty. kg	%	Qty. kg	%	Qty. kg	%
Beco	1976	34.60	17.20	49.71	16.90	48.85	0.43	2.50	0.31	1.63	0.74	4.33
Sartaj	1974	32.60	15.39	47.21	16.40	50.30	0.39	2.53	0.36	2.34	0.75	4.87
	1975	34.60	17.02	49.21	17.41	50.30	0.37	2.17	0.34	1.99	0.71	4.17
Itfaq	1970	31.00	15.00	48.39	16.00	81.60	0.43	2.86	0.32	2.13	0.75	5.00
	1973	33.00	16.00	48.48	16.50	50.00	0.41	2.56	0.35	2.18	0.75	4.75
	1975	35.00	17.00	48.57	17.00	48.57	0.39	2.29	0.35	2.06	0.74	4.35
Gazi	1973	30.60	15.20	49.67	15.10	49.35	0.40	2.63	0.32	2.10	0.72	4.73
National	1975	32.40	15.40	47.53	16.50	50.92	0.42	2.73	0.32	2.08	0.74	4.81

Table 5 Grain Losses Observed by Harvesting Wheat with MS-70 Combine Harvester

Experiment	Grain Losses per ha									
	Cutter Bar (Shatter)		Cylinder		Rack		Shoe		Total	
	Qty. kg	%	Qty. kg	%	Qty. kg	%	Qty. kg	%	Qty. kg	%
1.	84.90	2.90	3.90	0.13	10.15	0.35	11.09	0.38	110.04	3.76
2.	83.24	2.20	6.33	0.17	14.03	0.37	14.02	0.37	117.62	3.11
3.	86.61	2.40	7.41	0.20	10.47	0.29	14.26	0.39	118.75	3.30
4.	77.27	2.63	6.69	0.23	8.75	0.30	12.42	0.42	105.13	3.57
Average	83.80	2.53	6.08	0.18	10.85	0.33	12.95	0.39	112.88	3.43

highest harvesting and threshing grain loss of 12.70% was recorded in case of National threshers whereas lowest grain loss of 12.33% was recorded in the case of Beco threshers.

Combine Harvesters

The grain losses by combine harvester are classified into i) cutter bar; ii) cylinder; iii) rack; and shoe losses. Grain losses determined by harvesting the wheat with combine are shown in **Table 5**. The total grain losses were observed as 3.43% of the yield. The cutter bar (shatter) loss was 2.53%, cylinder loss was 0.18%, rack loss was 0.33% and shoe loss was 0.39%. The cutter bar losses were greater than other losses due to low lying (lodged) wheat passed over by the cutter bar to grain shattered on to the ground by reel and guard action. Cylinder losses were lowest than the other losses due to cylinder adjustments.

Impurities in Wheat

Table 6 Impurities in Wheat Threshed by Various Methods of Threshing. unit: %

Foreign Matter	Combine harvester	Stationery thresher	Bullock threshing
Ear tips	0.75	1.37	0.43
Stem nodes	0.87	1.06	–
Straw/awns/leaves	0.41	0.44	–
Barley seed	–	–	1.86
Straw/dust/weed seeds	–	–	0.65
Clods	–	–	0.64
Total	2.03	2.87	3.58

The wheat threshed by conventional method, stationery threshers and combined by harvesters was studied to determine the quality of the bagged wheat.

Table 6 shows the impurities recorded in the wheat threshed by various methods of wheat threshing. It is clear from the data that all kinds of impurities in wheat threshed by conventional method averaged to a maximum of 3.58%. However, the barley seeds collected were 1.86%, clods 0.64%, unthreshed ear heads 0.43%, straw, dust and weed seeds, 0.65%.

The impurities in the wheat threshed by stationery threshers were unthreshed ear tips 1.37%, nodes of stem 1.06%, straw and leaves 0.44%. All kinds of impurities averaged 2.87%.

The impurities found in wheat threshed by combines were 0.75% ear tips, 0.87% nodes of stems, and 0.41% pieces of straw and awns. The total impurities averaged 2.03%.

It is concluded that the best quality of wheat in terms of minimum impurities was produced by the combines and the wheat threshed by the conventional method contained the highest percentage of impurities among all the three methods of threshing wheat.

Conclusions

1. Harvesting losses increased with delayed harvesting after ripening of the crop from 1.41 to 4.8% in

first week.

2. Harvesting losses ranged from 2.28 to 2.99% for harvesting the crop at 0800 h to 1600 h on the same day.
3. Grain losses from the conventional harvesting and threshing method were as high as 16.07%.
4. Grain losses from tractor operated threshers were lowest of 4.33% for the Beco threshers and highest of 4.81% for the National thresher.
5. Grain losses from tractor operated combine harvesters were lowest at 3.11% on farm-2 and highest of 3.76% on farm-1.
6. The grain losses in conventional method of harvesting and threshing wheat were 3.37% more than prethreshing and threshing by mechanical threshers and 12.64% more than combining the wheat with tractor operated combines.
7. The total grain losses on prethreshing and mechanical threshing of wheat was 9.27% more than combining the wheat with tractor operated combines.
8. The grain losses were lowest at 3.43% for the tractor-operated combines and highest at 16.07% for the conventional method of harvesting and threshing.

Suggestions

1. The timely operations of wheat harvesting and threshing should be carried out to minimize grain losses.
2. The threshers and combines should be adjusted properly according to the operator's manual in order to minimize the grain losses.

REFERENCES

1. Brown, W.T. and G.H. Vasey. 1967. Wheat harvester survey. Uni. of Melbourne, Dept. of Agri. Enging.: 1-103.
2. Chaudhry, M.A. 1979. Wheat losses at the threshing and winnowing stages. AMA Japan 10(4): 67-70.
3. Devrajani, B.T. 1981. Grain losses in wheat–Mechanized versus traditional methods. Paper presented at 2nd Annual convention of PSAE. April 9-10 Lahore, 1-5.
4. Iqbal M., G.S. Sheikh and J.K. Sial. 1980. Harvesting and threshing losses of wheat with mechanical and conventional methods. AMA Japan 11(3): 66-70.
5. Moshabir, P.M. and A.U. Khan. 1981. Wheat threshing in the barani (rainfed) areas of the Punjab. Paper presented at 2nd. Annual convention of PSAE. April 9-10, Lahore 1-13.
6. Tripathi, S.K. 1979. Status of post-harvest handling operations for food grains and proposed mechanization of grain market in India. AMA Japan 10(3): 77-80. ■■

Agricultural Mechanization in Thailand



Gajendra Singh
Division of Agricultural and
Food Engineering
Asian Institute of Technology
Bangkok, Thailand

Background

Before 1955, the sources of farm power in Thai agriculture were only human labor, animal and some water power, mainly used in water wheels. In 1955, 262 tractors were imported from various countries but the Japanese-made two-wheel tractors (power tillers) had the largest share. The number of imported tractors increased significantly during the following years.

In 1957, the Agricultural Engineering Division of the Ministry of Agriculture released the design of an axial flow pump named 'Debaridhi water pump' to the local manufacturers. In 1958, the Division released the design of a 4-wheel tractor named, 'Iron Buffalo' for commercial production. Due to high cost this tractor could not compete with imported units. Two firms in 1960 and 1964 established assembly lines for large tractors, namely, Ford and Massey Ferguson.

In 1964-65 workshops around the Bangkok area began to modify the design of imported 2-wheel tractors. In 1967, there were five firms producing 2-wheel tractors. Their lower price relative to the imported machines and their suitability to local conditions made these machines popular. In 1969 a firm in Ayudhaya producing 2-wheel tractors started manufacturing a simple 4-wheel tractor.

In 1975, three firms started producing axial flow threshers modified from the IRRI design. A rice transplanter (12-row and power-operated) was imported by a local firm in 1978. It was produced locally also but could not be sold in significant numbers. During 1981 and 1982 a number of reaper harvesters were imported from China and are being adapted by the local firms.

Local Manufacture of Farm Machinery

Based on a survey by the Agricultural Engineering Division in 1980-81 (Jaruwat 1981) there were about 120 agricultural machinery manufacturers in Thailand. These firms vary in size, ranging from a small workshop having a working area of about 50 m^2 and few workers to large manufacturers having a working area of more than 3 000 m^2 and employing more than 100 workers. In power-operated farm equipment, the local manufacturers produce mainly power tillers, small 4-wheel tractors, rice threshers, maize shellers and axial flow water pumps. The list of main products and their annual production by local manufacturers in given in **Table 1**.

In a survey conducted in 1982 the number of agricultural machinery manufacturers was estimated at 130 (Jaruwat 1983) and divided into the following categories:

Firm size	No. of firms	Annual production
Large	10	more than 2500 units
Medium	20	1000-2500 units
Small	100	less than 1000 units

There are now 20 medium-to large-sized firms producing power tillers and small 4-wheel tractors, 14 of which produce power tillers, three produce 4-wheel tractors and three others produce both power tillers and 4-wheel tractors. Seven of the firms producing power tillers are located in Bangkok and suburbs and others are located in nearby towns in the Central Plain. Two large manufacturers of small 4-wheel tractors and three manufacturers producing power tillers and 4-wheel tractors are located in Ayudhaya. One firm producing power tillers and another producing 4-wheel tractors are located in Nakhon Sawan in the North-eastern Region. Some of these firms have established branches in other regions. The number of power tillers and 4-wheel tractors manufactured locally are given in **Table 2**. It is estimated that

Table 1 Local Manufacture of Farm Machinery

Items	Annual Production (Units)	Number of Firms
Power tiller	50,000	25
2-axle tractor (15-18 hp)	5,000	12
Mouldboard plough (animal-drawn)	300,000	10
Disc plough	3,000	20
Ridger	500	5
Frame for animal draught plough	15,000	10
Water pump	5,000	10
Rice thresher	3,500	20
Other crop threshers	200	8
Maize sheller	1,500	20
Peanut sheller	60	2
Self-propelled transplanter	200	3
Manual transplanter	30	1
Sugarcane planter	50	3
Rice mill	1,000	20
Coffee pulper	20	1
Winnower	500	10
Cassava slicer	1,000	6
Mechanical weeder	10	1
Fertilizer applicator	10	1
Animal feed mill	10	2
Trailer	3,000	10
Farm truck	1,500	2

Source: Jaruwat Mongkoltanatas, 1981.

the local firms have capacity to produce about 65 000 power tillers and 8 000 small 4-wheel tractors annually.

Imports of Farm Machinery

The distribution of agricultural machines imported during 1974-79 is shown in **Table 3**. The number and value of imported farm tractors during 1979-81 is given in **Table 4**. The number of tractors imported during 1978-80 was about 4 000 annually and the majority of these tractors were the large size (60-80 hp) class. In 1981 the number of tractors imported increased to 12 862 (**Table 4**). These included a sudden increase in imports of power tillers from China and of new and used tractors from Japan. One of the power tillers from China is very similar to the Thai design but is probably cheaper than the local make. The large tractors are imported in the c.k.d. (completely knocked down) or p.k.d. (partially knocked down) forms.

Table 2 Distribution of Power Tillers and Small 4-wheel Tractors Manufactured in Thailand

Year	Power tiller	4-wheel tractor	Total
1974	24,808	2,324	27,132
1975	27,860	2,582	30,442
1976	31,766	2,914	34,680
1977	35,465	3,258	38,723
1978	39,579	3,808	43,387
1979	38,756	4,142	42,898
1980	50,075	6,853	56,928
1981	60,090	7,000	67,090

Source: Jaruwat Mongkoltanatas, 1983.

The used 4-wheel tractors imported from Japan are of many makes and models, notably Kobota, Yanmar, Hinomoto, Iseki, Mitsubishi, and Satoh and most of them are in the 14-25 hp range. Most of these tractors have been used for about 1 000 h and are about 5 years old. The price of these

Table 3 Distribution of Selected Imported Agricultural Machines, 1974-79

Item	1974	1975	1976	1977	1978	1979
Farm tractors	1,112	4,231	5,257	6,161	4,298	3,348
Water pumps	168,524	149,021	208,101	202,101	258,369	281,668
Ploughs	37,709	1,141	31,242	2,260	824	12,570
Harrows	56	105	834	2,558	988	1,636
Cultivators	52	128	117	45	42	16
Distributors	12	23	14	638	144	69
Harvesting machine	30	34	12	72	6	13
Grass mowers	5,661	3,812	3,919	6,226	6,636	2,885
Threshing machine	2	32	16	49	480	2
Cleaning machine	371	215	206	485	162	10
Rice polishing machine	43	127	155	340	256	3,335
Sprayers	5,659	20,301	22,978	62,353	46,191	82,058

Source: Customs Department – 1979 Statistical Data.

Table 4 Distribution and Value of Imported Tractors

Country	1977		1978		1979		1980		1981	
	Number	Value Million ฿	Number	Value Million ฿	Number	Value Million ฿	Number	Value Million ฿	Number	Value Million ฿
Japan	3,443	47.71	2,471	77.99	1,607	56.05	1,452	69.01	6,686	220.80
South Korea	302	4.29	450	6.77	200	3.02	–	–	54	1.33
Taiwan	120	0.42	5	0.04	136	3.05	300	0.81	402	4.68
Belgium	199	36.30	1	0.19	–	–	–	–	–	–
West Germany	214	34.92	20	3.50	40	7.40	56	13.37	153	40.18
Romania	120	12.06	18	2.63	28	3.14	123	13.79	25	3.72
U.K.	3,443	424.00	1,079	158.39	890	142.06	1,327	251.25	1,647	293.48
China	–	–	–	–	140	3.71	422	12.21	3,760	92.05
Russia	–	–	–	–	199	20.13	82	7.48	94	11.04
New Zealand	–	–	–	–	–	–	103	0.45	–	–
Others	182	21.39	255	24.95	108	22.85	27	1.46	41	2.65
Total	6,161	581.09	4,298	274.46	3,348	261.41	3,892	369.83	12,862	669.93

Source: Customs Department – 1981 Statistical Data.

