International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.XVI, NO.2, SPRING 1985

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

ISEKI

ISEKI···Dedicated to producing abundant harvests and world peace

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

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

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

ISEKI & CO., LTD.

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

KANEKO SUPA CAR

"HYDRAULIC EIGHT-WHEEL DRIVE CA...

Model 1500D

①EASY TO OPERATE

All you have to do is to work two levers. Nothing other than this. Only with the two levers, you can drive forward and back, turn in evry direction, whirl round, speed up and down and brake. It's very easy to operate because of no clutch, no brake, no gear-box and no accelerator. (Emergency foot-brake and parking brake are standard equipment)

②SMALL SHARP TURN, 360 DEGREES WHIRLING

The Skid Steering System, by which the right wheels and the left drive independently, allows sharp spin turning. The out-side wheels drive forward and the in-side, reverse, so that the Kaneko Supa Car easily makes a turning on a narrow lane anywhere it can run through. Changing direction, freely.

③LOW CENTER OF GRAVITY, LOW GROUND PRESSURE

The Kaneko Supa Car is well designed to position the center of gravity low and have the low ground contact pressure. The well-balanced Hydraulic Eight -Wheel Drive Car is able to work everywhere such as hilly, uneven, dune, snowy lands and marshes (c-rawler type).

④MULTI-PURPOSE FARM CAR

Farm implements and equipment using the hydraulic pressure operating are available. Any kind of farm work can be done by the Kaneko Supa Car in coo-peration with the varieties of implements.

Animal Husbandry: Forage Harvester, Corn Harvester, Rotary Mower, Roll Baler, Manure Spreader, Vaccum Tank, Front and Rear-mounted Loaders, etc.

Garden and Orchard: Grass Mower, Carrot Digger, Speed Sprayer, etc.

Forstry: Winch and others.

Transportation: High-dump Wagon, Lifting Dump Wagon, etc.

⑤REMOTO CONTROL AVAILABLE

Remoto operation is available, too, with the Kaneko remoto control device (optional).

⑥TRACTOR-MOUNTED IMPLEMENTS ACCEPTABLE

Tractor-mounted implements is usable for the Kaneko Supa Car when they work together with the P.T.O. Three Point Hitch Linkage. (AT-1, Category 1,opti-onal)

⑦SIMPLE ATTACHING AND DETACHING OF IMPLEMENTS

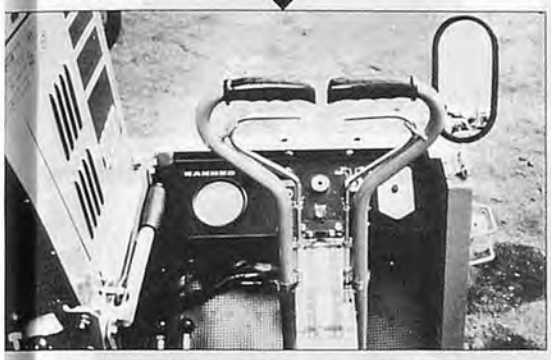
The "Kaneko Quick-set System" makes it easy to attach the implements to the "Kaneko Supa Car" and detach them from it and possible to do the job by a single person.

※Of course, safety designs are taken into consideration in every aspect of the Kaneko Supa Car.

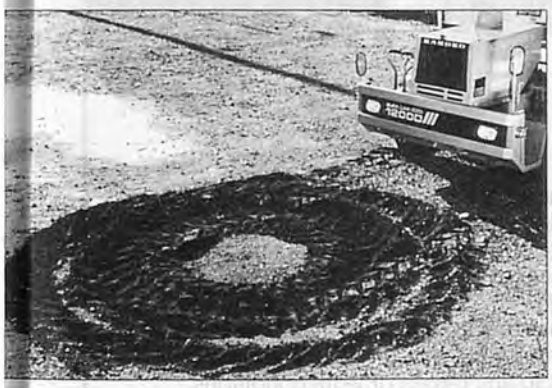
ic Eight-Wheel Drive, Low Center of Gravity, Low Ground Pressure, Water-cooled Diesel Engine

LF-PROPELLED, MULTI-PURPOSE FARM CAR

C A.....



eration Easily contolled with the two levers. (1200D).



0-degree spin turn (1200D)

eration on the hilly land (1200D)

"Kaneko Supa Car" Is Proud of Multi-purpose Operation.

- Model 1500D(42ps) (Turbo Engine)
- Model 1350D(35ps)
- Model 1200D(25ps)
- Model 800D(19ps)

Forage Harvest and Lifting Dump (1500D)

Corn Harvester and High Dump Wagon (Spiral drum is optional 1200D)

(1200D)
Manua Spreader and Rear Loader

Roll Baler Making Compact Hay-bale (1200D)

Front-mounted Rotary Mower (1200D)

KANEKO AGRICULTURAL MACHINERY CO., LTD.

Overseas Division
26-11, Higashinihonbashi 2-chome, Chuo-ku, Tokyo 103 Japan
Phone: (03)862-2459 Cable: AGRIKANEKO 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.

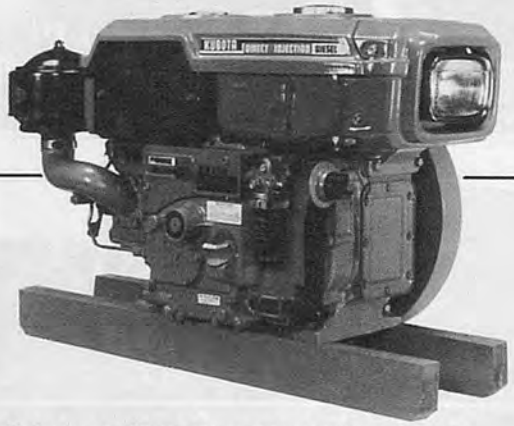
Kubota products provide power, economy and versatility wherever there's a need.

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

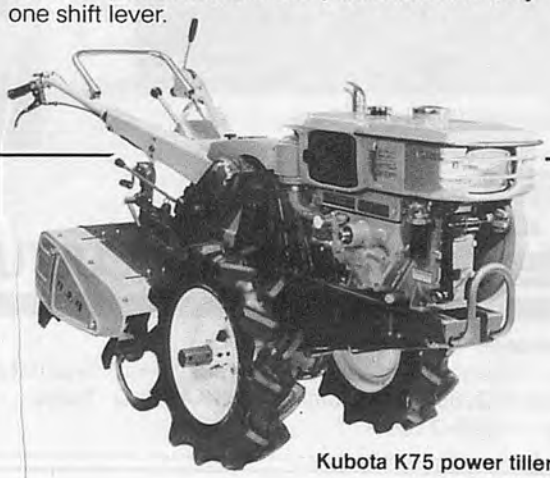
Kubota tractors are known 'round the world for their compact versatility.
Kubota diesel 2WD and 4WD tractors come in three separate series: B (14—19HP), L (25—38HP) and M (55.5—81HP). Our M7500 four-wheel drive diesel tractor gives you a choice of 16 forward and 4 reverse speeds, to let you easily adapt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

International specialized medium for agricultural mechanization in developing countries

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.XVI, NO.2, SPRING 1985

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)
Ampratwum, David Boakye (Ghana)
Choudhury, Md. Shahansha-ud-Din (Nigeria)
Igbeka, Joseph C. (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)
Ghaly, Abdelkader E. (Canada)
Phillips, Allan L. (Chile)
Valenzuela, A.A. (Chile)
Mirdha, A.H. (Mexico)
Chancellor, William J. (U.S.A.)
Esmay, Merle L. (U.S.A.)
Goyal, Megh Raj (U.S.A.)
Srivastava, Krishna P. (West Indies)

- 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)
Henderson, Harry D. (Lebanon)
Bardaie, Muhamad Zohadie (Malaysia)
Shrestha, Bala Krishna (Nepal)
Afzal, Mohammad (Pakistan)
Chaudhry, Allah Ditta (Pakistan)
Chaudhry, Md. Siddique (Pakistan)
Devrajani, Bherulal T. (Pakistan)
Mughal, A.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 (SriLanka)
Peng, Tien-Song (Taiwan)
Singh, Gajendra (Thailand)
Pinar, Yunus (Turkey)

- 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)
Shuji Kobayashi, Manager (Head Office)
Hiroshi Yamamoto, Manager (Branch Office)
Advertising Rate: 300 thousand yen per a page

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

Copyright © 1985 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 47th issue since the issue, Spring of 1971

EDITORIAL

Wanted : A Realistic World Agricultural Policy

Looking back into some 1984 newsmakers, one is appalled to recall the famine that struck in many parts of Africa which sent shock waves around the world. Many were stunned and wondered how and why such a calamity should still happen in the present century. As a matter of fact, to this day, starvation and death still stalk the lives of millions in those famine stricken areas.

And yet that bleak picture is in stark contrast with what is happening in other parts of the world where farmers are equally suffering – not from production shortfall – but from overproduction of crops and livestock! Some of these progressive farmers are even emabarrassed by their achievement of overproduction which could ultimately mean much lower prices for their products, hence smaller returns to investment.

This is a classical example of poor and traditional farmers (as in Africa and Asia), on the one hand, and on the other, the progressive and modern ones (as in the US and other advanced countries) who are, in a sense, both suffering brought about by their own misfortune or fortune. To be sure, this case is both a contradiction and an irony – a situation indeed that calls for a realistic global agricultural policy.

Of course, it will not be easy to reconcile the differences in the quantity and quality of resources available to the poor and small farmers with those of the prosperous and modern ones. Even in theory, academicians will be shy to advocate that the prosperous farmers relinquish, for a song, part of their resources to their poor cousins in the guise of evening out their differences, or, so that food might be distributed more equitably around the world. But ways must be found to reduce the glaring disparity and contradiction.

One suggestion that comes to mind is to base the floor prices of agricultural products upon the average productivity of farmers, world-wide. In a way, this proposition stands to benefit the large farmers the most which is quite natural and reasonable. But then consumers elsewhere will also naturally opt for lower retail prices of the farm products they buy.

This suggestion is probably crude and will only be workable after exhaustive studies and lobbying among politicians and policy-makers but is doggedly aiming at stabilizing food availability through the simple operation of demand and supply so that people on one side of the globe will stop dying from want of food and, on the other side, farmers will stop being embarrassed by overproduction of foodstuff.

In a small way, AMA is calling for a new world order as befits a plausible solution for the disparity in food availability, or, at least, agitate for some changes for the sake of mankind.

Yoshisuke Kishida
Chief Editor

April, 1985
Tokyo

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol. XVI, No.2, Spring, 1985

Yoshisuke Kishida	9	Editorial
N.K. Awadhwal C.P. Singh	11	Dynamic Behaviour of Wet Soil and Tillage and Traction in Wet Land
Mario Ibanez C. Edmundo J. Hetz	21	Appropriate Technology-Animal-Drawn Equipment for Small Farmers in Nūble, Chile
A.A. Mainul Hussain S.M. Farouk N.N. Sarker	25	Improved Animal-Drawn Moldboard Plough Utilizing Available Draft Power
B.V. Ramana Rao P. Sharma S.C. Chowdhry	27	Design Characteristics and Performance of Wind Mills for Pumping Irrigation Water
Ghanshyam Das Avinash Agarwal	30	Simple Attachments to Indian Country Plough
Peter Burudi K.P. Srivastava	33	Windpump for Irrigation in Hararghe Region of Ethiopia
G.C. Misener	39	A Tractor-Mounted Digger for Potatoes
R.S. Devnani M.M. Pandey	41	Design, Development and Field Evaluation of Vertical Conveyor Reaper Windrower
B.D. Shukla T.P. Ojha C.P. Gupta	53	Measurement of Properties of Rice Husk Boards: Part II
Mridula Bhattacharjee Surya Nath	61	Suitability of Flexible Packaging Films for Rice, Dal and Wheat Flour
H.D. Banerjee A. Chakraverty A.K. Mahapatra P. Nishra	67	Combustion Process of Rice Husk for Amorphous Silica Production
N.S. Sandhar J.P.S. Malhotra	72	Results of an Opinion Poll on Safety Features of Tractors in India
Muhammad Saleh Soomro Sheruddin B. Bukhari	75	Status of Agricultural Machinery Manufacturing in Sind, Pakistan
A.Q.A. Mughal	79	Need for Smallholding Mechanization in Pakistan
Abstract	82	
News	83	
New Products	85	

New Co-operating Editors
A Note to AMA Contributors 32
Co-operating Editors 88
Back issues 90
Index to Advertisers 91

Dynamic Behaviour of Wet Soil and Tillage and Traction in Wet Land

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

C.P. Singh
Professor
Dept. of Farm Power and Machinery
Punjab Agriculture University
Ludhiana, India

Abstract

Rice is a major food crop and is usually grown by transplanting in flooded fields which present extremely unfavourable conditions for mechanization. Poor dynamic properties like strength in shear and compression, friction, adhesion and plastic flow of wet soil provide a basis for its characterization and solution of design problems of tillage and traction devices. Rheological models help in simulating the soil behaviour under the influence of external forces. Much work has been done to modify the traction devices and new traction aids have been developed to improve traction and mobility of agricultural machines in paddy fields.

Some measures of the quality of puddle like cone penetration depth, angular velocity of an inclined bar, mean weight diameter and puddling index have been identified. Design and development of equipment for wet land tillage have come a long way. Shapes of cutting blades and other factors affecting their performance have been studied in detail. Many equipment like push type rotary tiller and differential slip tiller have been developed and comparative performance of many types of equipment used for puddling have been studied. This paper summarizes the findings of such studies conducted by various researchers in different countries.

Introduction

Rice is the staple food of approximately one-half of the world's population. Much of the paddy is grown and consumed in Asia. It is grown on about 129.6 million ha of land which is more than 40% of the area under cereal crops.

Paddy is usually grown by transplanting seedlings under flooded conditions. Transplanting requires a soft soil bed which is made through puddling. This wet, soft soil environment presents extremely unfavourable conditions for vehicle traction and mobility in the paddy field and is the most important cause for slow progress of mechanization of rice cultivation processes.

A number of studies have been conducted to understand the dynamic behaviour of wet soil and to design and develop more efficient tillage implements and traction devices for wet land cultivation of rice. In this paper an attempt has been made to summarize the information available from such studies.