Table 5 Distribution of Farm Machines in Thailand

Item	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82*	Average % increase during 1975/76-1980/81
Power-tillers (single axle tractors)	90,001	113,286	151,504	192,004	230,591	280,591	330,000	42.3
4-Wheel tractors under 45 hp	14,575	16,427	23,942	26,984	31,158	36,158	49,000	29.6
4-Wheel tractors over 45 hp	13,338	17,569	22,826	28,987	33,285	37,117	41,000	35.7
Sprayers (manual and engine)	1,310,464	1,379,436	1,452,038	1,528,461	1,604,884	1,680,000	1,175,000	5.6
Water wheel engine (irrigation)	56,891	68,219	81,923	89,775	107,730	125,811	146,927	24.2
Water pump (irrigation)	251,288	277,084	317,328	359,308	473,975	517,975	603,548	21.2
Cleaning machine (winnowers)	42,342	47,423	53,114	59,488	66,806	74,782	83,801	15.3
Shelling equipment (maize)	5,721	6,407	7,175	8,036	9,000	10,079	11,287	15.2
Threshing (rice)	3,955	4,430	4,962	5,557	6,224	18,394	20,601	73.0
Rice mills	24,658	24,914	25,170	25,426	25,682	25,947	26,212	1.0

* Estimated numbers. Source: Office of Agricultural Economics, Ministry of Agriculture, Thailand.

tractors depends upon their condition and previous use varying from ฿ 25 000 for a 15-hp unit to ฿ 45 000 for a 25-hp unit. These prices are about one-third to half the price of the locally manufactured tractors.

The dealers do not provide any warranty for the old tractors and carry no or limited spare parts. As these tractors have been used only for a year or so by the Thai Farmers and no survey has been conducted to determine the frequency of breakdowns and associated repair costs, it is difficult to estimate the total operating costs per unit area or time. It is to be expected, however, that these tractors for which spare parts are not available will have limited life resulting in very high total operating costs per unit area to the farmer.

In addition to an engine, a tractor has other systems, i.e., hydraulic system, power transmission system and final drive, electrical system, etc. Thai mechanical and technicians are quite capable of repairing a wide variety of engines. However, in the case of old tractors the problem of repairs is associated with the non-availability of spare parts not only for different makes and models of engines but for the hydraulic and transmission systems of the tractor.

The number of farm machines used by the farmers in Thailand has been increasing very rapidly (Table 5). In 1982 the number of power tillers was estimated to be 330 000 units and there were about 49 000 units of small 4-wheel tractors and 41 000 units of large 4-wheel tractors in (Table 5).

Regional Distribution of Farm Machines

The highest concentration of farm machines in Thailand is in the Central Region (Table 6). About 41% of power tillers are in the Central Region. The Nothern and Southern Regions have about 26% each while only 7% of the power tillers are in the Northeastern Region. Similar is the case with the small 4-wheel tractors with 56% in the Central Region, 19% each in the Northern and Southern Region and only 6% in the Northeastern Region. In comparison to power tillers and small 4-wheel tractors, the share of large tractors in the Northern (33%) and Northeastern (24%) Regions is much higher. The highest concentration of water pumps is in the Central Plain (38%) followed by the Northern Region (23%), Southern Region (20%) and the Northeastern Region (19%).

The widespread use of power tillers and small 4-wheel tractors in the Central Region is mainly due to the relatively higher agricultural wage rate and higher income of farmers as compared to other regions. Power tillers and small tractors are very suitable for wet cultivation of paddy land because of the light weight and use of cage wheels. Their engines are also used to power water pumps, threshers, shellers, etc. Many farmers also have trailers for their power tillers and small tractors which are used for transporting inputs and farm products.

In the North, large tractors are used to cultivate recently acquired forest lands and upland crop areas. They are also used for cultivation before the rainy season mainly in the Northeast. Large tractors are also used in ploughing the low paddy land of the Central Region

Table 6 Regional Distribution of Selected Farm Machines in Thailand (1980/81)

Region	Power Tiller		4-wheel Tractor under 45 hp		4-wheel Tractor over 45 hp		Water Pump	
	Units	%	Units	%	Units	%	Units	%
Northern	71,414	25.5	6,833	18.9	12,356	33.2	119,743	23.1
Northeastern	20,395	7.2	2,121	5.9	8,752	23.6	95,625	18.5
Central	114,208	40.7	20,414	56.4	10,123	27.2	196,631	38.0
Southern	74,574	26.6	6,790	18.8	5 946	16.0	105,976	20.4
Total (Units)	280,591		36,518		37,177		517,975	

Source: Office of Agricultural Economics, MOAC, 1982.

Table 7 Ratio of Horse Power (hp) of Selected Farm Machines to Farm Holdings by Region and Agro-economic Zone, 1979/80 Crop Year.

Unit: hp/hectare

Region	Agro-econ. zone	Farm holding land (ha) (1)	Power Tiller (2)	4-wheel tractor under 45 hp (3)	4-wheel tractor over 45 hp (4)	Total (5)=(2)+(3)+(4)	Water pump
Northeast (NE)	1	1,887,378	0.013	0.002	0.025	0.04	0.041
	2	1,062,872	0.004	0	0.002	0.006	0.01
	3	1,853,307	0.014	0.002	0.001	0.017	0.045
	4	1,549,988	0.006	0.002	0.012	0.02	0.015
	5	1,534,646	0.005	0.007	0.136	0.198	0.067
Average NE			0.019	0.003	0.135	0.057	0.038
North (N)	6	1,275,940	0.079	0.017	0.314	0.410	0.088
	8	1,167,176	0.164	0.012	0.117	0.293	0.089
	9	756,037	0.157	0.032	0.201	0.390	0.12
	10	704,914	0.17	0.015	0.087	0.272	0.136
Average N			0.136	0.018	0.192	0.346	0.1
Central (C)	7	685,633	0.13	0.077	0.332	0.544	0.122
	11	1,597,188	0.419	0.101	0.194	0.714	0.281
	12	768,246	0.091	0.03	0.163	0.282	0.144
	13	769,520	0.206	0.013	0.102	0.326	0.094
	14	132,486	0.751	0.014	0.127	0.892	0.290
	15	481,534	0.116	0.034	0.086	0.232	0.118
	16	249,934	0.244	0.003	0.096	0.341	0.39
Average C			0.256	0.058	0.176	0.491	0.194
South (S)	17	1,360,095	0.108	0.007	0.062	0.177	0.031
	18	480,898	0.07	0.001	0.01	0.081	0.021
	19	312,805	0.044	0.006	0.021	0.071	0.029
Average S			0.094	0.006	0.045	0.14	0.029
Overall average			0.111	0.02	0.116	0.247	0.089

Source: Supachat Sukharomana, 1982.
Note: Average sizes assumed for power tiller, tractor (under 45 hp), tractor (over 45 hp) and water pump with 9, 12, 65 and 3.5 hp engines.

before the monsoon season. In areas where sugarcane and maize are the dominant crops, in addition to rice, the large tractors are quite popular. Most of the large tractors are owned by farmer-operators and are used extensively for custom work.

Because the size of area of each region differs, the availability of power per unit area (hp/ha) can be used as an indicator of the degree of mechanization for each region, agro-economic and crop type. The average horsepower per hectare of farm land for all tractors indicate that the Central Region is the most tractorized region, followed by the Northern, Southern and North-eastern Regions where the average hp/ha during 1979/80 were 0.49, 0.14 and 0.057, respectively, (Table 7). In the Central Region the tractor power available varies from 0.237 to 0.892 hp/ha in different zones.

Mechanization Support Arrangements

Sales and Distribution

The agricultural mechanization sales and distribution network in Thailand appears to be adequate to meet present requirements. Large-scale importers, especially importers of large tractors, have a limited market and can easily reach potential customers from main offices usually in Bangkok and dealers in other cities. Local manufacturers have various systems of handling the sales and distribution of their products depending mainly on the size of the firm. Many larger firms have established a dealership network. Some of the firms with manufacturing facilities in the Central Region have their dealers in the North and North-eastern Regions. Smaller manufacturing firms have arrangements for selling through agents who often handle a wide range of agricultural inputs, usually have one or two salesmen who travel a limited area contacting potential buyers or sell usually from their factory.

Credit

The farmers in Thailand generally have access to one or more sources of investment and operational credit: the publicly owned Bank for Agriculture and Agricultural Co-operatives (BAAC), the private commercial banks, dealers or suppliers, village or local money-lenders, and relatives or friends.

Credit sale is usually offered by local dealers. For a power tiller, small 4-wheel tractor, water pump and thresher about 50 percent down-payment is the common practice. The interest charge on the outstanding balance ranges from 12 to 48 % but the general rate is about 24% within one season (6 months) payment (Taenkan, 1980). Private commercial banks are generally willing to give credit to big and viable farmers. Sources of funds for investment on farm machines come mainly from farmers' own savings (Pathnopas, 1980).

Farm Mechanization Relationship with Production, Employment and Income

In Thailand, the increase in agricultural production over the past two decades resulted mainly from expansion in the cultivated area, where tractors have played a key role in clearing as well as cultivating the newly-opened lands. Large tractors are used for dry land preparation to enable the farmers to plant their crops at an early date as well as to conserve moisture more effectively. Tractors

and power tillers enable farmers to grow a second crop on a larger area than is possible by using buffaloes. Threshers reduce the threshing time and thus releasing labor for land preparation and planting operations for the second crop. Harvesting of the dry season crop usually starts early in the wet season. The threshers reduce time in threshing and thus reduce crop damage.

Anuwat (1982) used the wet season data of a sample of irrigated rice farms in Suphanburi Province in the Central Region. He found that the use of a small farm tractor in land preparation increased the farm output and decreased the labor requirement. Tractor farms were found to use more fertilizer and used high yielding varieties as well as transplanting most of the rice crop. He also found that tractor farms which used the transplanting method (99.8%) utilized more labor than those bullock farms which used the broadcasting method (26%). Given the assumption that both tractor and bullock farms employ the same amounts of inputs, Anuwat calculated that the adoption of a tractor increased output from 5 290 kg to 8 615 kg per ha, an increase of 62.85%. If only direct impact is considered, the increase is about 28.83%. The labor requirement declines by 14.66%.

Nongluck (1980) studied the factors influencing farm machinery utilization using farm level data of the 19 agro-economic zones obtained from the Division of Agricultural Economics. Using regression analysis, he found that multiple cropping enhances the use of farm machinery. The upland crop area cultivated was found to be positively related to the number of four-wheel tractors and water pumps. Four-wheel tractors were found more suitable for upland cultivation because they possess greater power for dry land tillage whereas 2-wheel tractors were mostly used for puddling in rice cultivation. The regions with higher labor wages and higher farm income were more mechanized than the regions with lower labor wages and lower farm income.

It might be suspected that workers released by farm machines could have caused some local unemployment problems. There is no evidence, however, in support of this view. The farming areas that have adopted mechanization more extensively are relatively more developed and have higher wage rates. The high wage rate indicates that labor supply is relatively scarce.

The rapid adoption of farm machines in Thai agriculture has generated significant employment in the farm machinery industry, marketing and repair services. It is estimated that about 10 000 workers are employed by the manufacturers of power tillers, small 4-wheel tractors and other farm equipment. It is difficult to estimate the employment created in the marketing and services system. It is estimated that the marketing costs account for about 15-20% of the factory price. Farmers who own farm machines may receive repair services from a local repair shop or local manufacturer. In the case of a small manufacturer the repair and maintenance services are offered by the manufacturer directly to the farmers. This type of business promotes employment in rural areas.

The adoption of new and high yielding varieties of rice is usually accompanied by the new production technology involving mechanization. In this regard farm mechanization may have helped in narrowing the urban-rural income gap but within the rural sector the income gap between the rich and poor may have, in fact, widened. Tractors and rice threshers, have proved to reduce cost in land preparation and threshing. Mechanization also improves farmers' income through double cropping and off-farm jobs. A farmer who owns a machine makes some additional income from contract work.

A farmer who owns a large 4-wheel tractor earns about US$400 per year from custom ploughing services (Pak-Uthai, 1981). A small tractor owner also rents out his tractor to farms in the nearby area. In 1979, rice thresher owners earned an additional income of US$ 640-1013 per machine from the custom services (Pathnopas, 1980).

Reasons given by farmers in using tractors for land preparation are "to save time in farm work", "can plant on time", and "easy work and reduces drudgery".

Supachat (1982) analysed the profitability of tractor and thresher investment using partial equilibrium analysis and the discount cash flow analysis. He found that considering the depreciation and the interest on investment and the returns from the machine, the total revenue is more than the total cost in the case of a large tractor, 2-wheel tractor and rice thresher. The rate of return on investment in large tractors is around 13-15% while it is about 12% for power tillers. These rates of return which are close to the opportunity cost of capital in the market indicate that there exists a high competitive market for custom services. The rice threshers have the highest rate of return on investment ranging from 40 to 45%. This rate of return would decrease as more threshers are bought by the farmers.

The adoption of farm mechanization improves the social welfare of the rural people and makes rural life much more pleasant. The gap between urban and rural

areas may decrease and, consequently, slow down the migration of people from rural areas to the metropolitan area.

Mechanization Strategy

It is recognized that most of the future increases in agricultural production can only come from an increase in the output of the existing cultivable area. Changes in the existing land use patterns will be required to:

(i) increase the amount of multiple (double and triple) cropping,
(ii) reduce the size of cultivable land which is presently fallowed each year, and
(iii) convert selected land areas from shifting cultivation systems to permanent systems.

Climatic conditions and the availability of irrigation water are the main controlling factors that determine the potential for increasing the area under multiple cropping. A considerable increase in double or triple cropped area is feasible but a crucial element in enabling it to be practised is the availability of adequate mechanical power, primarily for timely land preparation between crops. Whether this requirement for timeliness can be met with animal power which has a ploughing capacity of about 0.1 ha/day, or calls for mechanical power ploughing with an output of about 0.6 ha/8-h day for a power tiller and 3 ha/8-h day for large tractor, depends on the number of days available for land preparation and the area each farmer is intending to double or triple crop. It seems reasonable to assume that much of the present area which is double or triple cropped utilizes tractor power for primary tillage (Gifford, 1981). It is also likely that the new area which has potential for multiple cropping will utilize animal power for primary tillage in the initial stages of development, and the farmers will switch to tractor power as their incomes rise due to increased output. The strategy should be to ensure the availability of tractors (mainly power tillers) to the farmers who are advancing rapidly in management ability and income, with the understanding that they, in turn, would provide tractor hire services to their immediate neighbors.

A large amount of upland fallow land suggests that in addition to moisture constraint there is a farm power shortage at planting time. Because of this, farmers are unable to prepare the land for seeding during the very short optimum period of time within which the crop must be seeded for successful production. In addition, farmers give priority to their paddy land so as to ensure the production of enough rice for family consumption, and any conflict for farm power between paddy and upland crops is usually settled in favour of paddy. The approach suggested most frequently to reduce the size of annual upland, fallow, especially in the Northeast, is to prepare the land before the rainy season (i.e. in the dry state) so planting can be timed to fit climatic conditions rather than the needs of land preparation. This means, however, that ploughing should be carried out with tractors of over 45 hp. Generally, draft animal and small tractors are technically unable to plough upland soils in a dry state. The mechanization strategy to support a reduction in the area left fallow should be to provide adequate large tractors and appropriate implements which can carry out primary tillage, especially in the Northeast, before the start of the rainy season while the soil is still dry. The approach should be to support local progressive farmers in purchasing and operating large size tractors and implements on a multi-farm use basis with a radius of operation which would ensure economic and financial viability.

In the Central Plains, large tracts of land are ploughed dry immediately after the first early monsoon showers usually with large tractors as these areas get flooded during the rainy season and grow deep-water rice varieties. In the Central Region especially for land preparation and cultivation of sugarcane, farmers use large tractors. Four-wheel tractors are becoming very popular in areas where farmers grow upland crops like cotton, maize, soybean, mungbean, etc.

Shifting cultivation is most widely practised in the Northern Region mainly because farmers lack the power and equipment needed for permanent cultivation systems. The land is difficult to work with hand tools and often this level of technology is all that farmers have. Crop yields and incomes are low. The mechanization strategy to support the conversion of selected land areas, mainly in the Northern Region, from shifting cultivation to permanent cultivation system should focus on mechanical power technology for land clearing and forming, and for primary tillage. The approach should be to develop local farmer contractors, equipped with large tractors and appropriate implements which would be used on a multi-farm basis in a reasonable radius of operation.

Future Demand for Farm Machines

The demand for both power tillers and 4-wheel tractors is expected to increase steadily. According to the estimates of the

Table 8 Domestic Need for Tractors

Year	Power tiller	4-wheel tractor	Total
1975	29,660	2,982	32,642
1976	34,166	3,414	37,580
1977	38,465	4,058	42,523
1978	40,969	4,308	45,277
1979	44,240	4,740	48,980
1980	47,780	5,210	52,999
1981	51,600	5,730	57,330
1982	55,730	6,300	62,030
1983	60,180	6,930	67,110
1984	65,000	7,620	72,620
1985	70,200	8,380	78,580
1986	75,810	9,220	85,030
1987	81,870	10,140	92,010

Source: Bank of Thailand.

Bangkok of Thailand, the demand for power tillers will increase from 51 600 units in 1981 to 81 870 units in 1987. Similarly, the demand for 4-wheel tractors is expected to increase from 5 730 units in 1981 to 10 140 units in 1987 (**Table 8**).

If we assume that the annual purchases of selected power-operated farm machines by the farmers in Thailand for the next 3-4 years will be as is shown in **Table 9**, these purchases will amount to US$ 200 million annual investment by the farmers in the farm machines. All the engines (including locally assembled) to power these machines as well as some of the parts for hydraulic and transmission systems of the locally-made tractors are imported. The investment in imported engines, parts, and components for these machines is estimated to be about US$ 160 million, representing about 80% of the total annual investment.

Table 9 Estimated Annual Investmet in Selected Power-Operated Farm Machines in Thailand

Item	Numbers	Average size (hp)	Average Cost* (US$)			Total Cost (US$ million)		
			Local currency	Foreign** currency	Total	Local currency	Foreign exchange	Total
Power tiller	50,000	8	400	900	1,300	20	45	65
Tractor under 45 hp	5,000	18	2,000	3,000	5,000	10	15	25
Tractor over 45 hp	3,000	70	2,000	23,000	25,000	6	69	75
Water pump	60,000	5	50	450	500	3	27	30
Thresher/ sheller, sprayer, etc	5,000	8	200	800	1,000	1	4	5
			Total			40	160	200
			Percent			20	80	100

* Average cost also includes the cost of associated equipment and accessories.
** Foreign currency cost shown here mainly inlcudes the cost of power unit and some imported parts. As the materials for the construction of farm machinery are alsmot all imported, the foreign exchange cost would be higher if material costs are included.

REFERENCES

Anuwat Wongsangaroonsri (1982). Farm Mechanization, Production and Labor Requirement. Master's Thesis, Faculty of Economics, Thammasat University, Bangkok, Thailand.

Gifford, R.C. (1981). Report on Agricultural Mechanization Strategy Guidelines for Thailand. UNDP/FAO Project No. ThA/79/005. Bangkok, Thailand.

Jaruwat Mongkoltanatas (1981). Survey of Agricultural Machinery Manufacturers. Agricultural Engineering Division, Department of Agriculture, Ministry of Agriculture & Cooperatives, Bangkok, Thailand.

Jaruwat Mongkoltanatas (1983). Personal Communication.

Nongluck Jongsuwat (1980). Productivity Growth and Farm Machinery Adoption in Thai Agriculture. Master's Thesis, Faculty of Economics, Thammasat University, Bangkok, Thailand.

Office of Agricultural Economics (1982). Selected Economic Indicators Related to Agriculture, No. 84(6) 1982. Ministry of Agriculture & Cooperatives, Bangkok, Thailand.

Office of Agricultural Economics (1982). Agricultural Statistics of Thailand, Crop Year 1980/81, Agricultural Statistics No. 150. Ministry of Agriculture & Cooperatives, Bangkok, Thailand.

Pak-Uthai, Veera (1981). An Economic Analysis of Farm Machinery: A Case Study of Hired Tractors in 1979. M. Sc. Thesis, Kasetsart University, Bangkok, Thailand (in Thai).

Pathnopas, Renu (1980). The Economics of Rice Threshing Machines in Thailand: A Case Study of Chachoengsao and Suphanburi Provinces. Master's Thesis, Faculty of Economics, Thammasat University, Bangkok, Thailand.

Supachat Sukharomana (1982). The Impact of Farm Power Strategy in Thailand. Paper presented at the International Seminar on Farm Power, 25-29 October, 1982. A.R.T.I., Colombo, Sri Lanka. Department of Economics, Kasetsart University, Bangkok, Thailand.

Taenkam, Pathom (1980). The Small Tractor Industry. Master's Thesis, Faculty of Economics, Thammasat University, Bangkok, Thailand. ■■

The Farm Machinery Industry and the Development of Farm Mechanization in Japan



Hiroyuki Nishimura
Professor of Agric. Economics
College of Agriculture
Kyoto University
Kyoto 606, Japan

Abstract

The improvements in Japanese agriculture have not been solely based on the efforts of the farmers alone. This paper will look at the contribution of the farm machinery industry to the development of Japanese agriculture.

The rapid development of farm mechanization in the post-war years has been due to the efforts of the farm machinery industry in meeting the farmers' needs and demands. The advantages of mass production and improvement brought about by research efforts have resulted in high quality machinery being produced at prices farmers could afford. In addition, sales promotional activities have aided the mechanization of farming. Educational and machinery use programs, prompt and courteous after-sales services (repair and maintenance services) have all contributed to support the mechanization of the Japanese farming sector.

Note: This paper was partly reported at the Seminar on the Mechanization of Small-Scale Peasant Farming sponsored by the Agricultural Development Council, New York and J.C.I.E., 7-10, July 1980, Sapporo, Japan.

Introduction

The introduction of farm mechanization in Japan was the direct result of efforts to reduce farm drudgery and to substitute for the dwindling agricultural labor force. This, however, was not the only reason. For example, technological progress and the rationalization efforts of the farm machinery industry must also be considered. Farm machinery dealers have also played a vital role in bringing about the spread of farm machinery.

Farm mechanization after World War II experienced many changes. In 1949 the testing of machinery and implements began. In 1953, "The Machinery Development Law" was enacted to serve as a base to transform the old industry into a modern one. Government subsidies for training, guidance, research, inspection systems, and so forth were established by this law. Later, personnel for inspecting farm machinery were trained and field testing of machines was made mandatory in each prefecture. In addition, the Farm Mechanization Research Institute was established to improve the farm machinery industry. Furthermore, the modernization of small-and medium-sized industries was also supported and encouraged by "The Tentative Law for the Development of the Machinery Industry" of 1961, and by "The Law for Promotion of Modernization of Farms" in the following years. These lead to drastic changes in the methods of production and management systems.

Farm mechanization at the farm level was promoted by a series of agricultural structural improvement policies aimed at the modernization of farming. These involved subsidies to supply credit and other kinds of help for the acquisition of farm machinery and equipment. The first agricultural structural improvement policy was enacted in 1962. These policies created a great demand for farm machinery. The budget for farm mechanization and related projects of the Ministry of Agriculture since then increased year by year.

Mechanization was strengthened by the establishment and expansion of departments of agricultural machinery in the agricultural universities and experimental stations. Training institutes and research programs related to farm machin-

ery were supported in the same manner.

Production of Farm Machinery

The production of farm machinery in Japan started as a small-scale, traditional local industry which merged into a large-scale modern industrial factory system. The latter basically consists of different divisions of business such as research, facilities, structure, inspection systems, buying and selling, repairing, and other related activities.

In 1970, due to the rice production adjustment policy, the production of farm machines suffered a setback as there was a substantial decrease in production and many firms went bankrupt. However, the business revived again in 1977.

The trend of farm mechanization after World War II shows that in the initial stages the petroleum engine was produced in great numbers, but its development has been stagnant since around 1960. Since then the production of threshers and power cultivators increased. The production of binders, auto-tricycles and small trucks for farm use subsequently increased. The recent mechanization of rice production has resulted in the remarkable development of medium-size tractors, binders, dryers, processing facilities, and so forth in the 60's. From 1974, the demand for farm machinery increased due to technical advancements, especially due to the inventions and improvements of rice transplanters and combines, which permitted the mechanization of the entire farming process from plowing to harvesting.

The expansion of the farm machinery market in Japan after World War II was dependent upon the improvement of products and the creation of new product types. This can be seen from the fact that the machines are highly efficient and have diverse uses. For example, around 1955 the walking-type tractors and power tillers were developed, followed by wheel-type tractors and binders around 1965, and the improvement of wheel-type tractors, automatic rice combines and rice transplanters since about 1970 (Fig. 1). These developments suited the farmers' needs. For example, medium-size automatic combines have diverse uses and are suited to the small farm size and farmers' preferences.

The monopolistic centralization of production grew with the production of power cultivators in 1955. The large manufacturers captured 50% of total machinery production (75% for power cultivators) in 1960. The monopolistic power of the large firms seems to be well-established now. Small manufacturers faced difficulties with regards to quality improvement and forecasting demand in the small market. As the market expanded the benefits of mass production became evident. Furthermore, because sales activity in the village-level market had to be modernized with respect to the dissemination of information, services, and credit, large manufacturers had more advantages. At present, there are four manufacturers that monopolize the farm machinery market. They produce up to 40% of power cultivators as well as 70 to 90% of the tractors, transplanters, and combines.

Farm machine prices have been increasing. But in comparison with the wholesale price index, the increase of farm machine prices is comparatively low relative to other agricultural inputs such as fertilizer, chemicals, and so forth.