Dynamic Behaviour of Wet Soil

One of the goals of researchers has been to characterize soil with regard to tillage tool and traction device design so that the desired results can be obtained. Studies of dynamic properties provide a method to systematically develop a characterization that will apply to the reaction of soil to applied forces and furnish a basis for implement design. Resistance and strength properties characterize the reaction of the soil subjected to external forces. Those properties may better be called dynamic behaviour properties. Shear strength, resistance to cone penetration, friction, adhesion, plastic flow and time dependent deformation represent the dynamic behaviour of the soil.

Shear Strength

Shear strength is defined as the maximum resistance offered by soil to shearing stresses. It is made up of two components: i) internal friction or resistance due to interlocking of particles and friction between individual particles at their contact points; and ii) cohesion or the resistance due to interparticle forces which tend to hold

the particles together in a soil mass.

The strength of soil is affected by its structure, void ratio, rate of shear, moisture content and thixotropy. The term thixotropy is used to describe increase in strength with time at constant composition. In soils exhibiting thixotropy effects, the shear strength increases with increasing time of storage.

According to Greacen the shear strength of soil is important in agriculture for evaluation of changes in soil structure due to disturbance by mechanical means. Saturated agricultural soils may be considered as a bed of over-consolidated aggregates, the degree of over-consolidation being related to the extent of drying the aggregates have previously experienced. When the soil is wetted the void ratio and, therefore, the strength of the individual aggregates will be determined in part by the extent of swelling.

In saturated loose soil with free drainage the cohesion and friction components and, therefore, total strength are proportional to the applied normal load. In structured clay, compression energy may be either lost or stored in structural bonds so that no unique water content exists for a particular equilibrium load. Under normal load, saturated agricultural soil compresses to a density which appears to be a function of aggregated strength and the initial state of the bed, when a shear force is subsequently applied the soil compresses further to the ultimate void ratio after which there is only negligible change. The rate at which the ultimate void ratio is approached in saturated soil, above a critical load at constant shear, is determined by poor water conductivity rather than aggregate strength which can resist consolidation. This relation between strength and impermeability, both of which resist compaction will be important in determining the amount of permanent strain, when the duration of loading varies.

Kisu found that in submerged soils the resistance to cone penetration dropped by about 85% in unsubmerged soil in the top layer (0–15 cm) and by about 80%–50% in lower layers. With progressive time of submergence the soil resistance to penetration remained nearly constant.

El-Domaity and Chancellor conducted a triaxial test on saturated clay in the mid-range of the strain rate (0.2 to 2/sec) and found that the strength of saturated clay increased as the consolidation pressure increased. Increase in strain rate caused no change in value of effective angle of friction but caused regular increase in the value of effective cohesion. Visco-elastic form of analysis was applied to the plot of maximum shear stress vs the rate of strain. The slope of this plot represented plastic viscosity of the material. The results indicated that the same plastic viscosity applied to all the test specimen at various moisture contents and confining pressures used. The yield stress, defined as the intercept of those plots on the stress axis, increased with an increase in the level of confining pressure.

Inccreasing moisture content in soils causes a rapid decrease in cohesion with aggregates. Therefore, shear strength of soil decreases with an increase in moisture content. At higher moisture content internal friction of soil approaches zero and at saturation shear strength is affected by cohesion only. In case of agricultural soils under action of tillage and traction devices the deformation rates are high enough to justify the assumption that the failure of soil takes place in the undrained condition. Thus for saturated agricultural soils the value of apparant angle of friction can be regarded as zero and the undrained strength can be equated to the apparent cohesion of soil.

The cone penetrometer and shear vane are most commonly used for estimation of soil strength *in situ*. The results of a penetration test are composite in nature. It provides only a crude estimate of soil strength. The main drawback of this test is that the results are not represented as a single value. In a shear vane test soil gets disturbed when the vane is inserted. The vane test usually, but not always, gives a larger strength value for a given soil than does the unconfined compression test.

Perlow studied the effect of the shear velocity at the outer edge of the vane blades on undrained shear strength and found a nearly linear relationship between field vane strength and shear velocity. Awadhwal found that vane shear strength of wet soil increased with shear velocity and the logarithm of the secant modulus decreased linearly with the logarithm of shear velocity. Madhav presented a method for evaluation of undrained modulus of a saturated soil from vane test results. The modulus of soil was obtained as,

$$G = \frac{T}{\Theta} \cdot \frac{1}{l_0 \; D^3}$$

where, T is the torque necessary to generate a rotation of Θ. Values of l_0 are calculated from a range of values of H/D H_0/D and Poisions ratio.

Where H, D and H_0, respectively, are the height of vane, diameter of vane and the depth from ground surface to the top of the vane blade.

Friction and Adhesion – The coefficient of apparent friction is a dynamic property of soil. Frictional forces occur between soil and other materials also. The adhesive forces between soil and other materials are due to a moisture film. Adhesion acts as an increase in normal load under saturated conditions. According to Nichols' classification, the friction phase is found when the soil is dry. As moisture is added adhesion begins and causes an in-

crease in the apparent coefficient of friction. The final lubricating phase occurs when enough moisture is present to provide a free water surface to lubricate the soil-metal contact surface. The apparent coefficient is usually higher in the lubrication phase than in the friction phase.

Plastic Flow – Plastic flow is a failure condition in soil. No criteria for this failure has been established although the phenomenon is clearly observed. Plastic failure can be described in terms of shear failure except that no distinct failure surface appears. Rather, the entire mass of soil in the neighbourhood of the applied force fails by deforming without any district separation on any surface.

Masujima and Kokubun reported that the study of soil plates made from the ploughed layer of soil by means of a coaxial cylinder viscometer indicated that pastes from non-dried soils showed Bingham flow with shear rate thixotropy. Air drying decreased the Bingham yield value despite increased concentration of the soil paste. Some pastes from dried soils showed dilatant flow. These differences were due to different stability of the soil microstructure under stress. Pastes in which aggregate stability increased with air drying showed decreased Bingham yield values and plastic viscosity. Pastes in which stability decreased with drying showed dilatant flow.

Rheological Characteristics – According to Waldron, in rheological studies, soil is usually considered a continuous medium in which both stresses and strains are continuous functions of the space coordinates. This assumption is not compatible with the particulate nature of soil, or even with the molecular structure of any material. However, its use can be justified by specifying that areas defining stress should not be vanishingly small, but should be large relative to fine structural units, such as soil particles or aggregates.

McMuradie examined the applicability of existing deformation theories infinitesimal and finite deformation elasticity theory, plasticity theory and linear viscoelasticity, to soils. He found that the Young's modulus and Poison's ratio were not constant during the deformation process and therefore elasticity theory is most generally applicable. Plasticity theory was found to be unsatisfactory as a general theory. From the performance of the creep test it was seen that the basic assumption of viscoelasticity theory, the time dependence of the relationship between stress and strain state, is valid for soil and concluded that visco-elasticity offers the best hope for a deformation theory for soils.

Rheological modes composed of linear springs in combination with linear dashpots and slides have been postulated to explain qualitatively elastic, plastic, and flow phenomena of soil under the action of sustained stress. Reiner investigated the possibility that the Bingham body may be regarded ideal for the behaviour of clay suspensions, soil paste peat suspension and drilling muds. Several more rheological models have been proposed to simulate soil behaviour. However, they are all insufficient in describing the time-dependent behaviour without limitations on a range of stress level, water content and lapse of time.

Traction on Wet Land

The efficiency with which a tractor converts energy into pull is extremely poor when operating on wet soil. The top layer of wet soil has a low shear strength so that sufficient thrust cannot be developed. Besides this the slipperiness, stickiness and sinkage limit the available pull and forward speed of a tractor. In such situations the middle layer of the soil bears the traffic load of agricultural machinery. In wet fields, with a hard pan at considerable depth, the utility of agricultural machines is limited due to their bogging down in the soil. In agricultural operations, the effect of the vehicle on the soil is more important than the maximum traction that can be developed. A tractor that develops the desired pull at high efficiency may not be useful if it makes ruts in the soil so severe that subsequent cultural operations cannot be done or are adversely affected.

Performance Evaluation – Performance evaluation of a traction device first needs establishment of fundamental criteria. Certain basic measurements of pull, rate of angular rotation, forward speed, load, and slip are usually required regardless of the fundamental criteria. Maximum pull in the range of 0–70% slip might be used as a basis on which traction performance is evaluated. The average pull for the normal range of operation provides a single value reflecting the traction performance. The average power efficiency (P.E.=

$$\frac{\text{D.B. Pull x forward velocity}}{\text{Torque x Angular velocity of wheels}})$$

in the range of operation would also provide a single value that reflects the energy efficiency aspect of traction performance. Traction efficiency defined as the product of work output (an index that represents work in dimensionless

$$\text{term} = (\frac{\text{Pull}}{\text{Weight}} \times [1\text{-slip}])$$

and power efficiency is a single value that reflects overall traction performance.

Factors Affecting Performance – Mobility of tracked vehicles (crawler tractor) on wet land is influenced by the design of track and track shoe. A narrow track shoe performs better on wet soil and an

open track improves the performance of the vehicle, particularly in cases where a weak layer of soil covers a stronger sub soil. For covers a stronger sub-soil. For soils, a raised leading edge track shoe is of significant advantage over both conventional shoes and shoes with a triangular cross-section due to increased tractive forces and decreased sinkage. The spacing of shoes has a very large effect on the performance of crawler tractors. The maximum tractive forces generated decrease by a large amount as the spacing of the shoes is reduced.

Tractive performance of a tractor on soft paddy soil is affected by its fundamental specifications such as front and rear axle load ratio, total tractor weight and tyre size. The drawbar pull is large when the front axle weight is less and the ratio of front axle load to rear axle load is small as the travelling resistance of the front wheel is small and thrust of rear wheel is large. Thus the front axle load should be as small as possible provided that steering stability is not lost. Lighter tractors perform better on soft soils because the driving force increases proportionally with the driving axle load but travelling resistance increases exponentially with the driving axle load but travelling resistance increases exponentially with tractor weight especially on soft wet soil. Consequently, drawbar pull is less when the tractor is heavy.

Application of a drawbar load improves the performance of lighter tractors on wet soil because it increases the driving axle load by the effect of weight transfer. For wet soil the relationship between the maximum drawbar pull (F kg) and tractor weight (W kg) is established as:

$$F = K_1 W + K_2$$

Where, K_1 and K_2 are positive constants. In wet, soft soil high lug tyres show improved performance and the drawbar pull increases by 1.5 to 3 times compared to that of an ordinary lug tyre.

Data on the ground pressure of the projected wheel area indicates that small tillers with large wheels have ground pressure of 0.035 to 0.05 kg/cm^2. Tractors with cage wheels, larger power tillers and wide track type tractors have ground pressure of 0.2 to 0.3 kg/cm^2. Standard tractors on rubber tyres alone have ground pressure of 10 or more. Tractors having wheels with low ground pressure work better in soft soil than those with higher pressure.

Performance Prediction – For assessment of mobility of a tractor in wet land the resistance of soil to cone penetration at a depth equal to one-third of the wheel diameter is of great importance. Standard tractors with cage wheels work well on soils with a cone index above 2.8 kg/cm^2 at 30 cm depth, but at cone index below 2.1 kg/cm^2 at 38 cm depth the tractor may bog down in the soil. Japanese power tillers with special wheels for flooded soils work well in soils with a cone index above 2.1 kg/cm^2 at 23 cm depth but bogging may occur if the cone index goes below 1.4 kg.

It is important to have a simple method to judge trafficability on wet soil. For this purpose a standard for judging trafficability of tractors has been established (**Table 1**), after stipulating the applicable condition for work speed, ploughing depth travel reduction ratio, sinkage and expressing the soil conditions which satisfy them in terms of the cone index and rectangular plate sinkage.

Traction Aids – In wet land the ground conditions may become so extreme that conventional tractors

Table 1 Standard for Judging Trafficability of Tractor (Kokubun, 1970)

	Limits tolerable for farm work						The limit available for safe farm work					
	Wheel tractor					Crawler Tractor	Wheel tractor					Crawler tractor
	Tyre			Girdle	Half-track		Tyre			Girdle	Half-track	
	Self-propelled	Rotary tilling	Plowing	Self-propelled			Self-propelled	Rotary tilling	Plowing	Self-propelled		
1	2	3	4	5	6	7	8	9	10	11	12	13
Cone index (kg/cm^2)	2.5-5.0	2.5-5.0	4.0-6.5	2.0-3.5	2.0-2.5	1.5-3.0	5.0	5.0	6.5	3.5	2.5	3.0
Rectangular plate sinkage	9.5-4.5	10.5-6.0	3.0-0.0	11.0-3.5	10.0-8.0	15.0-5.0	4.5	6.0	0.0	3.5	8.0	5.0
Consistency index determined by wet soil	0.2-0.5	0.2-0.5	0.4-0.6	–	–	–	0.5	0.5	0.6	–	–	–

Remarks: 1. Cone index indicates to the mean of 0 to 15 cm vertically (Angle of apex 30°, the base area is 2 cm^2)

2. Consistency index $= \frac{\text{Liquid limit-moisture content}}{\text{Plasticity index}}$

do not develop adequate traction for mobility. In such cases various traction aids are used to improve the traction.

In puddled soil conditions, cage wheels perform better than pneumatic wheels because when a wheel operates in puddled soil it sinks and displaces a certain volume of puddled soil which develops an upward thrust on the wheel soil interphases. The upward thrust is less in case of a cage wheel because of less volume of displaced soil. It has also been found that angle iron lug wheels perform better than open centre pipe and puddle lug wheels

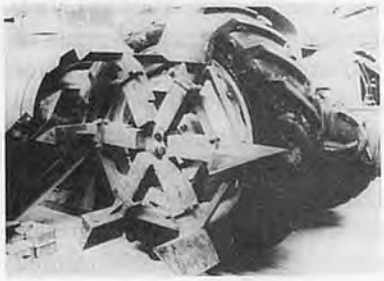


Fig. 1 Extendible lug wheel (IRRI Annual Report, 1971).

tive efficiency.

A triangle shaped box lug provides both floatation and traction. The lugs are rubber tipped and extend to full tyre diameter for better traction. These permit the mud to escape between the lug avoiding the wave of mud created by a wide solid wheel. Extendable lug wheels, equipped with triangle shaped box installed on radial arms (**Fig. 1**) also provide both floatation and traction. These wheels have the advantage that the lugs can be locked in any radial position to provide a desired degree of traction assistance.