There has been a trend of price

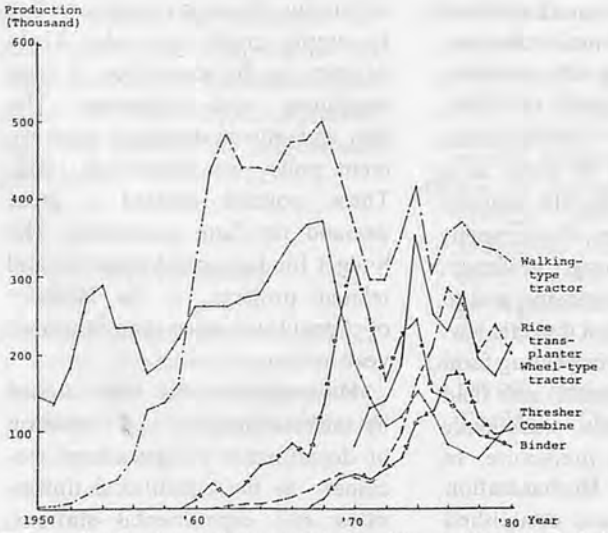


Fig. 1 Production of farm machinery. (Power-tiller is included among walking-type tractor) Source: Production Yearbook, MITI

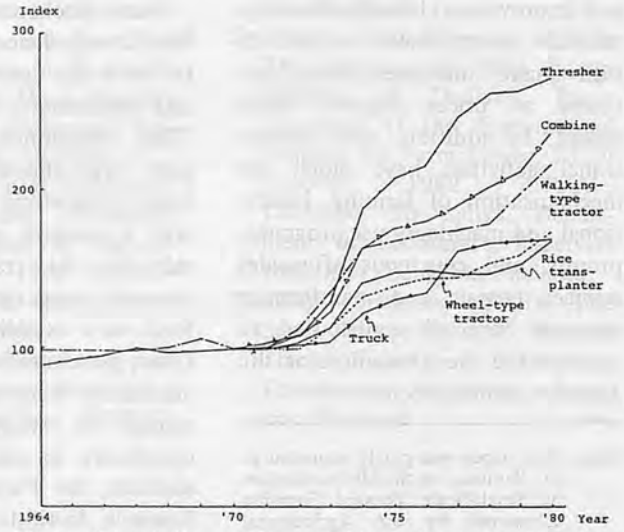


Fig. 2 Price indices of farm machinery in rural areas. (Base year: 1970=100; Source: Farm Machinery Yearbook, Shin Norin-sha)

increases in the farm machinery sector. Since 1970 the prices of threshers, combines, and dryers have tended to increase due to the substantial improvement in the machines. In contrast, due to mass production and intense sales competition, the prices of tractors and binders remain low (Fig. 2).

Farm machines have different price system than other products. For example, the Zen-noh (National Federation of Agricultural Co-operatives) has about a 30-percent share of total farm machinery sales. It consults two times a year with individual manufacturers to determine the price. As a buyer, the Zen-noh is said to have substantial power.

Management of the Farm Machinery Industry

With regard to the farm machinery output, there are comparatively few finished products, most of which are sub-contracted or have components ordered from other firms.

After World War II most factories producing military hardware were converted into units producing farm machines. Though most of them were obsolete, new technology was adopted during the period of economic growth. Along with this technological progress, the productivity per worker also increased. Efforts to increase the efficiency of production can be seen in Fig. 3. In response to farmers' demands for a reduction in the labor inputs and a shortening of work hours, manufacturers developed design of machines to meet these needs.

Research institutes have been established and the budgets for research and development of each farm machinery manufacturer have been increasing. In the case of Company U, the cost of development in relation to the total sales amounts to 1.5-3.0% (Fig. 4).

In 1970, the farm machinery industry suffered reduced revenue and as a result had to improve its management. To compound the problem, during the following next few years manufacturers suffered from the effects of the dollar shock which made economic conditions stagnant. After that, there was some improvement and the industry recovered. However, rice production adjustments have affected the revenue revival.

Marketing Channels

Marketing channels for farm machinery in Japan can be classified into two main lines: i) dealers and ii) agricultural co-operatives. The dealers (retailers) have formed a common organization [Federation of Farm Machinery Merchants' Co-operatives] to compete with the agricultural co-operatives. The integration of retailers and the direct sale system is the major vehicle for conducting sales activities. Most wholesalers also conduct retail business. Recently, each manufacturer developed its own wholesale business and distribution system. For example, in Japan, these manufacturers had 209 sales agents out of which 90% belong to the

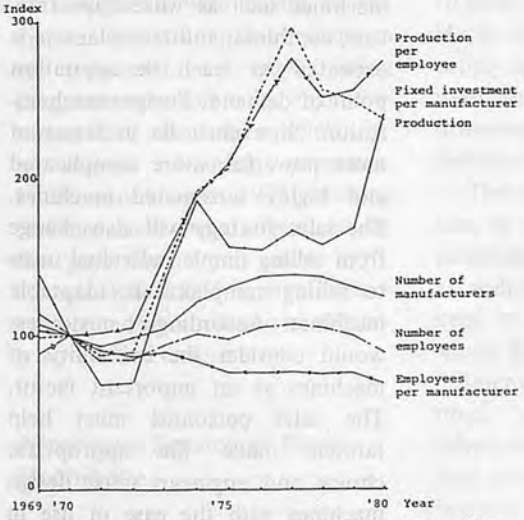


Fig. 3 Trends in production and number of employees and manufacturers. (Source: Statistical Yearbook of Industry, MITI)

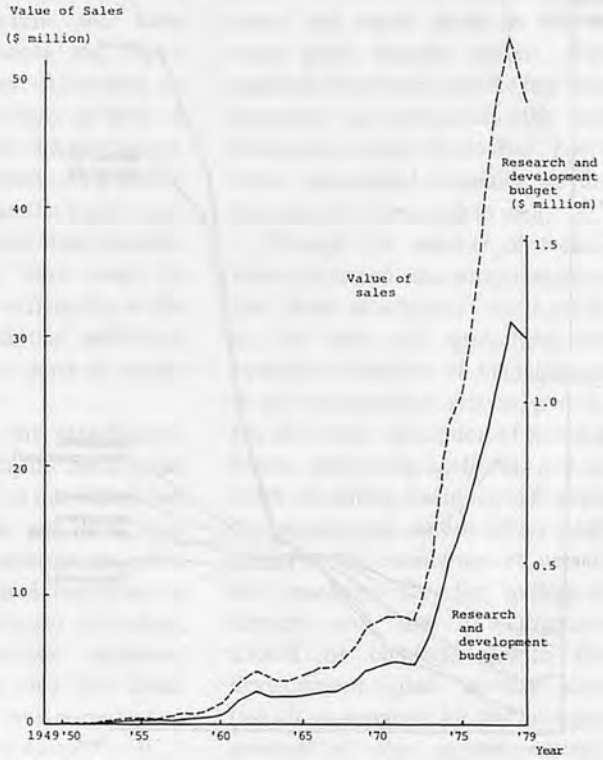


Fig. 4 Research and development budget. (Data: Courtesy of U Company)

four large manufacturers in 1976. These agents dealt exclusively with one manufacturer's products, while wholesalers and small dealers dealt with the farm machinery products of several manufacturers. The fierceness of competition has forced retailers to rationalize their business operations and as a result, their sales performance has improved to some extent. This phenomenon is shown in Fig. 5 where it shows that the sales per retailer has been increasing tremendously while the number of retailers has decreased and the trend line of employees per retailer has been slightly increasing.

The agricultural co-operatives created marketing channels in 1961 to deal in farm machinery. Before World War II the agricultural co-operatives' marketing channels had only a 5-percent share of the total farm machinery sales. However, the goverment policy during the war (controlling production and distribution of manufactured machinery) helped them to secure about 30-percent share of the total sales (2). They had to compete with manufacturer-dealer channels again when the wartime control was withdrawn. Though the share of business by agricultural co-operatives increased until 1967, their sales share afterwards appears to be on a declining trend.

There are several problems in regard to the sales of farm machinery by agricultural co-operatives. For example, the sales are based upon advance orders by the agricultural cooperatives at the beginning of the year. The prices of machines sold by agricultural cooperatives are not always as competitive as those offered by retailers. It has also been argued that the after-sale services offered by agricultural co-operatives have not been adequate nor satisfactory.

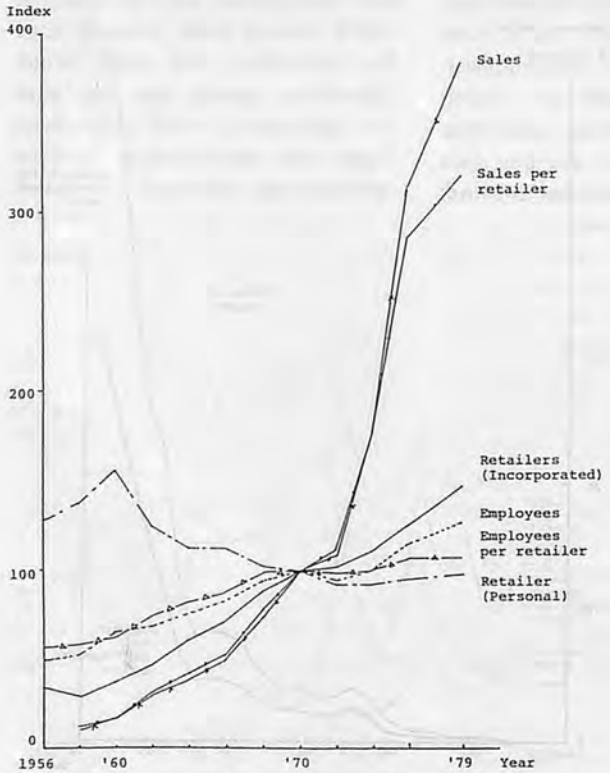


Fig. 5 Trends in sales, employees and number of retailers. (Source: Statistical Yearbook of Commerce: Industry, MITI)

Sales Promotion and Market Expansion

Innovation and improvement in farm machinery has been continuously carried out by the industry. This has also led to price increase in different models. The farmers have difficulty in making choices on which model to use and often cause them to invest in some unnecessary equipment. This is partially due to the industry's sales promotional activities.

These intense promotions have also brought out another problem; i.e., the traded-in and second-hand machine business that has also expanded. Recently the sales of second-hand machines has increased. It has been estimated that their share of the total demand is approximately 40% (3). However, their sales market and distribution systems have not been satisfactory since the machinery dealt with are neither well-standardized nor widespread except in some cases. It is crucial that the quality of machines is guaranteed and properly evaluated. The government started experimental marketing facilities for second-hand farm machinery in 1979.

During the early 1980's, the expansion in the use of farm machines such as wheel-type tractors, combines, and transplanters is expected to reach its saturation point of demand. Further mechanization, then must be in terms of more powerful, more complicated and highly automated machines. The sales strategy will also change from selling simple individual units to selling complex but adaptable machines. Accordingly, customers would consider the suitability of machines as an important factor. The sales personnel must help farmers make the appropriate choice and engineers must design machines with the ease of use in mind.

Technical Training in Machinery Use

Accompanying the intense sales competition has been the establishment of service stations for machinery use and better training of technicians. Manufacturers have recognized the importance of training institutes since the early stages of farm mechanization. For an example, the Institute of Company S was founded in July, 1949 to train technical personnel. In pace with the development of farm mechanization, training programmes were offered to farmers, agricultural extension workers, technical advisers and related personnel (Fig. 6). The number of trainees has increased substantially. There are variations in the training programs.

The National Federation of Agricultural Co-operatives undertook a policy of training in order to provide better services. As a result, several agricultural machinery training centers were set up all over the country in order to secure reliable technicians in an effort to improve sales and services. Later, many training centers were established among the local agricultural co-operatives.

Programs aimed at improvements in the skills and techniques of servicemen with regard to the maintenance and repair of machines are supported, not only training programs sponsored by manufacturers but also, since 1963, by government training programs. Furthermore, since 1971, training facilities have been subsidized by the government and since 1975, licences for skilled operators have been issued upon passing an officially authorized examination.

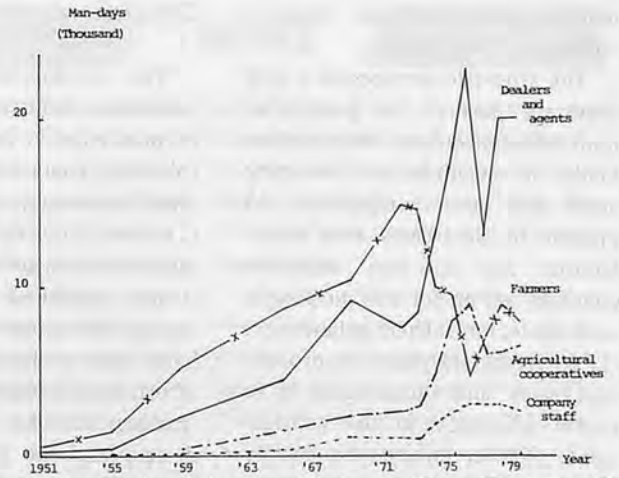


Fig. 6 Number and types of trainees. (Data: Courtesy of U Company)

After-sales Service of Farm Machinery

Sales agents (dealers) have played an important role in farm mechanization. They give elaborate instructions to farmers on the methods of, not only handling new machines, but also their maintenance. It is estimated that about 40% of the dealers sales margin is devoted to these activities (4).

In the development of farm mechanization, it is important not only to have capable technicians and better facilities, but also to properly manufacture and keep parts for maintenance and repair of farm machinery. According to law, manufacturers have to keep in stock spare parts for the life expectancy of the machinery. As a matter of fact, many manufacturers used to keep them beyond these periods. Much effort has been made to supply spare parts efficiently to the users and to maintain sufficient inventory of spare parts in recent decades.

The need for the standardization of spare parts has been of an increasing concern of manufacturers as well as dealers, and thus they keep a large inventory of parts which have identical functions in different machine types (elements, rings, plugs, nozzles, strainers, valves, wires, tires, etc). This trend may continue to save costs and to improve services for users.