There are many more methods of improving traction. The comparative performance of these methods may be represented in terms of relative values which express the performance of these methods in comparison to the performance of air-filled tires alone. The relative values were calculated on each slip-pull and drawbar hp-pull curve at four points, namely; 15% and 30% slip, maximum power and maximum pull. The comparative performance of some methods, shown in **Figs. 2** and **3** for improving traction are given in **Table 2**. The relative performance of a traction aid in terms of pull and maximum power may be predicted if the performance of any one of the aids listed in **Table 2** is known. For example the relative value of water-filled tyres plus chain instead of air filled tyres increases the pull and power by an average of 65% and the maximum variation from this average may be ±20% depending on the load condition and drawbar pull.

In extremely soft soil conditions where an ordinary wheel or crawler tractors connot travel, an auger tractor (**Fig. 4**) performs well. The auger tractor gets floatation by hollow rotors and traction by rotor fins. The traction ratio of the auger tractor on very soft soil ranges from 0.1 to 0.4. Under similar soil con-

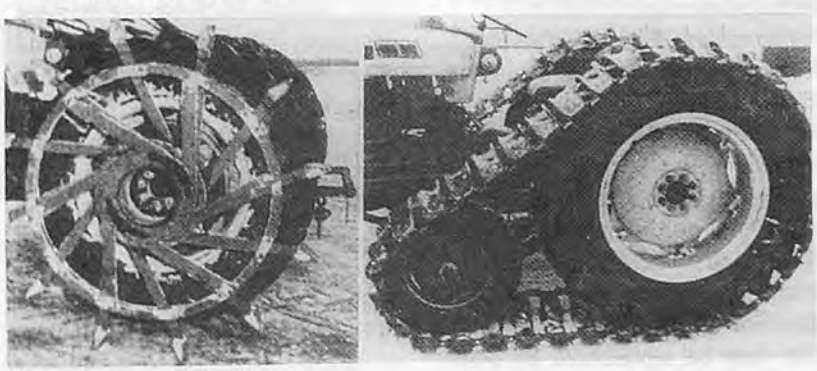


Fig. 2 Wheels with stakes and half track (Southwell, 1964).

Fig. 4 Auger (screw) tractor (Kisu, 1971).

Fig. 3 Dual wheels and wheels with chain (Southwell, 1964).

Table 2 Performance of Methods for Improving Traction

Equipment	Relative performance
1. Air filled (13.6 x 28) tires	1.0
2. Air filled (13.6 x 28) tires plus wheel chains	1.06 ± 0.12
3. Air filled (14.9 x 28) tires	1.14 ± 0.15
4. Dual air filled (13.6 x 28) tires	1.34 ± 0.3
5. Solution filled (13.6 x 28) tires	1.53 ± 0.17
6. Solution filled (13.6 x 28) tires plus wheel chains	1.65 ± 0.2
7. Air filled (13.6 x 28) tire plus stakes	1.85 + 1.0 − 0.5
8. Air filled (13.6 x 28) tires plus half tracks	2.04 ± 0.3
9. Solution filled (13.6 x 28) tires plus stakes	2.33 + 1.2 − 0.5
10. Dual solution filled (13.6 x 28) tires	2.34 ± 0.4
11. Solution filled (13.6 x 28) tires plus half	2.52 ± 0.55

(Southwell, 1964)

ditions the tandem unit formed by connecting two tractors with front wheels removed, seems promising as it performs well where a single tractor will not work.

Tillage of Wet Land

The ultimate aim of tillage is to manipulate soil to a desired condition and final soil condition is a measure of soil manipulation. The term soil condition includes all physical characteristics of soil that are pertinent to its use.

Puddling is a common practice in land preparation in lowland rice growing areas. It may involve plowing, rotary cultivating and levelling of the soil in flooded condition. Puddling may be defined as the process of tilling soil at high moisture content by a mechanical device which causes shear and compression or both. It may also be defined as the process in which soil loses granular structure and become defloculated. Bodman and Rubin defined puddling as the reduction in the apparent specific volume (reciprocal of bulk density) of a soil by doing mechanical work on it.

The objectives and advantages of puddling may be summarized as follows:

1. *Prevention of water percolation* – When the submerged paddy field is puddled a muddy suspension is created. The larger particles of soil in the suspension settle first and finer ones later. These particles block the pores in the top soil surface and reduce the percolation of water. During the puddling operation the soil layer just below the puddled soil (hard pan) is compacted by the puddling equipment. This causes crushing and blocking of the pores in the hard pan and results in a reduction of water percolation.

2. *Weed control* – As the top soil is stirred the weeds are burried under the soil, the reductive gas produced in the soil is discharged and the activities of micro-organisms are stimulated, thus accelerating the decompositions of green manure which were plowed under by the plowing practice.

3. *Levelling of soil surface* – Undulated paddy fields can be levelled by puddling. Accordingly, the water level will become readily adjusted. Thus the uniformity in the rice plant growth can be maintained well.

4. *Ease of transplanting* – As the soil is stirred and the clods are broken up the soil becomes soft so that seedlings can easily be pushed into mud to the extent of 4-6 cm deep with little resistance and without any damage to the seedlings. However, when the mud is too soft seedlings will be pushed in too deep or may not stand upright and plant growth will be affected adversely.

5. *Mixing and distribution of fertilizers* – Due to the stirring of the top soil the fertilizer applied is mixed properly with the soil. It helps in uniform intake of nutrients by the plant roots.

Characterization of Puddle – Soil is a granular material composed of solids, water and air. The solid matrix of the soil is built up from stable groups of primary particles called aggregates. Aggregates are arranged in a porous matrix occupied by air and water. The geometric arrangement of the solid material is called soil structure.

It may be represented by composite quantities like bulk density, percentage of pore space, pore size distribution, and particle size distribution. Structure and material properties of soil collectively control the entire soil behaviour.

During puddling operation the soil is rigorously manipulated, soil structure is thoroughly disturbed and the air-filled pore volume is drastically reduced. This description of all the quantities representing structure and material properties of soil is an essential step towards characterization of puddled soil. A description of the puddled condition, to be useful, should be quantitative and must be easily. interpreted in terms associated with the objective of puddling. Attempts have been made to describe the puddled soil.

Based on the concept of the destruction of large pores and the apparent sinkage in specific volume of a soil due to puddling, the sinkage depth obtained by centrifuging the sample of puddled soil was suggested as a measure of the degree of puddle.

Three other methods, namely; analysis of water stable aggregates by wet sieving of puddled soil, measurement of specific weight of puddled soil and measurement of moisture content of puddled soil were tried to quantify the measurement of puddle. The mean weight diameter, which represented aggregate status of water stable aggregate seems to be a reasonable method of judging the state of puddle. Measurement of hydrualic conductivity of soil was tried as a measure of quality of puddle. Pandey and Ojha expressed pudding index as follows:

$$P.I. = \frac{V_S - V_C}{V_S} \times 100$$

where,

P.I. = puddling index

V_S = volume of soil settled in the sample

V_C = volume of clear water

This relationship gives negative values of P.I. when $V_S < V_C$. Another relationship was suggested for calculation of the puddling index.

$$P.I. = \frac{V_S}{V} \times 100$$

where,

P.I. = puddling index

V_S = volume of settled soil in the sample

V = total volume of sample

This relationship holds good from no puddling condition, *i.e*, $V_S = 0$ to full churning of soil in water. The major drawback of

this relationship is that the value of P.I. is dependent on the depth of water standing in the field.

The dynamic properties of puddled soil are represented by resistance to cone penetration, falling cone depth and inclination angular velocity of a bar. The cone index obtained by inserting a cone penetrometer is representative of characteristics of puddled soil. The main drawback of this test is that it is not so easy to conduct and the results cannot be shown as one value.

In order to represent the dynamic properties of puddled soil, the mean and standard deviation of water depth, the pan depth and penetration depth of a falling cone should be measured. The inclination angular velocity of 0.5 cm^2 steel bar of 10 cm length, penetrated to 5 cm depth in puddled soil, with 10-15° of inclination angle should be measured. This is considered to be an excellent measure to predict the supporting force of soil for rice seedlings.

Awadhwal examined the merits and demerits of shear strength parameters like yield shear strength, secant modulus, energy of deformation and rheological characteristics like degree of plasticity, viscosity, parameters of viscoelastic model and some other soil characteristics like relative density and hydraulic conductivity of puddled soil for selecting a measure of quality of puddle. The shear yield strength was found to be the most suitable basis for quantification of the state of puddle. The term degree of puddle was defined as,

$$D.P. = 1 - \frac{Tp}{Tup}$$

where,

D.P. = degree of puddle

Tp = shear yield strength of puddled soil

Tup = shear yield strength of unpuddled soil

Performance of Tillage Equipment — The performance of a tillage tool includes two aspects, first the tillage should be performed effectively; that is, the soil condition should be altered with the smallest expenditure of energy required to operate the tool. Secondly, the final condition must be of the desired quality, that is, it should closely meet the intended objective of tillage.

The performance of a tillage tool depends largely on the design of its soil cutting portion. Considerable work has been done to improve the design of blades of rotary tillers for use in wet land.

The 'L' shaped blades require more power but give greater forward thrust to the vehicle on which they are fitted as compared to the 'C' blades. The change in curvature between the horizontal and vertical portion of the blade have more influence on the power requirement than is suggested by the accompanying change in the soil surface area/volume ratio.

The comparison of performance of two sets of rotary tiller blades having different shapes, designated as power and speed blades, respectively, (Beeny & Khoo, 1970) show that the speed blades are inferior to the power blades in exerting a forward thrust on the cultivating tractor. The speed blades use only 75% of the horsepower demanded by the power blades with no observable difference between the resulting puddled seedbed.

The adjacent rotary blades interact so the boundary between tilled and untilled soil plays an important role in the tillage process. This boundary must be considered in tine design. A rotary blade with a smaller cutting angle produces less tilling resistance.

'L' shaped rotary tiller blades have been designed that prevent grasses, weeds and straw from wrapping around and clinging to the blades. The blades were convex in relation to the direction of travel. The optimum angle of curvature of the blade was determined as 67.5° at the point of attachment to the drive shaft, 57.5° at the end of vertical section and 61-62° at the end of the bent tip of the 'L' blade.

These experimental blades worked with about 1 m high grass and straw in wet rice land with very little tangling.

For the evaluation of a puddling implement the level of performance may be based on the following requirements:

1. Reduction in water percolation rate to a desired level.
2. Power requirement per unit of soil puddled must be low.
3. Burying of weeds.
4. Puddled bed should have appropriate softness.
5. Puddled bed must be sufficiently deep and reasonably levelled.

The performance and effectiveness of different tillage implements vary greatly. Attempts have been made to evaluate the relative performance of commonly used equipment for wet land tillage and to develop new equipment to solve the problems of tillage in wet land.

In the past the criteria like energy requirement, cone index of puddled soil, depth of puddle, reduction in percolation losses, cost of puddling, crop output and overall economy have been used for comparison of performance of various puddling equipment.

Awadhwal presented a method for comparing the performance of two puddling machines by accounting for the specific energy spent in puddling and measuring the shear strength ratios of puddled soil. The term performance ratio was defined as the ratio of the efficiencies of the puddling equipment. It was proved that

Performance ratio

$$= \frac{E_A}{E_B} = \frac{J_B \, ln\,(TrA)}{J_A \, ln\,(TrB)}$$

where,

E = efficiency of puddler
J = specific energy spent in puddling
Tr = ratio of vane shear strength of puddled soil to vane shear strength of unpuddled soil.

Suffix A and B indicate the association of the quantity with puddling equipment A and B, respectively.

A study of puddling performed with an indigenous plough, mouldboard plough, disc harrow, rotary cultivator and tractor with cage wheels shows that the rotary cultivator is most efficient in terms of reduction in percolation losses. The rotary blade puddler, rotary cultivator and power tiller perform better in terms of energy requirement, crop output and overall economy as compared to cultivator, pedal type puddler and double cage wheels. The performance of double cage wheels as a puddling equipment is poor and its depth of cultivation is comparatively low.

Every tillage equipment may have one or more typical problems associated with it. For example a comb harrow (**Fig. 5**) collects vegetative matter on its spikes and produces merely a scratching action on soil without a sufficient burying effect. Rotary tillers are prone to wrap grass and straw around them, give limited tillage depth and poor inversion of soil.

A PTO-driven push type wet land rotary tiller (**Fig. 6**) using alternately cutting and supporting blades (designed and built by IRRI) decreases the tractor wheel slippage to a greater degree than a conventional rotary tiller.

A rotary harrow (**Fig. 7**) which can be attached to a small walking tractor could puddle and bury the weeds into the flooded field. The tilling time requirements do not differ significantly from the conventional comb harrow, but the fuel consumption of rotary harrow was less than that of comb harrow. When a drum is placed inside the rotary harrow it exhibits adequate floatation to save the tractor from bogging. It buries the weeds better than the comb harrow and is easier to operate on level land. But it consumes more fuel and requires more time for the same work than the comb harrow. The rotary harrow exhibits some advantages under certain field conditions, however, its economy and performance does not clearly justify its higher cost.

The concept of differential slip tillage was tried for wet land tillage at IRRI, Philippines. A walking tractor was equipped with an extra pair of cage wheels and power was taken from the front wheels. The tiller had excellent mobility and tillage action on soft paddy fields. When it was operated alongside a conventional light weight tiller, the differential slip tiller, in spite of being heavier, continued to be mobile while the lighter tiller was repeatedly bogged. Thus a differential slip tiller can provide improved mobility and achieve tillage without any additional implement in soft paddy fields.

Conclusion

Considerable work has been done to study strength, friction, adhesion and flow characteristics of wet soil and some rheological models have been proposed. Yet the reaction of soil to external forces, soil condition after mechanical manipulation and its time dependent behaviour cannot be predicted without limitation on the range of stress level, rate of deformation, water content of soil and lapse of time. Description of wet soil with regards to tillage tools and traction devices still remains a goal to be attained by researchers.