At the initial stage, agricultural co-operatives had a disadvantage because of the lack of after-sale service system. Farmers had machines repaired at the manufacturers' or dealers' repair shops because the agricultural co-operatives did not have their own service stations at that time. To overcome this weakness, the *Zen-noh*, Prefectural Economic Federations of Agricultural Co-operatives, and agricultural co-operatives set up their maintenance and repair shops as well as spare parts supply centers. The number of technical service facilities increased up until about 1967 and remained constant thereafter. There were accelerated increases in the number of technicians as well.

Though the number of technicians increased, the service appears less than satisfactory, particularly in the case of agricultural co-operatives because of inadequacies in the management system, personnel allocation, allocation of working hours, evaluation methods, and so forth. In selling machines to farmers the agricultural co-operatives must consider the economics of use of the machines for the individual farmers and that the machine should be compatible with the development plan in the area (which is designed by the advisory services of the agricultural co-operatives). Due to these considerations, the agricultural co-operatives

remain weak at sale business relative to other dealers.

The after-sales services are a very necessary part of the process of farm mechanization, since various kinds of machines are becoming more and more complicated. At present, in most cases, each manufacturer has its own wholesale company set up for this purpose in each prefecture. Their policies are: (1) to formulate plans for production, sales, and financing so as to ensure efficiency in the management; (2) to ensure the proper stocking of finished products as well as spare parts; (3) to distribute and place salesmen and technicians more efficiently; and (4) to back up the products with after-sales services.

Manufacturers also provide safety checks for the machinery, and a compensation program exists for accidental injuries sustained while operating the machines. The users' benefits are supported by these services.

Conclusion

The development of the farm machinery industry, together with its marketing in Japan has had the following characteristics: (1) great effort in research and development; (2) based on new technology and improved management productivity, it has continued to develop; (3) strong sales promotion techniques have been evolved; (4) substantial efforts in machinery education and training for the company staff, dealers, and the farmers have been spent; (5) great efforts and action to provide a system for prompt, courteous, and elaborate after-sales services for the farmers have been provided; and (6) substantial support by government policy measures for both farmers and business has been actively provided.

The highly-mechanized farming operations that prevail in Japan today have been realized and stimulated on the basis of the foregoing development of the farm machinery industry.

REFERENCES

1. Nishimura, Hiroyuki; "Inasaku Kikaika no Keizai to Shakai (Economy and Society of Farm Mechanization)", Kaihara (ed.) Inasaku no Kikaika (Farm Mechanization in Rice Production), Ryokuei-sha, Tokyo, 1976.
2. Kishida, Yoshikuni (ed.); Noh-ki Sangyo Hyaku-nen (A Hundred Year of Farm Machinery Industry), Shin Norin-sha, 1968.
3. Yonemura Junichi; Farm Machinery Marketing and After-sale Service Network in Japan, Agricultural Mechanization in Asia, Spring, 1979, Shin Norin-sha.
4. Kishida, Yoshikuni; Historical View of the Development of Agricultural Machine Industry in Japan, Agricultural Mechanization in Asia, Autumn, 1971, Shin Norin-sha. ■■

INDEX TO ADVERTISERS

Howard Alatpertanian Sdn. Bhd 93
Kaneko Agricultural Machinery Co., Ltd. 4
Kobashi Kogyo Co., Ltd. 92
Kubota, Ltd. 2
Mametora Agric. Machinery Co., Ltd. 94
Matsuyama Plow Mfg. Co., Ltd. 93
Ochiai Cutlery Mfg. Co., Ltd. 6
Ohashi Agricultural Machinery Mfg. Co., Ltd. . . 92
Shizuoka Seiki Co., Ltd. 91
Tokai Industry Co., Ltd. 91
Toyosha Co., Ltd. 3

Shin-Norinsha Celebrated 50th Anniversary on October 14, 1983

The Shin-Norinsha Co, Ltd, publisher of AMA, celebrated the 50th anniversary at the reception hall of Palace Hotel in the center of Tokyo.

The party was attended by 400 distinguished guests from circles related to agricultural machinery: manufacturers, foreign diplomats government officials, universities, sales companies and associations, etc.

The Founder and Chirman Mr. Yoshikuni Kishida declared that the company will make fresh start for the coming 50 years on this day.



Saudi Agriculture 84—Third Agriculture, Irrigation and Agri-Industry Show

April 8-12, 1984, Riyadh, Saudi Arabia

Saudi Arabia is expanding its agricultural programme on an unprecedented scale. US$2.4 billion is being invested under the third Five-Year Development Plan, with the aim of making the Kingdom self-sufficient in agricultural produce at the end of the five year period in 1985. US$19 billion is being invested in irrigation projects over the same period.

Substantial investment in overseas technology has already brought a massive increase in agricultural development particularly in the dairy, poultry and crop production sectors. Wheat production alone has been stepped up from 3,343 tonnes in 1978 to 230,000 tonnes last year . . . but still the Kingdom is importing 75 per cent of its food needs. Saudi Arabia is committed to reducing this figure under the Development Plan and further agricultural investment is constantly under way.

Saudi Agriculture '84 will offer agri-industry around the world the best opportunity to demonstrate its ability to take part in this multi-billion dollar green revolution.

Saudi Agriculture '83 attracted 420 exhibiting companies on 255 stands from 25 countries with major participation from Britain, France, West Germany, Italy, Austria, Holland, Denmark, Sweden, Canada, USA and Australia 6 500 visitors including ministry delegations from Saudi Arabia, Bahrain, Kuwait, Qatar, Oman, Yemen and North Africa.

For details contact:
Gerry Dobson
Overseas Exhibition Services Ltd
11 Manchester Square
London W1M5AB, U.K.

Agroindustry Indonesia '84

October 23-27, 1984
Jakarta, Indonesia

Indonesia is now considered to be one of the most significant areas of the world for agricultural expansion. With a population of nearly 150 million people, Indonesia is the fifth most populous country in the world. The total land area is 200 million hectares, of which approximately one-third is suitable for agricultural use. The Indonesian government is committed to massive agricultural development, to increase production of all food and commercial crops, both for domestic consumption and developing exports.

Agroindustry Indonesia follows the first highly successful International Agricultural Exhibition held in Jakarta, November 1981. This show attracted over 350 exhibiting companies from 24 countries, and was visited by 5 469 trade-only buyers from all parts of Indonesia. The exhibition will be held at the Hall of Nations, and adjoining outdoor space, Jakarta Fair Grounds, in central Jakarta close to all major international hotels.

For further information contact:
Tim Etchells
Overseas Exhibition Services Ltd
11 Manchester Square
London W1M5AB, U.K.

Postharvest Institute for Perishables: An Introduction

The Postharvest Institute for Perishables (PIP) was founded because of concern with food losses from harvest to consumption in developing countries. The Institute was founded in October, 1980, at the University of Idaho, Moscow, Idaho, U.S.A. by means of a Cooperative Agreement with USAID. PIP is associated with two private development firms – Development Alternatives, Inc. (DAI) and Agri-Food Systems International, Inc. (AFSI) – which have substantial experience in providing technical assistance to developing countries. PIP also cooperates with international donor groups, research centers, bilateral and multilateral assistance groups, the U.S. Peace Corps, the private sector and others

in its efforts to reduce postharvest losses of perishable commodities.

The goals and objectives of the Postharvest Institute for Perishables are:

1. To increase the availability (without increasing production areas) of fruit, vegetable, root, tuber, spice, nut and oilseed crops, and to enhance the basic diet of people in developing countries by reducing postharvest food losses.
2. To reduce costs of these perishable commodities by improving the efficiency of marketing.
3. To encourage the development of processing and other industries associated with fruit, vegetable, root, tuber, spice, nut and oilseed crops.

Postharvest Assistance

PIP is prepared to provide assistance to developing countries in a variety of ways, including, but not restricted to:

1. Determine causes of postharvest losses.
2. Assess postharvest losses from harvest to consumption.
3. Prolong the storage and shelf life of perishable commodities.
4. Conduct feasibility studies on the potential for processing specific perishable commodities.
5. Assist in promoting export of fresh or processed perishable commodities.
6. Analyze and provide suggestions for governmental policies.
7. Help instructional institutions develop curricula and extension aids relevant to assessment and prevention of postharvest losses.
8. Provide microfiche or paper copies of any literature related to postharvest technology.
9. Coordinate placement in U.S. universities of developing country student candidates for Master's degrees or short-term non-degree programs relevant to assessment, reduction and prevention of postharvest losses in perishable commodities.

Technical Assistance Teams

PIP provides experienced technical assistance teams in response to requests from developing countries. The free services of a team may be provided for a maximum of 20 person-days at no cost to the host country or to the local AID Mission. Team services for periods longer than 20 dyas will require additional support funding.

Upon request, postharvest specialists – economists, engineers, entomologists, food technologists, horticulturists, plant pathologists, rural sociologists and others – are available for direct technical assistance to USAID Missions, host countries and AID/Washington.

Short Courses, Workshops and Seminars

Upon request from a developing country PIP can provide the services of appropriate postharvest specialists to conduct short courses, workshops or seminars in any field of postharvest technology.

Information Services

Information, documents and bibliographies on all phases of harvesting, handling, storage, marketing and processing related to reducing postharvest losses in fruit, vegetable, root, tuber, nut, oilseed and spice crops is available from:

Paulette Foss George
Postharvest Institute for Perishables
Information Center
Library Room 314
University of Idaho
Moscow, Idaho USA 83843
Telephone (208) 885-7059
Telex - TWX II: 510 776 0923
UI CID MOCW

Requests from developing countries will be answered free. Others will be assessed a nominal fee.

Specialized Training

Training consisting of degree or non-degree programs designed to assist qualified developing country personnel solve postharvest problems of perishable commodities is provided by PIP. Students sponsored under this program will usually study at a U.S. university for one or two years. Non-degree special programs may be of shorter duration and tailored to a specific need.

Cost

Short-term technical assistance and training is provided to host countries through USAID Missions. Depending upon the circumstances and budgetary limitations, Missions may be asked to furnish local per diem and transportation costs. Extensive assistance, or repeat visits, will require funding from Missions or other projects to support PIP teams.

How to Apply

Host country institutions and agencies desiring technical assistance or training may request such assistance through their USAID Mission. The Mission will submit the request through:

Dr. Robert F. Morris
S&T/AGR/AP 413A, SA-18
Agency for International Development
Washington, D.C. 20523
Ref: Project No. AID/DSAN-CA-0265
Pass cable to: Dr. Robert Morris
S&T/AGR/AP 413A

For additional information or for publications from the Information Center (PIPIC), write to:

Postharvest Institute for Perishables
College of Agriculture
216 Morrill Hall
University of Idaho
Moscow, Idaho USA 83843
Telephone (208) 885-6791
Telex - TWX II: 510 776 0923
UI CID MOCW

■■

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.2 Autumn, 1971
☐Vol.3 No.1, 1972
☐Vol.3 No.2, Summer, 1972
☐Vol.4 No.1, Spring, 1973
☐Vol.4 No.2, Autumn, 1973
☐Vol.5 No.1, Summer, 1974
☐Vol.6 No.1, Spring, 1975
☐Vol.6 No.2, Autumn, 1975
☐Vol.7 No.1, Winter, 1976
☐Vol.7 No.2, Spring, 1976
☐Vol.7 No.3, Summer, 1976
☐Vol.7 No.4, Autumn, 1976
☐Vol.8 No.1, Winter, 1977
☐Vol.8 No.2, Spring, 1977
☐Vol.8 No.3, Summer, 1977
☐Vol.8 No.4, Autumn, 1977
☐Vol.9 No.1, Winter, 1978
☐Vol.9 No.2, Spring, 1978
☐Vol.9 No.3, Summer, 1978
☐Vol.9 No.4, Autumn, 1978
☐Vol.10 No.1, Winter, 1979
☐Vol.10 No.2, Spring, 1979
☐Vol.10 No.3, Summer, 1979
☐Vol.10 No.4, Autumn, 1979
☐Vol.11 No.1, Winter, 1980
☐Vol.11 No.2, Spring, 1980
☐Vol.11 No.3, Summer, 1980
☐Vol.11 No.4, Autumn, 1980
☐ **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
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

New Machines from Howard-Alatepertanian Sdn. Berhad



The HOWARD "STINGER" is a strong small ROTAVATOR useful for: Backyard gardens; Nurseries; Glass houses; Vegetable cultivation; Inter-row weeding; Mixing garden mulch and potting soil; Small farm applications, etc. Cutting width: 508 mm

Engine: 3½HP or 5HP petrol engine



The HOWARD HFS500 Disc Spinner Fertilizer Spreader has a tough tubular steel frame and fibreglass hopper.

Features: Adjustable flow control; Back shield; Corrosion resistant plating; Adjustable spinner plates; Category 1, 3-point linkage; Fibreglass hopper;
Capacity approx. 470 kg

Specification: (H x L x W) 103 x 132 115 cm; Weight=63 kg

O.E.M. prices ex-factory Kuala Lumpur:

Stinger less engine	M$475
Stinger with 3½HP Shibaura engine	M$730
Stinger with 5HP ditto	M$087
HFS500 Fertilizer Spreader	M$845

The "Pulsa 3" Water Oscillation Hand Pump for Deep Wells



The "Pulsa 3" pump has two basic organs: an upper part which is situated outside the well and which comprises a plunger actioned by a lever, and a lower part at the bottom of the well comprising an elastic element (a series of special balls) inside a container closed at the bottom by a no-return valve. The two parts are joined together by a single one inch 16PN flexible plastic pipe.

After installation and once-only initial priming, the lever of the "Pulsa 3" is moved down and up. This movement is transmitted by the lever to the plunger, then by the plunger to the mass of water present in the feed pipe, and finally by the water to the special balls at the bottom of the well which favour and ensure the continuation of the oscillatory movement of the water. The actual pumping is thus done by the water being pumped as it oscillates in the column. As the water moves downwards, it transfers the energy to the special balls, and when it returns upwards the cinetic energy is such that the water, as it tends to continue its upward wourse, sucks into the feed pipe through the foot valve a certain quantity of water for each downwards/upward cycle. The pump is designed in such a way that the plunger in the upper part of the pump frees itself from its gasket as the new water enters the feed pipe at the bottom of the well, so that an equal quantity of water spills out of the pipe at the top, thus concluding the pumping cycle.

The "Pulsa 3" differs from all other deep well hand pumps in that it is the pump itself which determines the rhythm of pumping and not the user.

The construction of the "Pulsa 3" is entirely in heavy duty stainless steel and without organs of transmission or parts in relative movement below ground level. The weight of the pump (34 kg for the pump and 18 kg for 50 m of feed pipe) ensures extreme facility of installation and maintenance.

The "Pulsa 3" can be used vertically or horizontally with respect to the source of water. It can be used as a mobile unit. Operational depths with the one model are from 15 m to 50 m.

A 75 page complete manual is available:
Fluxinos Export Office
Viale Europa 6B
20060, Bussero,
Italy. ■■

BOOK REVIEW

Animal Drawn Multipurpose Tool Carriers

(India)

by B.K. Garg and R.S. Devnani

This bulletin contains the information on the animal-drawn multipurpose tool carriers which have been developed during the past 25 years. About 25 different designs of tool carriers developed in India and other countries are reported. The few latest designs of NIAE, U.K., ICRISAT, Hyderabad and French designs developed by Engr. Jean Nolle for African countries, some of which are commercially manufactured have also been reported. Looking to the present status of resource availability at the farmers level the animal power shall continue to serve the needs of the farmers in most of the third world countries including India. Therefore, animal power has attracted the attention of engineers, policy makers, planners, economists as the means of achieving higher productivity in agriculture.

The efficient and convenient tool carriers can be utilized to enhance the effectiveness of animal power. This is particularly important because of the high cost of the animals and their maintenance. The tool carriers of riding and walking type are a right step in utilizing the animal power because they take into account the crop-soil system as a whole and enable the utilization of the animals to the optimum level. The major field operations such as tillage, seeding, weeding and interculture and transport can be effectively carried out with the use of improved tools. It is hoped that this bulletin would serve the purpose and highlight the importance of tool carriers and their different attachments among the users, extension workers, manufacturers in the developing countries.

Size: 27 x 21 cm, 81 pp

Published by Central Institute of Agricultural Engineering Nabi Bagh, Berasia Road, Bhopal 462010, India

Year Book of Agriculture and Forestry Statistics 1982

(Korea)

It contains updated statistics on basic agricultural data, food grain production, livestock, farm household economy and agricultural production costs as well as information on food grain consumption, index number of agricultural and forestry production and additional statistics on farm chemicals, fertilizers and machinery in modern Korea. This publication also includes basic statistics on both domestic and foreign agricultural developments required for policy making and planning in agricultural development.

In accordance with the increasing demand that users have placed on our text, we have made considerable efforts to improve the quality of our data and to extend its coverage.

Size: 26 x 20 cm, 355pp

Cloth bound

Published by Director-General, Agriculture & Fisheries Statistics Office, Ministry of Agriculture and Fisheries, Republic of Korea

Land Drainage

(Netherlands)

Edited by M.J. Gardiner

This work is the result of a seminar on Land Drainage, held at Jesus College, Cambridge, United Kingdom, under the auspices of the Land Use and Rural Resources Programme Management Committee which is an advisory body to the Commission of the European Communities. The seminar was organized by the British Ministry of Agriculture, Fisheries and Food in collaboration with other organizations such as the Agricultural Research Council.

A subdivision is made into the following main topics: Drainage and reclamation of soils of low permeability; monetary aspects and planning of drainage; drainage in problem areas; and research and development. The volume contains twenty papers by experts from throughout the European Community but particularly from regions where land drainage is a serious problem. It also reports on visits to the Field Drainage Experimental Unit, Cambridge, to the ARC Letcombe Laboratory and to the Field Drainage Farm, Brimstone, Farrington.

The volume concludes by reporting the results of discussions on future research and development needs. It therefore presents an overall view of the current position in these aspects of land drainage and reclamation on a European Community basis.

Size: 25 x 18 cm, 343pp

Cloth bound, Price US$35.00

Published by A.A. Balkema Publishers P.O. Box 1675, Rotterdam, Netherlands

Small Hydropower Development – Renewable Sources of Energy Volume IV

(Thailand)

This volume on small hydropower development is the fourth in a series of sectoral directories on renewable sources of energy being issued under the ESCAP publications programme on co-operation among developing countries. Beginning with the second volume in the series, on biogas, the title was changed from TCDC to ECDC-TCDC to reflect the expanding scope and contents of the volumes intended to promote and support economic as well as technical co-operation among developing countries.

The present volume, like the preceeding ones on solar energy, biogas and wind energy, includes not only inventories of experts and institutions and the projects undertaken by them but also technological as well as economic details of the designs, prototypes and hardware developed in ESCAP member countries in Asia and the Pacific. The scope for co-operation among developing countries is also outlined. While it is hoped that more details will be forthcoming, the information contained in these volumes may be found adequate for initiating programmes of co-operation among developing countries.

While every endeavour has been made to include as many experts and institutions as possible the coverage may not be exhaustive. The secretariat invites suggestions for improving the coverage of these volumns.

Like the earlier publications issued in the ECDC-TCDC series, funds for the present volume have been made available by the Netherlands Government as extra-budgetary assistance to ESCAP. This exemplifies "triangular co-operation" under which developed countries contribute to a joint undertaking to promote co-operation among developing countries.

Size: 26.5 x 19 cm, 309p

This publication can be obtained, subject to availability, from ECDC-TCDC Services ESCAP Secretariat, The United Nations Building, Rajadamnern Avenue, Bangkok 10200, Thailand

---

Tractor and Small Engine Maintenance, Fifth Edition

(U.S.A.)

---

by Arlen D. Brown and R. Mack Stirkland

This book has been written for tractor operators, ranchers, farmers, teachers and students, as well as for all who own or operate small engines of the kind which power lawn mowers, garden tillers, riding mowers and compact tractors. Since the first three editions, entitled *Farm Tractor Maintenance*, dealt only with the subject of farm tractors, the title of the fourth and fifth editions has been changed to *Tractor and Small Engine Maintenance* in order to reflect this expanded coverage.

Tractors and their engines have gone through a tremendous amount of change and improvement since the last revision. The diesel engine has replaced the gasoline engine and the LP Gas engine on all but a few of the smaller farm tractors. Diesel engines are now available for agricultural use ranging from 3.5 to over 650 horsepower.

The emphasis for tractors has been shifted to more efficient and economical power units transmissions and drive-trains. Hydraulically operated or assisted tractor functions or operations have been greatly increased. The modern tractor has many more operator conveniences and monitoring systems that notify the operator if there are any mechanical or operational problems with the unit.

Approximately 120 new illustrations have been added to assist the reader. However, the new information contained in this book was not added as a replacement for the old, but rather as a supplement to it. There are still many thousands of older model tractors in use today, and they will continue to be used for years to come.

The need for preventive maintenance increases with the increase in tractor power, complexity and cost. Hopefully this book will assist the operator in preventing many costly and unnecessary repairs.

Size: 21.5 x 14.5 cm, 383p

Published by the Interstate Printers and Publishers, Inc. 19-27 North Jackson Street Danville, IL 61832, U.S.A. ■■

Co-operating Editors


Van Lancker


G B Hanna


A Kandiah


K P Srivastava


D. B. Ampratwun


M S Chaudhry


M S Choudhury


J.C. Igbeka


J P Mittal


E U Odigboh


N G Kuyembeh


A H Abdoun


M A Bedri


A. B. Saeed


W T Weerakoon


I de A Nääs


A L Phillips


A A Valenzuela


A H Mirdha


M R Goyal

— AFRICA —

Julien G. Van Lancker
Professor Visitor (Agricultural Engineering), University of Brundi, Brundi

George B. Hanna
Chairman, Agricultural Engineering Dept., College of Agriculture, Cairo University, Giza, Cairo, Egypt.

Arumugam Kandiah
Institute of Agricultural Research, P.O. Box 2003, Addis Ababa, Ethiopia

Krishna Prakash Srivastava
Head of the Department of Agricultural Engineering College of Agriculture, Addis Ababa University, P.O.Box 138, Dire Dawa, Ethiopia

David Boakye Ampratwum
Part-Time Lecturer, Agricultural and Food Engineering, University of Ghana, Legon, Ghana

Muhammad Siddique Chaudhry
Assistant Professor, Department of Agricultural Engineering, Alfateh University, Tripoli, Libya

Md. Shahansha-ud-Din Choudhury
Principal Research Fellow, Dept of Agricultural Engineering, Institute for Agricultural Research, Ahmadu Bello University, P.M.B. 1044, Zaria, Nigeria

Joseph Chukwugozium Igbeka
Associate Professor, Dept. of Agricultural Engineering, Faculty of Technology, University of Ibadan, Ibadan, Nigeria

Jitendra P. Mittal
Lecturer Grade 1, Dept. of Agricultural Engineering, Ahmadu Bello University, Samaru, Zaria, Nigeria

E.U. Odigboh
Professor & Head of Agricultural Engineering Department, University of Nigeria, Nsukka, 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
Director, General Administration for Engineering, Ministry of Agric., F & NR., Khartoum, Sudan (Until Dec., 1983: c/o The National Agric. Training Centers, Ministry of Agriculture and Water, P.O. Box 558, Riyadh, Saudi Arabia)

Mohamed A. Bedri
Director of Industrial Projects Implementation Administration (Projects Bureau), Ministry of Industry, P. O. Box 715, Khartoum, Sudan

Amir Bakheit Saeed
Lecturer, Dept. of Agricultural Engineering, Faculty of Agriculture, University of Khartoum, Khartoum, Sudan

Wimala Tissa Weerakoon
Manager & Director, Technology Development and Advisory Unit, University of Zambia, P.O.Box 32379, Lusaka, Zambia

— AMERICAS —

Irenilza de Alencar Nääs
Assistant Professor, Agricultural Engineering Dept., State University of Campinas, SP, Brazil

Allan L. Phillips
Project Manager – FAO-UNDP Project CHI/77/002 Technical Assistance to the Agric. Engineering Institute at the University of Conception, Chillan, Chile

A.A. Valenzuela
Head, Agricultural Engineering Department, University of Conception, Chillan, Chile

A.H. Mirdha
Visiting Professor, Dept. of Agricultural Engineering, Faculty of Superior Studies-Cuautitlan of the National Autonomous University of Mexico, Apdo. Postal-128, Cuautitlan de R.R., 54800 Edo. de Mexico

Megh Raj Goyal
Assistant Researcher, Agricultural Experimental Station, University of Puerto Rico, Subestación de Frutales S.R. No.2 Buzón 101, Juana Diaz, Puerto Rico

William J. Chancellor
Professor, Agricultural Engineering, University of California, Davis, California 95616, U.S.A.

Merle L. Esmay
Professor, Agricultural Engineering, Michigan State University, East Lansing, Michigan 48823, U.S.A.

— ASIA and OCEANIA —

Shah M. Farouk
Head, Dept. of Farm Power & Machinary, Bangladesh Agricultural University, Mymensingh, Bangladesh

Kshirode Chandra Roy
Senior Scientific Officer, Bangladesh Agricultural Research Institute, Joyedebpur, Dacca, Bangladesh

Manbahadur Gurung
Horticulture Extention Officer, Ministry of Development, Dept. of Agriculture, HA Bhutan P.O.HAA, Bhutan

Wang Wanjun
Chief Engineer and Vice Director of the Chinese Academy of Agricultural Mechanization Sciences, 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
Professor, Water Technology Center, Indian Agricultural Research Institute, New Delhi 110012, India

S.R. Verma
Dean, College of Agricultural Engineering, Punjab Agric. University, Ludhiana 141004, India

Siswadhi Soepardjo
Chairman, Agricultural Engineering Dept., Bogor Agricultural University, Jalan Gunung Gede, Bogor, Indonesia

Jun Sakai
Professor, Dept. of Agricultural Engineering, Faculty of Agriculture, Kyushu University 46-05, Hakozaki, Higashi-ku, Fukuoka 812, Japan

Bassan A. Snobar
Associate Professor, Faculty of Agriculture, University of Jordan, Amman, Jordan

Chang Joo Chung
Professor, Dept. of Agricultural Engineering, College of Agriculture, Seoul National University, Suwen, Korea

Paris Andreou
Associate Professor and Chairman,


W J Chancellor


M L Esmay


S M Farouk


K C Roy


M Gurung


Wang Wanjun


S Chandra


A M Michael


S R Verma


S Soepardjo


J Sakai


B A Snobar


C J Chung


P Andreou


M Z Bardaie


B K Shrestha


A D Chaudhry


B T Devrajani


A A Mughal


R M Lantin


C C Lee


R P Venturina


M H A Aziz


S Illangantileke


S K Kamathamby


T S Peng


G Singh


T T Pedersen


G Pellizzi


A Moens



J Kilgour
Department of Agricultural Economics and Business, American University of Beirut, Beirut, Lebanon

Muhamad Zohadie Bardaie
Head, Dept. of Field Engineering, Power and Machinery, Faculty of Agricultural Engineering, University of Agriculture Malaysia, Serdang, Selangor, Malaysia