In paddy fields the extremely unfavourable soil condition creates serious problems of traction and mobility of rice production equipment. These problems have been solved to a great extent by modification in design and development of new traction devices. There is still much room for improvement of traction performance of agricultural equipment in paddy fields. These equipment need to be adopted for areas where the hard pan of the soil is quite deep and bogging down of machines is a big problem.

Considerable work has been done in design and development of equipment for wet land tillage and many new implements are available. But their efficiency is quite low and the performance can be further im-

Fig. 5 Walking tractor with comb harrow (IRRI Annual Report, 1967).

Fig. 6 Push type wetland rotary tiller (IRRI Annual Report, 1967).

Fig. 7 IRRI rotary harrow attached to a walking tractor (IRRI Annual Report, 1968).

proved for better economy.

Though some measures for description of soil puddle have been evolved, still the description of puddled soil remains far from perfect. The lack of a quantitative description of puddling is a major hindrance in performance evaluation of puddling equipment and in turn, hampers the improvement of these equipment.

There is great scope for improvement of the existing equipment as well as for development of new equipment for rice land preparation.

REFERENCES

1. Awadhwal, N.K. (1980). Investigation of dynamic behaviour of puddled soil. Unpublished Ph.D. thesis. Punjab Agricultural University, Ludhiana, India.
2. Baver, L.D., Gardner, W.H. and Gardner, W.R. Soil Physics. 4th Ed. John Wiley, New York, 1972.
4. Beeny, J.M. (1973). Rotary cultivation of wet rice land – comparison of blade shapes. Jr. Agril. Engg. Res. 18 (3): 249-251.
5. Bengali Baboo, (1976). Effect of lug angle of cage wheel on traction and puddling performance of pull wheels. Unpublished M. Tech. thesis. G.B. Pant Univ. of Agric. & Tech., Pantnagar.
6. Bhole, N.G. and Pandya, A.C. (1964). Measurement of quality of puddle. Jr. Agril. Engg. 1 (1): 27-37.
7. Bodman, G.B. (1949). Methods of measuring soil consistence. Soil Sci. 68(1): 37-54.
8. Dutta, P. and Ojha, T.P. (1970). Design of wheel parameters for puddled soils. Jr. Agril. Engg. VII (3), 60-65.
9. El-Domiety, A.H. and Chancellor, W.J. (1970). Stress-strain characteristics of saturated clay-soils at various rates of strain. Trans. A.S.A.E. 18(6): 685-689.
10. Fountaine, E.R. (1974). Investigation into the mechanism of soil adhesion, J. Soil Sci. 5: 251-263.
11. Gill, W.R. and Vanden Berg, G.E. (1968). Soil dynamics in tillage and traction. Agriculture Hand Book No. 315. Agri. Res. Service. USDA.
12. Greacen, E.L. (1960). Water content and soil strength. Jr. Soil Science 11(2): 313-332.
13. Haefelt, R. (1951). Investigations and measurement of the shear strength of saturated cohesive soils. Geotechnique (2): 186-280.
14. Ikeda, T. and Persson, S.P.E. (1968). A track shoe for soft soil. Trans. A.S.A.E. 11(6):746-749.
15. Jaswant Singh (1961). Note on measurement of puddling. Paper presented at Agril. Implement Seminar. I.C.A.R. New Delhi.
16. Kisu, M. (1971). Studies on the improvement of tractor performance. Tech. Report Institute of Agril. Machinery Omiya, Japan (1971) 21-41.
17. Kisu, M. (1977). Tillage properties of wet soils. Paper presented at the symposium "Soils and Rice" at IRRI Los Banos. Laguna, Philippines, Sept., 1977.
18. Koenigs, F.F.R. (1963). The puddling of clay soils. Netherlands J. Agric. Sci. (1963) 11, 149-156. Agric. St. Univ., Wageningen, Holland.
19. Kukubun, K. (1970). Relation between trafficability and physical properties of soil in paddy field. J.A.R.Q. 5(3): 33-37.
20. Komamura, F. (1976). Rheological studies on the behaviour of landslide. The Bulletin No. 53 of the Faculty of Agriculture, Japan, Mie University.
21. Komamura, F. and R.J. Huang (1974). New rheological model for soil behaviour. Jr. Geotechnical Engg. Divn. ASCE, 100 (7): 807-824.
22. Konaka, T. (1974). Similitude studies of soil dynamic properties in puddling field, Japan. Agric. Res. Qtly. 8(1):37-89.
23. Lambe, T.W. and Whiteman, R.V. (1976). Soil mechanics. Wile Eastern Ltd. New Delhi.
24. Madhav, R.M. and Rama Krishna, K.S. (1977). Undrained modulus from vane shear test. Journal of the Geotechnical Engg. Divn., ASCE, 103 (6): 1332-1337.
25. Masuda, S. (1972). Performance of the crawler tractors on muddy fields. Tech. Report No. 1(1972). Farm Power and Machinery Lab. Kyoto Univ. Kyoto, Japan pp 3-23.
26. Masujima, H. and Kokubun, K. (1969). Plasticity of paddy soils. Jr. Sci. of Soil and Manure. Japan 40(1): 397-300.
27. Matsubayashi, M. (1968). Theory and practice of growing rice. Fuji Publishing Co. Ltd. Tokyo, Japan.
28. McMuradle, J.L. (1963). Some characteristics of the soil deformation process. Soil Sci. Soc. Amer. Proc. 27(3): 251-254.
29. Mitchell, J.K. (1976). Fundamentals of soil behaviour. John Wiley & Sons, Inc. New York.
30. Murayama, S. and Shibata, T. (1958). On the rhyological characteristics of clays. Part I, Bulletin, No. 26, Disaster Prevention Research Institute, Kyoto, Japan.
31. Nichols, M.L. (1931). Dynamic properties of soils – II. Soil and metal friction. Agril. Engg. 12: 321-324.
32. Pandey, K.P. and Ojha, T.P. (1971). Optimum shape of rigid traction wheel for puddled soil condition. Jr. Agril. Engg. VIII (I) pp. 33-40.
33. Pandey, K.P. and Ojha, T.P. (1973). Effect of lug angle on tractive performance of a rigid wheel in puddled soil. The Harvester. Ag. Engg. Soc. I.I.T., Kharagpur. 15: 29-31.
34. Pandya, A.C. (1963). Puddling of soil for paddy cultivation. The Agril. Engineer (1962-63).

pp. 16-18, 22.
35. Payney, P.C.J. and Fountaine, E.R. (1954). Mechanics of scouring for cultivation implements. NIAE Memo. 116, pp 11.
36. Perlow, M. and Richards, A.F. (1977). Influence of shear velocity on van shear strength. J. Geotechnical Engg. Divn. ASCE, 103(1): 19-32.
37. Reed, I.F. (1966). Where we stand in the search of better traction. Farm Machinery World. April, 1966.
38. Reidy, F.A. and Reed, I.F. (1966). Traction in a submerged sand soil. Trans. ASAE 9(5): pp 464-467.
39. Reiner, M. (1949). Deformation and flow. H.K. Lewis. & Co. Ltd., London.
40. Sakai, J. (1977). Some design know-how on the edge curve angle of rotary blades for paddy rice cultivation. Agril. Mechanization in Asia 8(2): 49-57.
41. Singh, K.N. (1973). Performance studies on various puddling equipment. J. Agril. Engg. X (1): 14-18.
42. Southwell, P.N. (1964). An investigation of traction and traction aids. Trans. ASAE, 7(2): 190-194.
43. Taneja, M.L. and S. Patnaik, (1961). Technique of determining the degree and depth of soil puddle, Paper presented at Agril. Implement Seminar at Bombay (Oct. 1961). ICAR New Delhi.
44. Throne, D.W. and Peterson, H.B. (1950). Irrigated soils – their fertility and management. Blakiston Co. Philadelphia.
45. Tyagi, N.K., Acharya, N. and Mohanty, P.C. (1975). Effect of puddling implements on percolation losses and water use efficiency in rice field. Indian Journal of Agril. Science 45(3): 132-135.
46. I.R.R.I. Annual Report, (1963).
47. I.R.R.I. Annual Report. (1967).
48. I.R.R.I. Annual Report (1968).
49. I.R.R.I. Annual Report, (1971).
50. F.A.O. (1980). Production year book. ■■

1985 EDITION

FARM MACHINERY YEARBOOK

The 1985 edition now available has 216 pages of the latest comments, statistics and useful addresses pertaining to agricultural mechanization in Japan. The commentaries focus on trends in Japan's agricultural development and agricultural machinery industry and production and results of farm machinery research efforts.

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

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

SHIN-NORINSHA Co., Ltd.

7, 2-chome, Kanda Nishikicho, Chiyodaku, Tokyo 101 Japan

Appropriate Technology — Animal-Drawn Equipment for Small Farmers in Nũble, Chile

by
Mario Ibanez C.
Associate Professor
Agric. Engineering Dept.
University of Concepcion
Chillan, Chile

Edmundo J. Hetz
Associate Professor
Agric. Engineering Dept.
University of Concepcion
Chillan, Chile

Abstract

Small farmers in Chile depend very heavily upon animals as source of energy to operate their agricultural equipment. A study was carried out in the coastal area of the province of Ñuble in order to introduce appropriate technology equipment to these farmers who are trying to increase their productivity and earnings. Results show that 1) the use of an animal drawn grain drill significantly increased yields of wheat and the income of farmers; 2) their work capacity was greatly enhanced and achieving, consequently, timeliness in their seeding operations; and 3) given the scarce economic resources of these farmers a system of collective use for grain seeders should be established.

Introduction

This research project was carried out in the Quirihue and Cobquecura communities located in the coastal area of the province of Ñuble (**Fig. 1**).

The communities cover an area of 140 000 ha, approximately. Their soils have a clear forestal aptitude. However, small farmers in the area use a large percentage of the land (44% in Cobquecura) to grow wheat (Chile, INE, 1976). The scarce productive resources of these small farmers force them to practice a subsistence agriculture. Wheat production is a necessity which causes much soil erosion due to the steep slopes on which the crop is grown (Peña, 1973).

These small farmers are very dependent upon their animals as source of energy to work the land. However, their rudimentary tools and equipment, badly developed animals and inadequate seeding systems are some of the factors that more negatively influence wheat yields in the area (Vásquez, 1979).

Cultural and socio-economic conditions and the land ownership pattern make the introduction of technologies based on mechanical energy very difficult. Therefore, medium term production increments should be sought upon the improvement of their animal drawn equipment and cultivation systems (Ibáñez et al, 1983).

In the last 15 years several international research institutions, like IRRI, CIMMYT, IITA, ICRISAT, CIP and others, have been carrying out a sustained effort in order to develop "appropriate technologies". Several authors, among whom Dunn (1979), Eckaus (1977), Skromme (1980) and Hemmi and Atsumi (1980), who have carefully analyzed the adequacy of technology to the specific needs of agriculture in the developing countries.

According to Skromme (1980), "a technology is appropriate when it closely meets the specific needs of the intended user under the conditions existing on his farm; that he can readily acquire and does effectively and profitably use to significantly increase the quantity and/or quality of his food or fiber production."

A common characteristic in many developing countries, and one that conditions the appropriateness of a technology, is the lack of energy in the form of fossil fuels. The world average use of energy is 1.9 t of coal equivalent (t.c.e.) per year per person. However, this consumption for the U.S.A. is 12 t.c.e./year/person and for the developing nations is only 0.5 t.c.e./year/person (Dunn, 1979).

Even after all the tractorization and automation of agriculture, in North America and Western Europe, human and animal energy are still massively used in most of the agricultural production processes of all the developing nations, where tractors and their equipment are not profitable. It should not be forgotten that complex machines can be used only where the agricultural system generates incomes high enough to pay for their

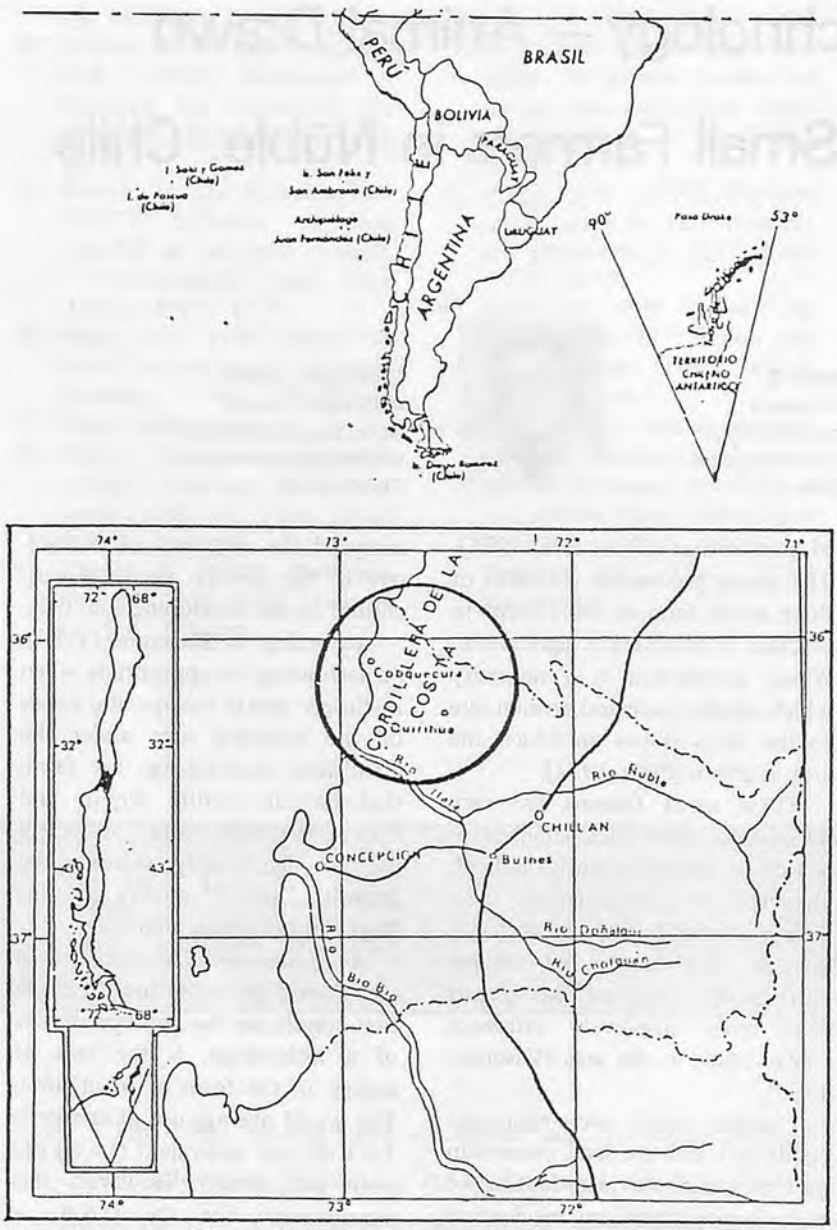


Fig. 1 Study area. Communities of Cobquecura and Quirihue. VIII Region, Chile.

acquisition, depreciation, operation, repairs and maintenance (Hopfen, 1970).