Bala Krishna Shrestha
Agricultural Engineer, 4/141, Pulchowk Behind the Fire Brigade, Lalitpur, Nepal

Allah Ditta Chaudhry
Associate Professor and Chairman of the Department of Farm Machinery and Power, University of Agriculture, Faisalabad, Pakistan (on leave to New Zealand: Agronomy Dept., Massey University, Palmerston)

Bherulal T. Devrajani
Principal Investigator, Sind Agriculture University, Tandojam, Sind, Pakistan

A.A. Mughal
Assistant Professor, Faculty of Agricultural Engineering, Sind Agriculture College, Tandojam, Sind, Pakistan

Reynaldo M. Lantin
Dean, Institute of Agricultural Engineering and Technology, University of the Philippines at Los Baños, College, Laguna 3720, Phillipines

Chul Choo Lee
Project Engineer, Projects Department, Asian Development Bank, P.O. Box 789, Manila, Philippines

Ricardo 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, Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Sri Lanka

Suppiah Kathirkamathamby
Head, Agricultural Engineering Research and Development Division, Dept. of Agriculture, Peradeniya, Sri Lanka

Tien-Song Peng
Specialist, Plant Industry Div. Joint Commission on Rural Reconstruction 37, Nanhai Road, Taipei, Taiwan

Gajendra Singh
Associate Professor of Agricultural Engineering, Asian Institute of Technology, Bangkok, Thailand

-- EUROPE --

T.Touggaard Pedersen
Professor, Agricultural Engineering at the Royal Veterinary and Agricultural University, Copenhagen, Denmark

Giuseppe Pellizzi
Professor, Institute of Agricultural Machinery, University of Milano, Via G. Celoria 2—20133 Milano, Italy

Adrian Moens
Professor & Head, Dept. of Agricultural Engineering, Agricultural University, Dr. S.L. Mansholtlaan 12, Wageningen, Netherlands

John Kilgour
Lecturer in Engineering Drawing and Design, National College of Agricultural Engineering, Silsoe, Bedford. MK45 4DT, U.K. ■■

New Co-operating Editor


Yunus Pinar

Date of Birth: May 31, 1956
Nationality: Turkish
Qualification:
1980 M.Sc. Agricultural Engineering, Atatürk University
Experience:
Worked as an agriculture High Engineer in Ministry of Village Works for about 7 month in 1980.

Present Position:
Assistant at Agricultural Engineering Department, Atatürk university, Erzurum, Turkey

BACK ISSUES

(Vol. 13 No. 1, Winter 1982 ~)

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 13 No. 1, Winter, 1982)

Editorial (Yoshisuke Kishida) 9
Agricultural Engineering Technology for Developing Country Students (Merle L. Esmay) 11
Status of Agricultural Mechanization in Mexico (Ahmed Hossain Mirdha) 15
Influence of Soil-Tool Parameters on Unit Draft (S. Swain) 19
Economic Efficiency of Tractors on Punjab Farms (Parkash Mehta) . . . 22
Effect of Lug Angle of Cage Wheels on Tractive Performance of Dual Wheels under Submerged Soil Conditions (S.K. Rautaray, K.N. Singh) 27
Determination of Optimum Drying Conditions and Development of Drying Equations for Thin-Layer Drying of Parboiled Wheat (A. Chakraverty, R.T. Kausal) . . . 33
Mechanization for Modern and Traditional Agriculture in Sudan (E.S. Mahmoud) 37
Evaluation of Farmer's Competence to Maintain Farm Tractors (Sheruddin B. Bukhari) 45
Measurement of Hydraulic Properties of a Brown Flood-Plain Soil of Bangladesh (S.M. Rahman, B.C. Basak, A.K.M. Habibullah) 48
Alternative Gas-Fuel Producer for Driving Gasoline Engine (Part 1) – Charcoal Gas Producer (Jun Sakai, Yasuo Shibata) 51
Soil Crusts vs Seedling Emergence: Review (Megh R. Goyal) 62
Food Production and Rural Development in Commonwealth Countries (Nurul Islam) 79
News 81
Book Review 84

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 13 No. 2, Spring, 1982)

Editorial (Yoshisuke Kishida) 9
Performance of a Tractor-Mounted Oscillating Soil Working Tool (P.V. Narayanarao, S.R. Verma) 11
Human Energy Expenditure in Manually-Operated Rice Transplanter (Md. Abdul Baqui, Reynaldo M. Lantin) 14
Sprinkler System Evaluation: A Case Report (Mahmoud H. Abdel Aziz, Mohammed Saeed Hadrat) 17
Application of Sprinkler Irrigation in the Sudan (Khamies Kajo Konda, Tawfig Fahmi Demian) 23
Influence of Selected Seedling Mat Parameters and Planting Speed on Performance of Rice Transplanter (I.K. Garg, C.P. Singh, V.K. Sharma) 27
Performance of a Simple Tractor-Mounted Deep-Hole Digger (R.D. Singh, Bhagwan Singh, K.N. Singh) 34
Development and Testing of a Manually-Operated Dung Cleaner (H.C. Joshi, D.N. Jana, D. Chaudhri) 39
A Comparative Study of Conventional and Mechanized Farming Relative to Energy Use and Cost (A.C. Srivastava) 42
Tillage Machines Combined with Moldboard Plow (Sheruddin Bukhari, Jori Istavan, Lehoczky Laszlo, Banhazi Janos) 51
Performance and Potential of Rubber Rolls in Husking Paddy (U.N. Singh) 56
Elastic and Visco-elastic Properties of Agricultural Products in Relation to Harvesting and Post-Harvest Processes (U.G.N. Anazodo) 59
Performance Evaluation of a Modified Fertilizer Applicator (K.C. Oni) 67
Status and Problems of Mechanization in Sierra Leone (N.G. Kuyembeh) . . . . . .
Forced Aeration: A Technique to Handle High Moisture Paddy under Humid Condition (Surya Nath, A.K. Ganguly) 77
News 79
New Products 81
Book Review 86

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol.13, No.3, Summer, 1982)

Editorial (Yoshisuke Kishida) 9
A More Efficient Buffalo Plow (R.C. Fischer) 11
Performance of Harnesses Used for Draught Animals (B.P. Varshney, T.N. Mishra, Akhilesh Kumar, R.P. Singh) 15
Fuel Consumption of Tillage Implements (Sheruddin B. Bukhari, Jan Mohammad Baloch) 20
Economic Evaluation of Land Levelling (Riaz A. Khattak Mohammad Asrar, Jehangir K. Khattak, S.U. Khan) 23
Contribution of Ground Water in the Evapo-Transpiration Demand of Soybean (Glycine Max. L.) (K.M. Hassanuzzaman, S.M. Rahman, M.R. Biswas) 25
Effect of Preplanting Irrigation on Cotton Cultivation (Md. Motiur Rahman Khan) 29
Mechanization of Oil Palm Fruits Harvesting and Transportation in Malaysia (M. Zohadie Bardaie, Wan Ishak Wan Ismail) 31
Mechanization of Oil Palm Plantation Technology (Naresh Chandra Saxena) 35
A Cassava Harvester: Design Analysis and Prototype Development (E.U. Odigboh, S.F. Ahmed) 40
Design, Construction and Performance of a Jute Decorticating Machine (M.A. Mazed, K.C. Roy) . . . 53
Mechanization of Paddy Production in Malaysia (A.A. Mainul Hussain) 56
Mechanization of Family Farms in Nigeria (U.G.N. Anazodo) 59
Standardization and Quality Control in Agricultural Machinery (R.N. Sharma) 66
Paddy Straw Utilization for Bags and Mats (M.M. Kashyap, Amar Singh) 69
Calotropis procera (Ait.) R. Br. – Ak:A New and Free Source of Fibre and Renewable Hydrocarbons (Subhash S. Arora, Kiran S. Arora) 71
News 78
New Products 79
Book Review 85

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 13, No. 4, Autumn, 1982)

Editorial (Yoshisuke Kishida) 9
Clearing of "Alang-Alang" Steppe Land in South Sumatra, Indonesia (Gajendra Singh, Bambang Pramudya) 11
An Automatic Cassava Planter (E. U. Odigboh) 15
Appropriate Tine Arrangement for Better Tillage and Efficient Tool Performance (Muhammad Saleh Soomro, G. Spoor R. J. Godwin) . . 21
Animal Drawn Multi-Purpose Tool Carriers (R. K. Bansal, G. E. Thierstein) 27
Use of Oil Bubbles for Estimating Flow Rates in Open Channels (Amir Bakheit Saeed) 37
Briquetting of Paddy Straw (Amar Singh, Y. Singh) 42
Deep Tube-Well Irrigation and Adoption Certain Practices for Rice Cultivation in Bangladesh (Paris Andreou, Fauzi Al-Haj, Md. Ismail Hossain) 49
High Temperature Flame Drying of Freshly Harvested Peanut Pods (A. C. Srivastava, W. K. Bilanski, P. White) 53
Cold Storage of Seed Potatoes in Paddy Straw Bags (A. K. Gupta, Amar Singh, V. Singh) 58
Costs of Owning and Operating Tractors: A Review (Sheruddin B. Bukhari) 61
Farmers' Knowledge and Facilities to Maintain Tractors on the Farms (Sheruddin B. Bukhari, Mohammad Iqbal Khan) 68
Energy Use for Crop Production in Bangladesh (Nripendra Nath Sarker, Shah M. Farouk) 71
Energy Efficiency of Power System Options for Irrigation (B. S. Pathak R. M. Engira, K. D. Mannan) 75
Tractive Power Losses in Tracks of a Tractor (Dipankar De, D. Chaudhuri, K. P. Pandey) 79
News 83
New Products 85

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 14, No. 1, Winter, 1983)
Editorial (Yoshisuke Kishida) 9
Systems Engineering in Precision Automatic Transplanting (Barney K. Huang) 11
Design of a Simple, Low-Lift, Wind-Powered Pump for Rural Use in Thailand (Desa Ahmad) 20
Anthropometric Survey of Indian Farm Workers (P. K. Gupta, A. P. Sharma, M. L. Gupta) 27
Water Conveyance for Farms and Minor Irrigation Schemes (R. C. Yadav) 31
Energy Recovery in Man-Powered Pumps (S. M. Nazrul Islam) 37
Profile of the Development of Agricultural Mechanization in China (Wang Wanjun) 41
Small Tractors in China (Kong Depeng, Ling Tongsen, Xü Guangqin) 44
Use of Combine Harvester in Malaysia (A. A. Mainul Hussain, Wan Ishak Wan Ismail) 53
A Centrifugal Impeller-Type of Sunflower Seed Decorticator (K. N. Nag, Pratap Singh, Rajash Bhandari) 55
Design-Related Physical Properties of Selected Agricultural Products (A. N. Waziri, J. P. Mittal) 59
Utilization of Rice Mill Wastes and By-Products: A Case Study in Thailand (Md. Wali Ullah) 63
Trench Silo for Bangladesh Farms (Md. Mahabubur Rahman Mollah, Ahmed Hossain Mirdha, Md. Habibur Rahman Khan) 65
Paradox of Tractorization in Pakistan (M. Yusuf Mubasher) 69
Agricultural Development and Requirement for Short Term Finance: Case Study of Binjharpur Block, Orissa (T. N. Datta, Anthony D'Costa) 77
Manual Labor Displacement with Tractorization (Bashir Ahmad) . . . 81
News 86

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol.14, No.2, Spring, 1983)
Editorial (Yoshisuke Kishida) 9
Development of Peanut Combine Harvester (Yang-ren Hwang) 11
Tillage and Irrigation on Water Use by Wheat in Grey Terrace Soil of Bangladesh (Z. Karim, A.J.M.S. Karim, A.A. Pahlwa) 17
A Model of Field Grain Sorghum Moisture Contents (Surya Nath, William H. Johnson) 21
Modification and Testing of a Manual Rice Transplanter (Gajendra Singh, Uqaili Khalid Hussain) 25
Properties of Parboiled Rice Produced from Japanese Paddy (Toshinori Kimura) 31
Development and Evaluation of a Granular Insecticide Applicator (M. Shyam) 34
Design, Development and Testing of a Bullock-Drawn, Single-Row Seed-Cum-Fertilizer Drill (D.N. Sharma, N.K. Bansal, M.L. Jain) 37
Accuracy of Measurement of Soil Water by Neutron Probe (Md. Abdur Rab) 41
Pneumatic Separator for Various Rice Fractions (P.K. Chattopadhyay, Prem Chand, T.C. Mishra, N.D. Patil) 49
Development of Wheel Pump for Low-Lift Irrigation (Choudhury Md. Amiruddin Khan) 55
Survey on Traditional Methods of Harvest and Post-Harvest Practices (K.V. Selvaraj, V. Subramanian) . . 59
Status of Selected Tillage Implements on Progressive Farms in Pakistan (Muhammad Afzal, Usman Mustafa, Tanvir Ahmad) 62
Implications of Farm Mechanization for Employment, Productivity and Income (Bashir Ahmad) 65
Performance Study of a Solar Cooker (Kedar N. Nag, A.N. Mathur) 69
Stabilization of Rice Bran by Conduction and Humid Heat Treatments (A. Chakraverty, N.C. Patel) 72
Use of Wind Power in New Zealand: Its Scope in Pakistan (Shamsuddin A. Mahar) 77
News 82
Book Review 85

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol.14, No.3, Summer, 1983)
Editorial (Yoshisuke Kishida) 9
Direct Seeding with Coated Rice in Submerged Paddy Field (Yoshiaki Nakamura, Haruhiko Murase, Sakae Shibusawa) 11
Evaluation of IRRI-Pantnagar bullock-Drawn, Six-Row Paddy Seeder (R.D. Singh, Bhagwan Singh, K.N. Singh) 15
Development of a Wetland Seeder from Mechanical and Ergonomical Considerations (V.K. Tewari, R.K. Datta) 21
A Progressive Approach to Minimum Tillage (G.S. Sheikh, Khalid Pervez, J.K. Sial, Muhammad Afzal, Abdul G. Ansari, Muhammad Yasin) 28
Evaluation and Modification of Two Peanut Shellers (Gajendra Singh, Pinai Thongsawatwong) 33
Renewable and Non-renewable Resources in Irrigation Pumping (T.B. S. Rajput, Ashwani Kumar) 41
Selecting and Adapting Farm Machinery to Rural Conditions (J.C. Igbeka) 45
Kinematics of Single Rotary Blade in Rice Harvesting Machine (M. Majumder, R.K.Datta) 49
Engineering Properties of Rice Husk Boards (B.D. Shukla, T.P. Ojha, C.P. Gupta) 52
Effect of Vane Inclination on Performance of Radial Vane Centrifugal Pump (Md. Quamrul Islam, Obaidul Islam) 59
Computer Prediction of Suitable Workdays for Mechanized Winter Wheat Operations in Chile (Edmundo J. Hetz, Arthur Gold, Luke E. Reese) 62
Tillage Practices in Mechanized Farms in Pakistan (Khwaja Altaf Hussain, Abdul Shakoor Khan, A.D. Chaudhry) 67
The Development of Agricultural Mechanization and its Strategies in Taiwan (Tien-song Peng) 71
Status and Scope of Wheat Production in Nigeria (O.P. Kataria) 75
News 81
Book Review 84

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 14, No. 4, Autumn, 1983)
Editorial (Yoshisuke Kishida) 9
Direct Seeding with Coated Rice in Submerged Paddy Field (2) (Yoshiaki Nakamura, Haruhiko Murase, Sakae Shibusawa) 11
Potential of Direct Drilling in Developing Countries (A.D. Chaudhary) . 15
Potential of Direct Drilling in Pakistan (M.A. Choudhary) 20
Some Developments in Direct Drilling Equipment in New Zealand (C. J. Baker) 25
Development of Rolling-Type Soil Crust Breaker (N.K. Awadhwal, G.E.Thierstein) 31
Field Performance Evaluation of Rice Reaper (Nadeem Amjad, David Gee-Clough) 35
Development and Testing of a Simple Baffle Type Grain Dryer (A. Chakraverty, H.G. More) 41
Experimental Results on Stored Food Products in Different Packaging Materials (Surya Nath, A.K. Ganguly) 45
A Computer Program for Agricultural Machinery Management: Selection of Optimum Farm Size (Shaukat Khan, Sharafeddin M. Sherif, Md. S. Chaudhry) 51
Response of Wheat Cultivars to Irrigation and Fertilizer Applications (S.M. Rahman, B.C. Basak, A.K.M. Habibullah, Mesbauddin Ahmed, M.R. Biswas) 55
Losses in Wheat Harvesting and Threshing (Sheruddin B. Bukhari, Jan Mohammed Baloch, Fakir Mohammed Rattar) 61
Agricultural Mechanization in Thailand (Gajendra Singh) 68
The Farm Machinery Industry and the Development of Farm Mechanization in Japan (Hiroyuki Nishimura) 75
News 81
New Products 83
Book Review 84

A NOTE 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, about 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)"

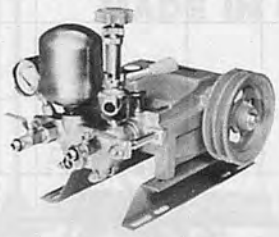
Procedure

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.

TOKAI, ALL-ROUND MAKER OF PREVENTIVE AND EXTERMINATING MACHINES



Power Sprayer Model TS-25



Knapsack Man-power Sprayer Model H-1

With 35 years' history of manufacturing and credit of users, Tokai is a most outstanding company in Japan which has specialized all along in the manufacture of preventive and exterminating machines. We produce hand-operating sprayers of some 20 kinds ranging from pack to shouldering models. In the area of power sprayers we turn out some 12 kinds ranging from the super light-weight and mini-size to all of the standard size as well as large-size power sprayers Tokai has put on the market lately some 10 kinds of speed sprayer - the Apolo series speciaily designed for use for orchards.

TOKAI SPRAY MACHINE CO.,LTD.

Head Office and Factory: 32, Midorien, Ogaki City, Gifu-pret., 503 Japan.
phone: 0584-78-6131(R)
telex: 0-4793-678 TOKAIS J
cable adress: "TOKAISPRAY" OGAKI JAPAN

Portable Moisture Meter for Rice, Wheat and Barley, MODEL CD-2

Digital Display, Temperature-compensated, No conversion table necessary with grain selection buttons.

Weighs less than 700 grams, can be put in your pocket.



SHIZUOKA SEIKI CO., LTD.
4-1 YAMANA, FUKUROI, JAPAN 437
Telex:04263707 SEIKI J
Phone (05384)2-3111,2477

1983 EDITION

FARM MACHINERY YEARBOOK

The 1983 edition now available has 227 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 ¥9,300 (sea mail) and ¥11,000 (air mail).

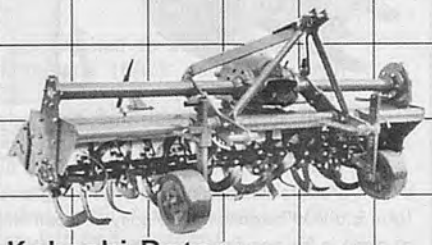
SHIN-NORINSHA Co., Ltd.
7, 2-chome, Kanda Nishikicho, Chiyodaku, Tokyo 101 Japan

KOBASHI





Our high level of technique has been attained through a long-time study on soils everywhere



Kobashi Tillage Blade
The supreme quality and the maximum output based on traditions and new techniques

Kobashi Rotor
A new series for 20 ps to 100 ps tractors incorporated with improved techniques

KOBASHI
KOBASHI KOGYO CO.,LTD.
684, Nakaune, Okayama City, Japan
Phone: 0862(98)3111
Telex: 5922188 KBSOKA J

KOBASHI

A line-up of superb, compact agricultural machines from Ohashi



AR-551·651
CULTIVATOR

HR-650
HAMMER-ROTOR

SB-77
PASTURE MOWER

SM-602
AUTO MOWER

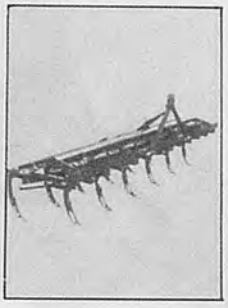
OHASHI AGRICULTURAL MACHINERY MFG. CO, LTD.
Head Office: Jojima-cho, Mizuma-gun, Fukuoka-ken, 830-02, Japan Tel. 09426-2-3161~4 Telex: 7428-34 HIFAX: 2-6078

HOWARD®

MADE IN MALAYSIA FOR THE NEEDS OF THE FAR EAST
AT PRICES THE AREA CAN AFFORD

HR11 ROTAVATOR | *HS21 SLASHER* | *STINGER* | *TINE TILLER* | *HFS500 SPREADER*



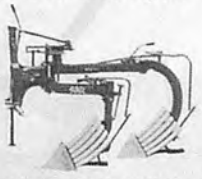

HOWARD ALATPERTANIAN SDN. BHD., P.O. BOX 8, BATU CAVES,
SELANGOR, MALAYSIA. TEL: 666677. TELEX: MA 30535

Niplo AGRICULTURAL MACHINERY

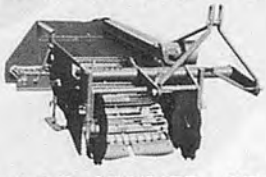
Rotary Tiller : DC-2000
The side drive system increases durability and makes complete tilling a certainty.
With the perfectly waterproof mechanism, it can be used in paddy fields.


Model DC-2000(60～100ps)

Reversible Plow : TR-255F
Reversing and width control of bottom can be easily operated by a single shifting of the handle.
Unique share shape reduces draft force and makes a small tractor as efficient as a big one.
Because of the differencial effect of moldboard fingers, soil is ideally inverted.


Model TR-255F(20～28ps)

Digger : D-653S
Highly elfective in digging root crops such as potatoes, onions and bulbs.
Specially designed share effectively scoops soil and crops.
Soil and crops are completely separated while they are conveyed backward by the swinging conveyer.

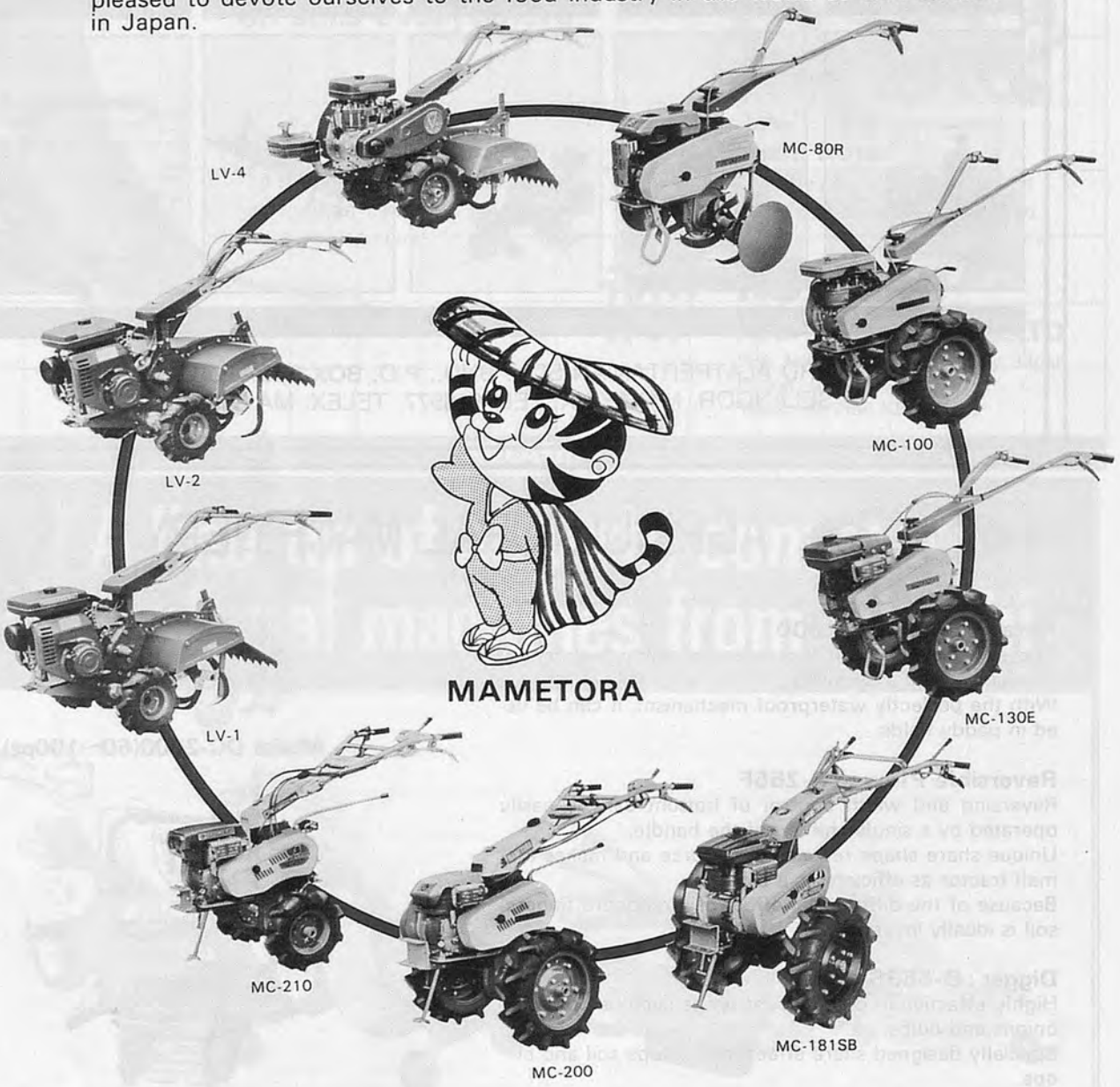

Model D-653S(25～35ps)

MATSUYAMA PLOW MFG. CO.,LTD.

2949, Shiokawa, Maruko-machi, Nagano-ken, 386-01 Japan

MAMETORA DEDICATES TO AGRI

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 goobs of high quality and are pleased to devote ourselves to the food industry in the world as well as that in Japan.



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

CULTURE ALL OVER THE WORLD

○ Preeminent above the rest for economical efficiency. Rational design. Nothing but small-sized agricultural machinery displays opration efficiency like this.



This is the first Full Automatic Transplanter TPA-1 that Engineering Division of Mametora Noki Co., Ltd. has developed for the first time in the world.
This is cassette type transplanter only to put in seedling boxes. Suitable for Chinese cabbage, lettcue, cabbage and cauliflower.



Tobacco transplanter that is mostly used for trans planting tobacco in Japan.



Plowing operation by Mametora Tiller.



Oil pressure is largely introduced to this planter, and so this Mametora Planter is easy to use. This can be used for planting all Kinds of seedlings from small to large.



Operation in a greenhouse by Return Cultivator SR Type. This has wide application for seedbed, ridge and cultivation in orchards.