The progress of motorization can also be delayed when farm sizes are too small, fields are irregular in shape, and when there is an abundance of unemployed labor. Other negative factors can be the lack of qualified labor and infrastructure for maintenance and repairs.

Under these conditions the improvement of hand tools and animal-drawn equipment is of great importance, because it constitutes one of the first provisions that can be taken to increase yields and income. Unfortunately, this is not always recognized and one often hears that energy and velocity are synonyms of progress, even where they do not justify the expenses or satisfy specific needs and their election is based mainly upon considerations of prestige (Hopfen, 1970).

The goal of this project is to study the introduction of appropriate technology equipment for small farmers of the Quirihue and Cobquecura communities. Emphasis is placed upon the use of an animal drawn grain drill equipped with a fertilizer attachment.

Materials and Methods

Specific Objectives

1. To determine the effects of an animal-drawn grain drill upon the yields of wheat and the production costs as compared with manual broadcasting of seeds.
2. To study the effects of fertilizer application.
3. To search for more efficient wheat production alternatives using animal-drawn equipment.

Experimental Work

During 1970-80, two experiments were carried out on the Pocillas and Cobquecura soil series (14 km N of Quirihue and 35 km N of Cobquecura). The same experiment took place in both places.

In a randomized block experimental design four treatments with four replications were compared: manual and grain drill seeding, with and without fertilization.

Treatment A – Manual broadcasting of the seed (wheat) and N and P fertilizers in normal doses. An animal drawn wooden plow was used immediately after boradcasting to cover the seeds and fertilizers with soil.

Treatment B – Seeding with a 12-row, animal drawn grain drill, with application of N and P fertilizers in normal doses.

Treatment C (Traditional) – Manual broadcasting of the seed, without fertilization and covering with an animal drawn wooden plow.

Treatment D – Seeding with a 12-row, animal drawn grain drill,

without fertilization.

Huenufén wheat was used as seed at the rate of 160 kg/ha. Seeding was carried out on June 5. The fertilizer used on treatments A and B consisted of 160 kg/ha of Chilean Nitrate, KNO_3, (24.0 kg/ha of N) and 160 kg/ha of triple superphosphate (72.0 kg/ha), applied at the time of seeding. Sixteen plots of 100 m^2 were used at each location.

Two oxen (500 kg each) were used to pull the wooden plow and the grain drill. All seedbed preparation operations were the same for all treatments and were carried out with a pair of oxen.

The common operations used on the 15th of April and May and May 30 were as follows: plowing with an iron plow; harrowing with a plank with spikes; and harrowing with a levelling plank.

Harvesting was likewise a common operation for all treatments. It consisted of cutting with a sickle, manual tying of bundles, transportation on carts, and separation and cleaning on a stationary thresher.

In order to measure the yield of each treatment, a 36 m^2 central subplot was harvested separately for each of the sixteen 100 m^2 plots.

The costs of production for the different operations were calculated according to the procedure presented by Saad (1978). These costs were subtracted from the gross income of each treatment in order to obtain an indication of comparable incomes.

Results and Discussion

The statistical analysis of the yield results and the cost analysis presented in **Tables 1-4** show that, on both locations, the highest yield was obtained with treatment B (grain drill plus fertilization). However, the highest income in Quirihue was obtained using treatment D (grain drill and no fertilization). In Cobquecura, treatment D provides income only slightly smaller than treatment B.

When results are averaged out for both locations (**Table 4**), treatment D provides the highest income. These results offer an attractive alternative for those farmers that do not have money to spend on fertilizers. Access to the use of a grain drill would allow them to obtain incomes as high as those farmers that use the seeder and fertilization.

The results shown on **Table 4** also point out that the application of fertilizers by broadcasting, although partially augmenting yields, does not increase the income of these farmers in a manner comparable with the financial stress created by the cash flow necessary to acquire and transport them.

Table 5 shows the advantages of machine seeding in relation with its work capacity. While the traditional system of manual broadcasting uses 5.25 man-journeys/ha (42 h), the

Table 1 Wheat Yields for Four Seeding Systems, with Animal-Drawn Equipment, in Quirihue and Cobquecura

Unit: kg/ha

Treatment	Yields	
	Quirihue	Cobquecura
A	1 488 b	1 825 b
B	1 904 a	2 387 a
C	1 097 b	1 189 c
D	1 623 b	1 871 b

Note: Yields with the same letter do not differ statistically at the 0.05 significance level.

Table 2 Production Costs and Incomes from which only the Differential Costs have been Subtracted, Quirihue

Treatment	Differential costs	Wheat yield	Gross income	Gross income minus differential costs**	
	US$/ha*	kg/ha	US$/ha	US$/ha	kg/ha
A	88.47	1 488	217.76	129.29	883
B	72.88	1 904	278.63	205.75	1 406
C	26.28	1 097	160.54	134.26	917
D	13.97	1 623	237.51	223.54	1 527

* 1 US$ = 82 Chilean Pesos (October 1983).
** In order to obtain the net income it is necessary to subtract from these columns the production costs common to all treatments (seedbeed preparation, harvest and inputs).

Table 3 Production Costs and Incomes from which only the Differential Costs have been Subtracted, Cobquecura

Treatment	Differential costs	Wheat yield	Gross income	Gross income minus differential costs**	
	US$/ha	kg/ha	US$/ha	US$/ha	kg/ha
A	88.47	1 825	267.07	178.60	1 120
B	72.88	2 387	349.32	276.44	1 889
C	26.28	1 189	174.00	147.72	1 009
D	13.97	1 871	273.80	259.83	1 776

* 1 US$ = 82 Chilean Pesos (October 1983)
** In order to obtain the net income it is necessary to subtract from these columns the production costs common to all treatments (seedbeed preparation, harvest and inputs).

Table 4 Mean Wheat Yields and Incomes for two Experiments Carried Out in the Communities of Quirihue and Cobquecura

Treatment	Quirihue		Cobquecura		$\bar{x}$ Treatment	
	kg/ha	US$/ha	kg/ha	US$/ha	kg/ha	US$/ha
A	1 488	129.28	1 825	178.60	1 656	153.94
B	1 904	205.75	2 387	276.44	2 145	241.09
C	1 097	134.26	1 189	147.72	1 143	140.99
D	1 623	223.54	1 871	259.83	1 747	241.68
$\bar{x}$ Location	1 528	173.21	1 818	215.65		

Table 5 Work Capacity and Labor Needs of the Seeding Systems

Seeding system	Effective field capacity		8-h-man journey
	h/ha	ha/8-h journey	ha
Ox-drawn grain drill	4	2	0.5
Manual broad-cast seeding and covering with an ox-drawn wooden plow	42	0.19	5.25

animal drawn grain drill employs only 0.5 man-journeys/ha (4 h).

These results point out the fact that control over seed location in the soil, as it relates to depth, distance, uniform distribution and dose, allows the farmer to increase his yields a great deal. If we consider now the socio-economic condition of these farmers, together with the results from fertilizer application, it appears that the use of grain drills is an interesting alternative to increase yields and income. However, lack of fertilization would deplete the soil and some solution should be found for this problem.

On the other hand, it is necessary to point out that these small farmers should have access to grain drills through multifarm use systems, like cooperatives, mechanization enterprises, machine hire schemes and mutual help (Lönnemark, 1967). It does not seem appropriate that each farmer acquire his own seeder, since results obtained by Vásquez (1979, clearly show that the large majority of them is in no condition as to make this type of investment and justify it in terms of the area they cultivate.

These limitations show the importance of establishing credit lines, technical assistance and training programs in order to facilitate the development of multifarm systems of machinery use. This would allow these farmers the use of other high return inputs without the high cash flow which they cannot afford.

Conclusions

From the results and experience obtained through this research project, the following conclusions can be presented:

1. The introduction of technology appropriate to the agricultural production conditions of the study area augmented the productivity of the labor force, reduced the drudgery of work and significantly increased yields.
2. The use of animal-drawn grain drills significantly increased wheat yields and the income obtained by the farmers, even when used without fertilization. Also, the work capacity of the farmer is considerably augmented allowing him to work a larger area with great timeliness of operation.
3. The small farmers of the study area do not have the knowledge level necessary to solve their technical problems and they lack the economic resources to acquire equipment, seeds and fertilizers. Therefore, it is most important to establish credit lines and training programs in order to improve the living conditions of the people and develop the agriculture of the area.
4. It is also necessary to develop multifarm systems of machinery usage, which will allow these farmers the benefits obtained from high return imputs without the very high expenditures that they so often demand.

REFERENCES

1. Chile. Instituto Nacional de Estadísticas. V Censo Agropecuario. 1976. Provincia de Ñuble. 1976.
2. Dunn, P.D. 1979. Appropriate Technology. Schocken Books, Hong Kong, 220 p.
3. Eckaus, R.S. 1977. Appropriate technologies for developing countries. National Academy of Sciences. Wash., D.C., U.S.A.
4. Hemmi, K. and Atsumi, K., 1980. Mechanization of small-scale peasant farming. Agricultural Development Council, Hokkaido University, Tokyo, Japan. (Report No. 21).
5. Hopfen, H.S. 1970. Aperos de labranza para las regiones áridas y tropicales. F.A.O., Roma, Italia. (Cua – derno de Fomento Agropecuario No. 92)
6. Ibañez, C.M., Concha, C.L. Y Phillips, F.R. Situación tecnológica de la labranza en suelos de secano de la Costa de la Provincia de Ñuble. AGRO-SUR 10 (2) 70-74, Univ. Austral de Chile, Valdivia. 1983.
7. Lönnemark, H. 1967. El empleo multipredial de la maquinaria agrícola. F.A.O., Roma, Italia. (Cuaderno de Fomento Agropecuario No. 85).
8. Peña, Mc. L. Recopilación de artículos sobre temas de conservación de suelos y aguas. Universidad de Concepción. Chillán, Chile, pp. 19-27. 1973.
9. Saad, O. Selecão do Equipamento Agrícola. Livraria Novel S.A. Segunda Edicão. Sao Pablo, Brasil, 1978.
10. Skromme, L.H. 1980. Appropriate Agricultural Mechanization in the Developing Countries. Proceedings of the Agricultural Sector Symposia. The World Bank. Wash., D.C., U.S.A.
11. Vasquez, G.L. Mecanización de la labranza, con tracción animal, en suelos de secano de la costa de la Provincia de Ñuble. Chillán, Chile, Universidad de Concepción. 78 p. Tesis mimeografiada. 1979.

Improved Animal-Drawn Moldboard Plough Utilizing Available Draft Power

by
A.A. Mainul Hussain
Professor
Dept. of Farm Power and Machinery
Bangladesh Agricultural University
Mymensingh, Bangladesh

S.M. Farouk
Associate Professor
Dept. of Farm Power and Machinery
Bangladesh Agricultural University
Mymensingh, Bangladesh

N.N. Sarker
Assistant Professor
Dept. of Farm Power and Machinery
Bangladesh Agricultural University
Mymensingh, Bangladesh

Introduction

About 80% of the farmers in Bangladesh use conventional country plough which varies in shape and size depending on the locality where it is used. The basic shape of the plough, including the steel share, has not gone through any major change during the last century (**Fig. 1**). The most important drawbacks of the existing country ploughs are (i) the plough bottom is carved out of a big piece of wood or a branch of tree; and (ii) the share is made of small mild steel plate without any inversion capabilities. Therefore, when the plough bottom is damaged the entire bottom has to be replaced with a new one, which is expensive. The plough share as originally designed has to be replaced completely when the tip has worn out. The share is designed in such a way that it deforms the soil near its tip and deflects it on both sides forming a narrow channel on its way. Since the conventional country plough deforms the soil instead of actually cutting through it, therefore, the pull imposed on the animal is quite substantial and the relative width and depth of cut is very limited compared to the draught power requirements.

The present study was conducted to determine the draft power requirement, field capacity and other performance characteristics of the conventional plough (**Table 1**).

The width of cutting edge of the mild steel share is only about 25 mm, average depth varies between 78 and 120 mm and the draft power requirement was 0.336 to 0.256 kW. In order to eliminate the difficulties as discussed earlier a new improved plough was designed (**Fig. 2**).

The major change and modification of the plough is in its large moldboard type share made of sheet metal. The share was designed so as to cut through the soil and at the same time invert it on the right hand side. The other most important improvement in the design is the use of small pieces of timber in the construction of the parts of the plough as shown in **Fig. 2** instead of a big piece of wood for carving out the plough bottom which is a great saving in terms of material which is in short supply. Tests were carried out with the improved plough and the results are shown in **Table 2**.

Improvements in the performance of the newly developed plough in comparison with that of the conventional ploughs are reflected in **Table 2**. However, draft power requirements for both types of ploughs are almost similar at the primary tillings. In the case of conventional ploughs, unlike the new plough, a sort of jerking tendency is a regular phenomenon as the pulling forces do seldom pass through the load center of the plough resulting in an unsteady tillage operation and thereby restricting the animals to work at relatively slow speeds.

With the new plough, as reported by some farmers, a slightly more area can be tilled per day, 0.12 to 0.16 ha. But the major

Acknowledgement: The authors are grateful to the Danish International Development Agency for the financial support rendered for the project. The authors are also grateful to Mr. R.I. Sarker and Mr. Daulat Hossain for their help during the experimental work.

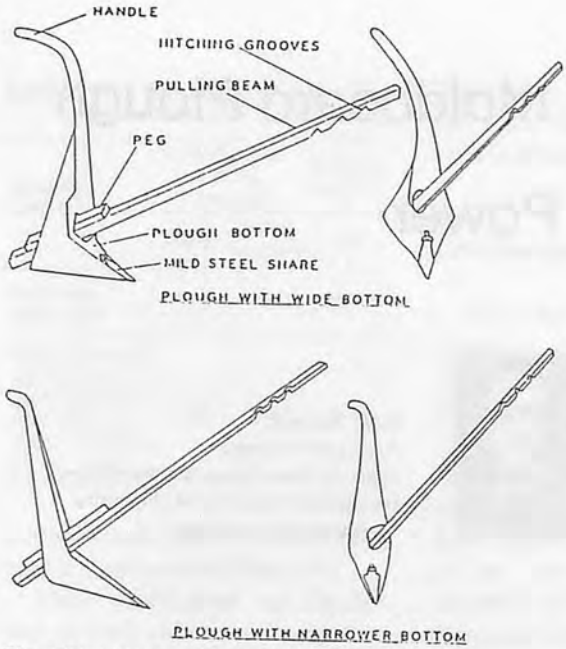


Fig. 1 Two versions of existing country plough.

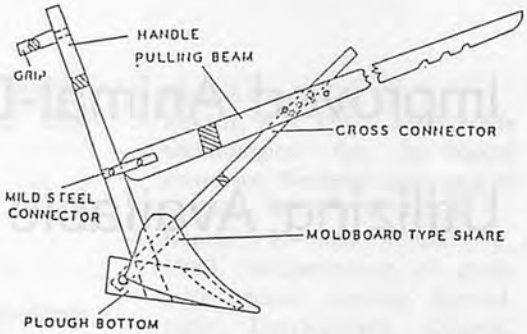


Fig. 2 New improved moldboard plough.

Fig. 3 Close-up view of experimental plough during field testing.

Fig. 4 Condition of field after first ploughing.

Table 1 Performance Results of Country Ploughs

Tilling No.	Pulling force kg	Average Depth mm	Average Width mm	Field capacity ha/h	Draft power kW	Specific energy requirements kW-h/ha
1	49.53 (12.45)*	78.0 (11.9)	120.0 (28.2)	0.0333 (0.0031)	0.336 (0.020)	10.08 (0.64)
2	46.60 (16.56)	94.0 (14.5)	198.1 (47.5)	0.0436 (0.0076)	0.295 (0.043)	7.00 (1.10)
3	42.99 (17.25)	116.4 (15.3)	262.8 (53.0)	0.0416 (0.0033)	0.301 (0.031)	7.23 (0.87)
4	43.75 (17.32)	119.7 (16.2)	275.8 (33.3)	0.0458 (0.0053)	0.256 (0.018)	5.57 (1.31)

* Figures in the parentheses indicate standard deviations of population 7.

Table 2 Test Results of Improved Plough

Tilling No.	Pulling force kg	Average Depth mm	Average Width mm	Field capacity ha/h	Draft power kW	Specific energy requirements kW-h/ha
1	47.59 (12.29)*	107.95 (10.72)	165.10 (17.50)	0.033 (0.002)	0.331 (0.002)	9.457 (1.021)
2	31.75 (09.35)	105.83 (10.59)	211.47 (21.60)	0.047 (0.007)	0.302 (0.003)	6.383 (0.925)
3	30.27 (07.72)	131.23 (13.73)	234.20 (29.97)	0.050 (0.003)	0.251 (0.001)	5.002 (0.571)
4	28.25 (08.87)	135.21 (09.27)	215.29 (25.21)	0.055 (0.004)	0.240 (0.003)	4.364 (0.325)

*Figures in parentheses indicate standard deviations of population 5.

advantage is in the lesser number of tilling operations for the complete preparation of the seed bed. Some model ploughs were distributed in the DANIDA-IRDP project area for the farmers for their test. The response from the farmers about the test was very eneouraging.

Recommendations:

i) The design and construction procedure of the new plough is very simple. So the village technicians (blacksmith and carpenters) with little training will be able to manufacture the plough with their existing facilities.

ii) The plough body can be made with any moderately hard piece of wood which unlike conventional ploughs, is not dependent on the availability of special variety of timber with particular shape and size of curvature and branches.

iii) The new plough may be manufactured almost at the same cost of local plough.

iv) The bottom and share of the plough are replaceable after a certain degree of wear. ■■

Design Characteristics and Performance of Wind Mills for Pumping Irrigation Water

by
B.V. Ramana Rao
Head
Division of Wind Power and Solar Energy Utilization
Central Arid Zone Research Institute
Jodhpur, India

P. Sharma
Foreman
Division of Wind Power and Solar Energy Utilization
Central Arid Zone Research Institute
Jodhpur, India

S.C. Chowdhry
T-7, Engineer
Division of Wind Power and Solar Energy Utilization
Central Arid Zone Research Institute
Jodhpur, India

Abstract

The performance of wind mills relating the wind speed in km/h and water output in ha-mm as influenced by the swept area of the rotors and depth of the water table has been theoretically evaluated and presented graphically. This graph can be conveniently utilized either to judge the suitability of any windmill in a given region or to optimise the design of a wind mill to suit a specific agroclimatic situation.

Introduction

With increasing prices of fuel, depletion of commercial energy sources and frequent failures in power supply, attention is being drawn on utilizing renewable sources of energy for pumping water for irrigation. Wind power is considered as one of the renewable sources of energy for pumping water in spite of the fact that winds are not steady both in speed and direction. However, winds blow almost everywhere in the world. Several studies were made in India to estimate wind power and identify areas suitable for utilizing wind energy by Krishnan and Garg (1975), Krishnan (1977), Rajagopalan (1978) and Srinivasa *et al* (1978). These studies did not indicate the extent to which wind power can be utilized for irrigation quantitatively. Ramana Rao *et al* (1980) have estimated the possible command area of a wind mill taking into consideration the rainfall, potential evapotranspiration, cropping patterns and wind regime in different arid regions of India. Several organisations, including the National Aeronautical Laboratory, Bangalore, Indian Institute of Sciences, Bangalore, Central Arid Zone Research Institute, Jodhpur, Tool-ORP Wind Mill Project, Ghazipur and Allahabad Polytechnic, Allahabad have developed different models of wind mills for pumping water for irrigation in India (Commission for Additional Sources of Energy, 1981).

The suitability of the wind mills for pumping water for irrigation in any region depends upon the wind regime, rainfall distribution, evaporative demand and depth of the water table. There is need to evaluate either the extent to which a given type of wind mill meets the irrigation requirements in a given region or desirable characteristics of a wind mill that will meet the irrigation requirements in different agroclimatic regions. In view of this, efforts was made to project the relationship between wind speed and water output from a wind mill in ha-mm as influenced by the design characteristics of wind mills.

Acknowledgements: The authors are thankful to Dr. K.A. Shankaranarayan, Director, CAZRI for his valuable encouragement in conducting the above study.

Fig. 1 Sail wing wind mill developed at CAZRI.

Material and Methods

A stream of air density ρ, flowing across an area A at a velocity V, has a flux of kinetic energy equal to $1/2\ \rho\ V^3 A$ per unit time. Therefore, the wind power (P) that can be tapped across an area (A) is given by

$$P = \frac{1}{2}\rho V^3 A \quad \ldots\ldots\ldots\ldots (1)$$

The actual power utilised (P_a) for lifting water of volume v with density 'd' from a depth 'h' in unit time is given by

$$P_a = vd\,gh \quad \ldots\ldots\ldots\ldots (2)$$

The efficiency of wind power utilization

$$\eta = \frac{2\,v\,dgh}{\rho\,V^3 A} \quad \ldots\ldots\ldots\ldots (3)$$

The volume of water pumped in unit time

$$v = \frac{\rho\,V^3\,\eta\,A}{2\,hd\,g} \quad \ldots\ldots\ldots\ldots (4)$$

From equation (4), the value of v can be obtained in m^3/sec by substituting the values as given below.

ρ = density of air in kg/m^3 (1.18 kg/m^3 at temperature 25°C and pressure 76 cm of Hg)

A = area in m^2 across which wind energy is tapped.

d = density of water in kg/m^3 (1 000 kg/m^3).

g = acceleration due to gravity in m/sec^2 (9.8 m/sec^2)

h = depth of the water table in m.

V = wind velocity in m/sec.

As wind velocity is usually expressed in km/h (V*),

$$V = \frac{5}{18} V^*$$

By substituting wind velocity in km/h in equation (4), it becomes

$$v = \frac{\rho\,A\eta}{2hdg}\ \frac{(5\ \ V^*)^3}{18} \quad \ldots (5)$$

By expressing v in ha-mm, it will be convenient to understand the area and the extent to which land can be irrigated. One ha-mm is equal to 10 m^3. After substituting the values for ρ, d and g, the quantity of water in ha-mm that can be pumped in one day is given by

$$v = \frac{0.0115\,\eta\,A\,V_*^3}{h} \quad \ldots\ldots (6)$$

Chowdhry *et al* (1981) have shown that the efficiency (η) of the wind mill depends upon the wind speed. Therefore, the efficiency of the wind mill at different wind velocities as given by Chowdhry *et al* (1981) were considered in the present study. The swept area (A) of the wind mill depends upon the wind mill and depth of the water table (h) depends upon the local conditions. The water output in ha-mm at different wind speeds were estimated using equation (6) for different values of (A/h) ranging from 2 to 25.

Results and Discussion

Fig. 2 shows the relationship between wind speed in km/h and water output in ha-mm for values of A/h = 2, 5, 10, 15 and 25. Supposing that the average wind speed is about 12 km/h in a particular month, a wind mill with a swept area of about 30 m^2 can lift water equal to 5 ha-mm from water table of average depth 15 m, *i e*, A/h = 2.

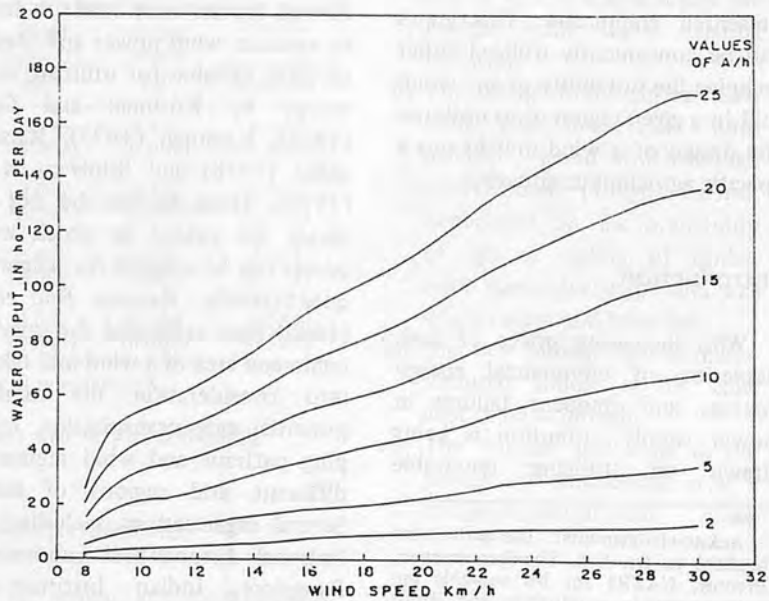


Fig. 2 Design characteristics of wind mills for pumping water for irrigation.

If the evaporative demand is about 5 mm, the wind mill can irrigate about 1 ha at potential rate during the month. Thus, these curves are very useful in determining the command area of a wind mill by knowing the wind regime, depth of the water table and swept area of the wind mill.

These curves can also be utilized for determining the design parameters of the wind mills suitable for a given location. If the daily evaporation rate is about 5 mm, depth of the water table 10 m and average wind speed is 15 km/h the value of A/h required to irrigate 3 ha land will be about 5. As h = 10 m, the swept area (A) of the wind mill should be about 50 m^2. The diameter of the rotor (D) required to produce swept area (A) is given by the formula

$$D = 1.128 \sqrt{A} \quad \ldots\ldots\ldots \quad (7)$$

Therefore, the diameter of the rotor required to produce a swept area of 50 m^2 is equal to 7.98 m or nearly 8 m. So, a wind mill with rotor radius of 4 m is required under such conditions.

However, one should bear in mind that there will be considerable diurnal as well as seasonal variations in wind speed, evaporative demand and depth of the water table. Therefore, the curves presented in **Fig. 2** will serve as a guideline under normal situations only.

REFERENCES

Chowdhry, S.C: Ramana Rao, B.V. and Sharma, P. (1980). Performance of a sail wind mill. AMA 12 (1): 66-68.

Commission for Additional Sources of Energy (1981). National paper, India. U.N. Conference on new and renewable sources of energy, Nairobi. 10-21 August 1981. Department of Science and Technology, New Delhi, pp. 32.

Krishnan, A. and Garg, H.P. (1975). Wind power for pumping water. Indian and Eastern Engineer. 117(3): 70-74.

Krishnan, A. (1977). A case for wind power utilization. Commerce (Annual Number) pp. 105-110.

Rajagopalan, G. (1978). Energy potential of wind. Unpublished M.E. dissertation. Dept of Aeronautic Engineering, Indian Institute of Science, Bangalore.

Ramana Rao, B.V.: Rama Krishna, Y.S. and Chowdhry, S.C. (1980). Wind power potential for irrigation in the arid regions of India. Indian J. Power and River Valley Development. 30: 129-133.

Srinivasa, U.: Narasimha, R. and Govindaraju, S.P. (1978). Wind power potential of Karnataka. Res. Rep. No.78FM. Dept. of Aeronautics, Indian Institute of Science, Bangalore. ■■

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

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

Specific Information Service.

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

Survey & Research.

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

System Development.

Design of Developing System on New Products: from Ideas to Marketing.

Consultation.

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

Seminars & Meeting.

New Project & Up-to-date Subjects.

Publication Activities.

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

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

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

Simple Attachments to Indian Country Plough

by
Ghanshyam Das
Professor (Agric. Engg.)
G.B. Pant University of Agriculture and Technology
Pantnagar District, Nainital
U.P., India

Avinash Agarwal
Junior Research Officer (Agric. Engg.)
G.B. Pant University of Agriculture and Technology
Pantnagar District, Nainital
U.P., India

Abstract

The most common tillage equipment in India is the country plough. Four simple attachments to the plough frame have been proposed which are effective, simple, inexpensive and can be locally made by Indian village artisans.

Introduction

The Indian country plough is probably the most common tillage implement used by Indian farmers. It is estimated that there are about 40 or more types of this plough in use in the country which are basically the same, but with large variations in their shape, size, and weight due to varied soil types and tillage requirements. The main parts of the plough are (1) body (2) share, (3) shoe, (4) beam and (5) handle. The body is the main part of the plough to which the shoe with share beam and handle are attached. Generally, these parts are replaceable and can be taken out and refixed. The shoe and share assembly can be easily taken out and replaced, in most of the plough designs. For certain tillage operations which the country plough cannot perform, attachments can be fitted to the body either by taking out the shoe and share assembly from the body or along with it. The shoe and share assembly can be replaced after the operation with the attachment is over. Tillage operations, like construction of ridges and furrows, potato digging, paddy puddling, and raking operations can be done with some simple attachments to the plough body.

Furrow Opener

The furrow opener can be fabricated with a 2 mm thick mild steel plate. The width of the implement is 20 cm and its total length is 31 cm. The furrow opener is curved shaped with a concavity of 3.5 cm (Fig. 1). The cutting edge is sharpened for easy penetration into the soil. To attach the furrow opener to the country plough, the shoe and share assembly of the plough is taken out from the plough assembly. In its place the furrow opener is fixed with help of a frame welded to it, which fixes it tightly to the plough body and beam.

The furrow opener is a versatile attachment which can be used for making furrows for potato cultiva-

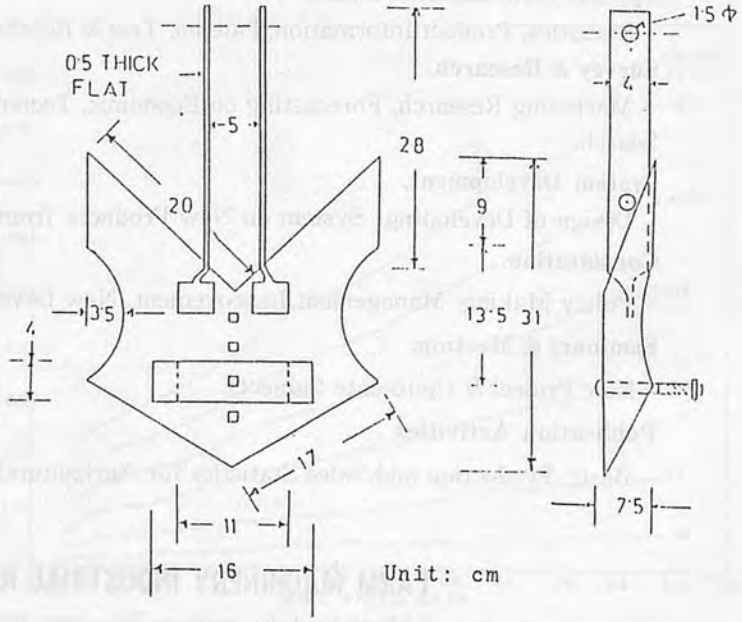


Fig. 1 Furrow opener.

Fig. 2 Furrow opener fitted to Indian country plough. Note the missing share-shoe assembly.

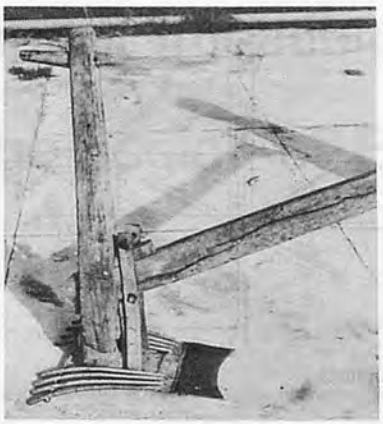


Fig. 3 Potato digger attached to Indian country plow. Note the missing share-shoe assembly.

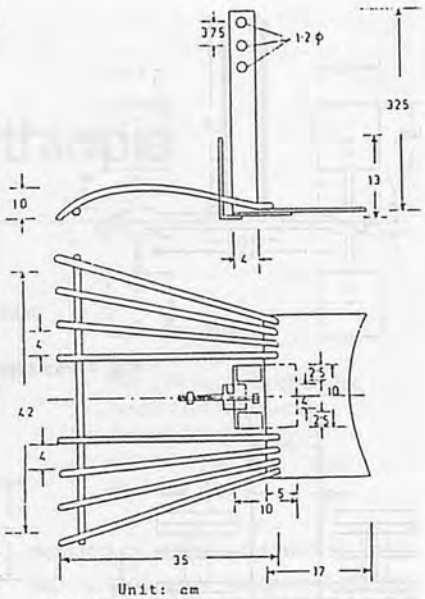


Fig. 4 Potato digger.

tion and other vegetable crops and for constructing field channels for irrigation water conveyance. The furrow opener attached to the plough body is shown in Fig. 2.

Potato Digger

The share plate of the potato digger attachment is concave shaped with a curvature of 3 cm in the front. It is made of mild steel plate of size 26 cm x 17 cm x .25 cm. To attach the potato digger to the plough, the shoe and share assembly of the plough is taken out from the plough assembly. In its place the potato digger is fixed with the help of a frame welded to it, which fixes it tightly to the plough body and the beam (Fig. 3). The details are given in Fig. 4.

Paddy Puddler Attachments

Two types of paddy puddler attachments were developed; namely fan type and cage wheel type (Figs. 5 and 6). The puddlers have the main components as two cage wheels of 22 cm dia., or two fan type rollers of 36 cm dia.. When a puddler is attached to the plough, the wheels of the implement get set on both sides of the shoe and share assembly of the plough. In this case the shoe and share assembly need not be separated, and the puddler attachments work along with the plough share in the field. Care has to be taken in operating the equipment in a trash-free field as the trash blocks the movement of puddler wheels. Details of the implements are illustrated in Figs. 7 and 8.

Field Rake Attachment

A field rake with 8 tynes was developed which can be attached behind the plough to collect weeds from dry or wet fields. This attachment can be fitted separately or along with the puddler attachments as shown in Fig. 9. The implement is provided with a clutch to lift the rakes to clear the trash.

Conclusion

Four types of simple attachments have been developed for the Indian country plough. The sizes of the equipments may be varied according to the size of the bullocks, type of plough and tillage conditions. All the equipments can be fabricated by village artisans. Since the implements are very simple in design, these can be easily maintained by the village artisans also.

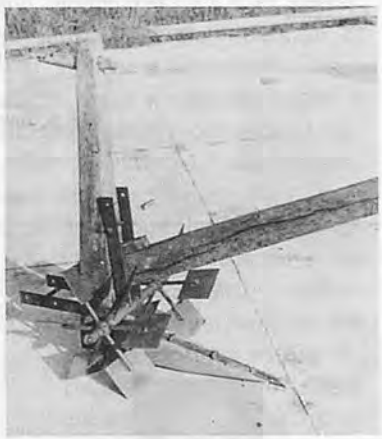


Fig. 5 Fan type paddy puddler in operating condition with Indian country plough.

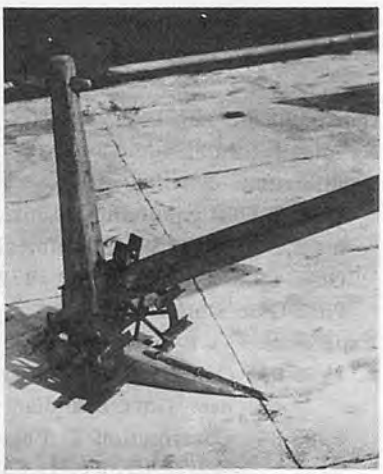


Fig. 6 Cage wheel type paddy puddler fitted to Indian country plough.

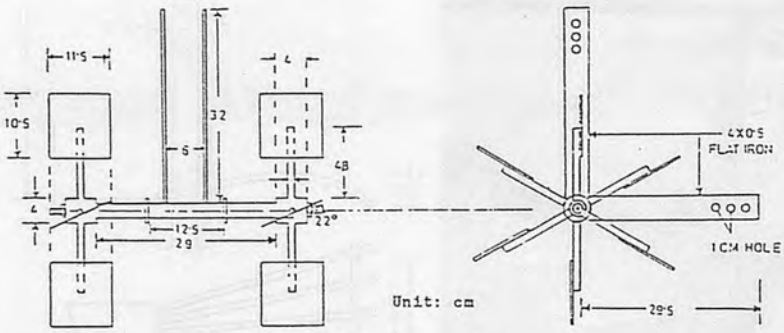


Fig. 7 Fan type puddler.

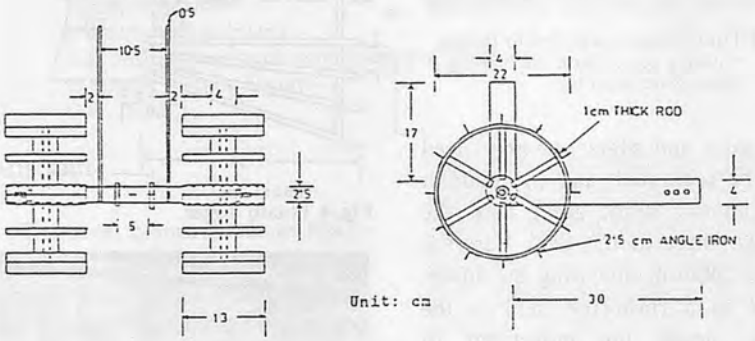


Fig. 8 Cage wheel puddler.

Fig. 9 Field rake fitted to Indian country plow. Note the clutch attachment.

REFERENCES

1. Michael, A.M. and Ojha, T.P. 1966. Principles of Agricultural Engineering, Vol.I. Jain Brothers, Jodhpur.
2. Michael, A.M. and Kneerim, C. 1965. Sinchai Krishi Kram Yantraon ka prayog. Ext. Bul.3. Udaipur University, Jobner (Rajasthan).

New Co-operating Editors

Naresh Chandra Saxena

Date of Birth: Jan. 16, 1940
Nationality: Indian
Qualification:
1963 B.E. (Civil Jodhpur Univ., India, 1970 M.S. (Structures) Ohio State Univ., U.S.A., 1972 Ph.D Ohio State Univ., U.S.A.
Experience:
1963-66 Construction Engineer, Govt. of India.
1983-84 Construction Engineer, Rajasthan, India
1972-74 Assist. Prof., Udaipur Univ., India
1975-77 Mosul Univ., Iraq
1978-82 University-Pertanian-Malaysia
1984- University of Agriculture, Morogoro, Tanzania
1980-82 AMA Co-operating Editor from Malaysia
Present Position:
Contract Officer, Department of Agric. Engineering and Land Planning.
Sokoine University, P.O.Box 3003, Morogoro, Tanzania

Mohammed A. Mazed

Nationality: Bangladesh
Qualifications:
B.Sc. (Eng.) Bangladesh Univ. of Engineering and Technology, M. Agr. Eng. National College of Agric. Engineering, Ph.D. Oklahoma State Univ., U.S.A.
Experience:
1969-72 Assistant Engineer, Bangladesh Machine Tools Factory, Joydebpur, Dhaka
1972-78 Assistant Prof., Bangladesh Agric. Univ., Mymensingh
1978- Chief Scientific Officer & Head of Agric. Engineering Div. Bangladesh Agric. Research Institue, Joydebpur, Dhaka, Bangladesh

Windpump for Irrigation in Hararghe Region of Ethiopia

by
Peter Brudi
Lecturer and Head
Manufacturing Engineering Section, Dept. of Agric. Engineering
Addis Ababa University
College of Agriculture
P.O.Box 138, Dire Dawa
Ethiopia

K.P. Srivastava
Lecturer and Head
Dept. of Agric. Engineering
Addis Ababa University
College of Agriculture
P.O. Box 138, Dire Dawa
Ethiopia

Abstract

The monthly average wind velocity at 2 m height of different stations within the Hararghe are used as an input to mathematical model to give monthly average daily water supply from a characterized systems matched windpump for the different stations. The double mass curve method was used to find the proper size of reservoir to be coupled with the windpump at various stations within the Hararghe region, under different constant daily demands and for secured irrigation throughout the year. One system that matched the windpump is fabricated and installed at Tinikie Farmer's Cooperative, Alemaya, alongwith a reservoir of gross capacity 96 m^3. The windpump output is compared with the output of mathematical model for the station Alemaya.

Acknowledgement: The authors thank the Federal Republic of Germany Embassy and German Volunteer services, Addis Ababa for providing generous fund and executory help in running the Windpump Project. The authors are thankful to Mrs. Heike-Rutz Brudi for her help in the preparation of this paper, and also wish to express their sincere appreciation to Mr. Yilma Yoseph, Mr. Abebe Fanta and Mr. Tesfu Girmahun for their assistance and involvement in the Windpump Project of the Department.

Introduction

Ethiopian agriculture requires immediate energy input to it, in all the forms, for a multiple rise in productivity. Besides other energy inputs, the energy required for assured irrigation throughout the year is one of the principal activators in the whole agricultural production system. The main grid electric supply system for use in the rural areas is yet to be expanded, but its expansion itself may not optimally meet all the energy requirements in its magnitude and form, as is required in the rural areas. An assured and self manageable form of energy is more suited both techno-economically and from management point of view, especially for Ethiopia where the villages are scattered in remoteness and isolation devoid of electric network, but are enriched with solar and wind energy.

A first-hand study of the wind velocity distribution in the different parts of the country indicates that there is a good scope of utilizing wind power for pumping irrigation water in several parts of the country (1, 2). A critical analysis of wind velocity distribution patterns reveal its highly non-uniform and uncertain nature. But for crop production, the supply of irrigation water has to be assured in quantity and in time. To obtain a fixed daily demand of water, and also its utilisation, not only require a system matched windpump but a complete wind pumping system with a reservoir and a complete package of water and crop management practices to make windpump irrigation a success for crop production (3, 6).

The objective of the present study was:

i) To obtain the monthly average daily water supply from a characterized systems matched windpump at the various stations within the Hararghe region, for different months in a year, by using a mathematical model developed for the region;
ii) To find the proper size of reservoir to be coupled with the windpump for the various stations within the Hararghe under different daily demands of water;
iii) To compare the output of the mathematical model with the output of windpump fabricated in the Department of Agricultural Engineering and installed at Tinikie Farmer's Cooperative in Alemaya.

Materials and Methods

Theoretical power which can be

tapped from wind on the basis of linear momentum theory is given by:

$$P = 0.593 \times 0.014 \times A \times V^3 \quad \ldots\ldots\ldots (1)$$

Where, P = power, W

A = swept area, m^2

V = wind velocity, km/h

The monthly output in terms of energy for a windpump designed for the maximum power coefficient at a given speed ratio and a given number of blades with systems matching of individual components, and site wind energy pattern is obtained by (3, 5):

$$P = 0.006 \times n_o \times A \times V_o^3 \times K_s \times k_p, \text{ kWh} \quad \ldots (2)$$

Where, A = swept area of the windpump rotor in m^2

V_o = monthly average wind velocity in km/h at site at 2 m height.

n_o = overall efficiency of windpump

K_s = statistically obtained coefficient for a number of sites with different wind energy patterns, and is the ratio of monthly windpump output on hourly wind velocity basis to to the monthly windpump output on monthly average wind velocity basis. K_s ranges from 1.25 to 2.82 for different site characteristics and wind energy pattern.

k_p = the coefficient for obtaining the monthly windpump output when its rotor is at height range of 8-10 m and at a known site characteristics. The k_p value ranges from 3.3 to 6.3.

The statistical study of wind velocity variation at 2 m height at different stations in the Hararghe region, and the nature and extent of topographical variation within the region suggests a K_s value of 2.12 and kp value of 5.8. Thus, for the Hararghe region of Ethiopia, the monthly output in terms of energy of a windpump will be given by:

$$P = 0.006 \times n_o \times A \times V_o^3 \times 2.12 \times 5.8 \text{ kWh}$$

$$\text{or, } P = 0.074 \times n_o \times A \times V_o^3 \text{ kWh} \quad (3)$$

If system-matched windpump of rotor swept area A m^2 working under total head of 14 m is erected within the Hararghe region at height range of 8-10 m, then the water output in m^3/day (Q) from it can be obtained by equating Equation (3) with monthly water horsepower expressed in kWh, that is,

$$0.074 \times n_o \times A \times V_o^3 = \frac{Q \times 1000}{24 \times 3600} \times H \times \frac{0.746}{75} \times 24 \times 30$$

$$\text{or, } Q = 0.886 \times n_o \times \frac{A}{H} \times V_o^3 \quad (4)$$

A relation between the overall efficiency (n_o) of a systems-matched windpump and the monthly average wind velocity (Vo) has been obtained and is given by:

$$n_o = 0.195 - 0.006\, V_o \quad (5)$$

Substituting the value of n_o in Equation (4)

$$Q = \frac{A}{H}(0.173\, V_o^3 - 0.005\, V_o^4) \quad (6)$$

The equation (6) gives the daily water output in m^3 from windpump having rotor swept area A m^2 erected at height range of 8-10 m within the Hararghe region, and working under a total head of H m.

The double mass curve method was adopted to find out the required reservoir capacity under different daily water demand and daily supply from windpumps at different stations within the Hararghe region. The methodology is illustrated in **Fig. 1** for the station Alemaya. The monthly average value

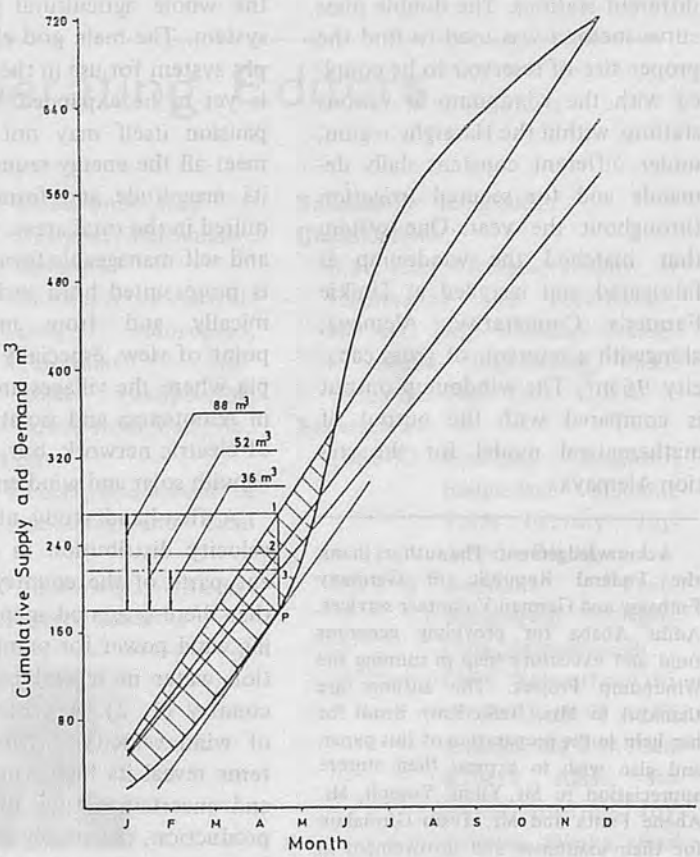


Fig. 1 Cumulative water supply curve of windpump and cumulative, demand curve of three daily demands for station Alemaya.

Table 1 Monthly Average Wind Velocity and Daily Windpump Output for Different Months at Various Stations within Hararghe Region

Month	Stations											
	Alemaya		Dire Dawa		Gode		Graawa		Hamaro		Midegalola	
	A	B	A	B	A	B	A	B	A	B	A	B
Jan.	4.4	26	4.4	26	11.7	361.1	7.7	123.5	7.8	127.0	7.6	116.5
Feb.	5.3	44	5.2	41.5	13.2	485.5	10.2	258.0	7.6	116.5	7.5	125.9
Mar.	6.6	81.3	6.7	83.0	12.0	384.1	11.3	333.6	7.5	115.9	7.2	102.3
Apr.	7.1	99.4	7.2	102.3	9.2	195.3	11.7	369.6	7.5	115.9	11.0	309.5
May	6.0	63.7	6.0	63.7	9.0	185.1	8.5	157.7	7.3	105.4	9.4	207.4
Jun.	9.8	235.8	14.4	589.0	16.1	747.9	10.2	256.7	9.6	218.5	8.1	141.5
Jul.	9.2	197.8	10.9	304.3	19.4	1 053.7	12.3	410.9	14.5	596.3	6.8	87.4
Aug.	7.0	95.6	8.6	163.2	17.0	829.8	10.9	302.2	14.6	605.4	6.0	63.7
Sep.	5.2	41.8	6.7	83.0	14.2	573.5	8.8	175.0	8.6	163.2	6.1	64.6
Oct.	6.2	68.4	7.3	107.0	7.5	115.9	8.0	134.2	7.3	104.6	7.5	115.9
Nov.	4.8	33.3	4.9	34.8	6.7	83.7	7.3	107.0	7.5	115.9	8.5	156.9
Dec.	5.0	37.6	4.3	24.5	9.5	213.2	6.6	79.6	7.5	115.9	7.9	131.4

Remark: A – Monthly average wind velocity, km/h; B – Monthly average daily windpump output, m^3.

Table 2 Required Reservoir Sizes for Different Daily Water Demand Levels at Stations within Hararghe Region

Daily water demand (m^3)	Stations				
	Dire Dawa Reservoir Size, m^3	Gode Reservoir Size, m^3	Grawa Reservoir Size, m^3	Hamaro Reservoir Size, m^3	Midegalola Reservoir Size, m^3
30	MS	MS	MS	MS	MS
60	60	MS	MS	MS	MS
90	135	MS	MS	MS	MS
120	285	MS	MS	MS	MS
150	NF	MS	130	170	290
180	NF	MS	224	320	NF
210	NF	224	343	NF	NF
240	NF	310	464	NF	NF
270	NF	NF	NF	NF	NF

Remarks: MS – Minimum size, which is equal to 75% of daily water demand.
NF – Not feasible.

of wind velocity at 2 m height for different months in Alemaya station. *i e* V_O, are substituted in equation (6) to obtain monthly average daily output (Q) from a windpump having rotor diameter 5 m, *i e*, $A = (\pi/4) \cdot 5^2$, erected at height range of 8-10 m and working under total head of 14 m, *i e*, H = 14 m. These values of Q thus obtained for different months are cumulated and plotted against different months, which gives a supply curve. Three cumulative demand curves for the constant daily demands of 48 m^3, 52 m^3 and 60 m^3 are also plotted against different months. For three daily demand level, the reservoir sizes are obtained by finding the maximum vertical distance between the supply curve and demand curves within the deficit region shown bv hatched line. Thus, the vertical distances p1, p2, p3 give reservoir sizes of 88 m^3, 52 m^3, 36 m^3 for the three constant demand levels 60 m^3, 52 m^3, 48 m^3, respectively, (**Fig. 1**).

Similarly, by using equation (6) values of Q for different months and for different stations within Hararghe have been worked out and are given in **Table 1** for a windpump of rotor diameter 6 m erected at a height range 8-10 m and working under total head of 14 m. Also, the required reservoir sizes at different daily demand levels for different stations within Hararghe, except for Alemaya station, have been found out, and are given in **Table 2**. The MS in the table means the minimum size of reservoir that is required to take care of the variation of the output of windpump in a day, and within period when the irrigation is usually provided, which is always a day-time hour, except when the irrigation is through sprinkler or drip. This minimum size of the reservoir for different constant daily demand is found to be 75% of the daily water demand under rotational irrigation planning (7). The NF in the table means "not feasible," and is the case when the cumulative deficit becomes greater than the cumulative surplus under a given daily demand.

A windpump of specification given below was fabricated in the Manufacturing Engineering Section of the Department of Agricultural Engineering, and installed in the Tinikie Farmer's Cooperative, Alemaya. The view of the windpump as installed in the field is given in **Fig. 2**. The pump's figure dismantled from the windpump unit, and its internal details are shown in **Figs. 3 and 4**, respectively. The location of windpump, reservoir, and details of windpump site in the Farmer's Cooperative is shown in **Fig. 5**.

Specification of the windmill type Tool 12 Pu 500 (4,8) (Slightly modified):

Rotor diameter 5 m
Number of blades 12
Design of blades, 10% arched steel sheet
Tip speed ratio 2
Maximum power coefficient 0.38
Transmission (modified)
Crank - connecting rod - cross-head system,
Crank radii .06, .09, .12 in.

Fig. 2 Windpump installed at Tinikie Farmers' Cooperative.

Fig. 3 Pump dismantled from the windpump unit.

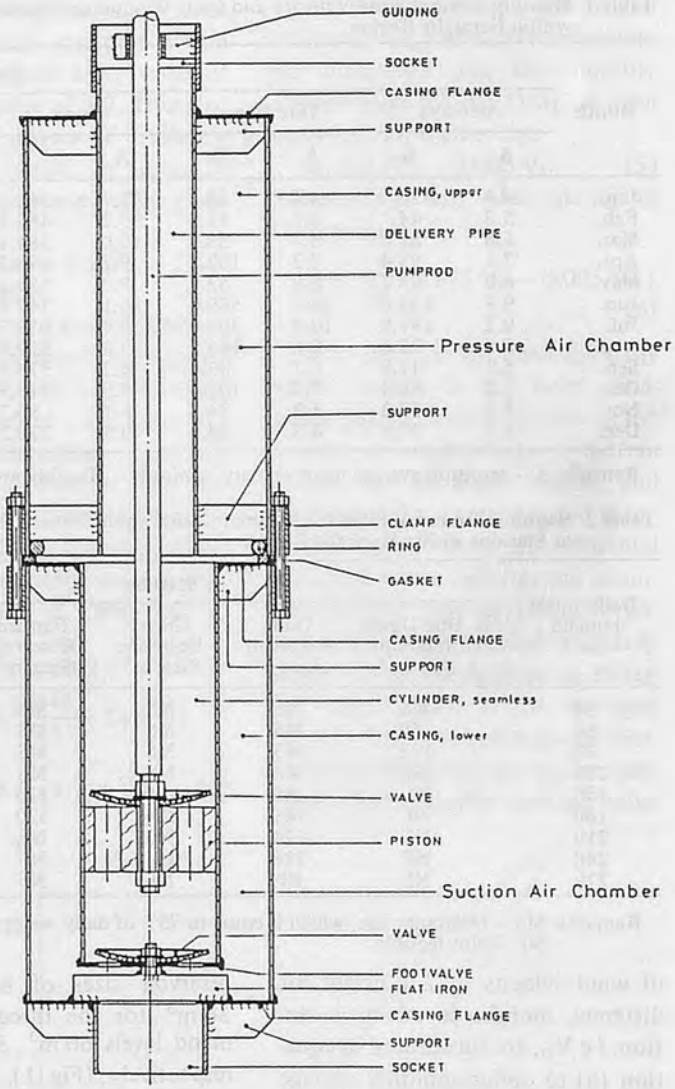


Fig. 4 Internal detailes of the pump.

Security system

Automatic system. Rotor is turned out of the wind leg by indication of auxilary vane.

Cut in wind speed

Depending on wind regime

Pump (a 6″ pump is connected to the windpump in Alemaya) various diameters 3″, 4″, 5″, 6″ and 8″ depending on elevation, head and wind regime. Single acting reciprocating piston pump with centrally positioned internal airchambers.

Tower

Modified to a three leg tower of the Arusha Windmill (a type of windmill produced by Dick Stanley) with cross bracings.

A reservoir of size 16 m x 4 m x 1.5 m with gross capacity of 96 m^3 and net capacity of 88 m^3 to supply daily water demand of 60 m^3 **(Fig. 1)** was constructed at the highest elevation of the field. A view of the complete reservoir and part of reservoir with windpump are showin in **Figs. 6 and 7**, respectively. The reservoir has one overflow pipe spillway, and two pipe outlets with sluice valve fixed at the bottom at North, South end of the reservoir. An integrating type of flowmeter is connected in the discharge line of the windpump to measure the flow.

Results and Discussion

The monthly average of daily water supply from the windpump as predicted by the mathematical model for different months at various stations within the Hararghe region is given in **Table 1**. Except for the station Alemaya, the data for the wind velocity are taken from the report (1,2). The data for the Alemaya station is taken from the micro-meteorological station of the College of Agriculture, Alemaya. The table shows that the station Alemaya is comparatively poor in terms of water output from the windpump as compared to other stations within the Hararghe region, with Gode and Grawa stations giving a very good output. Even the Alemaya sta-

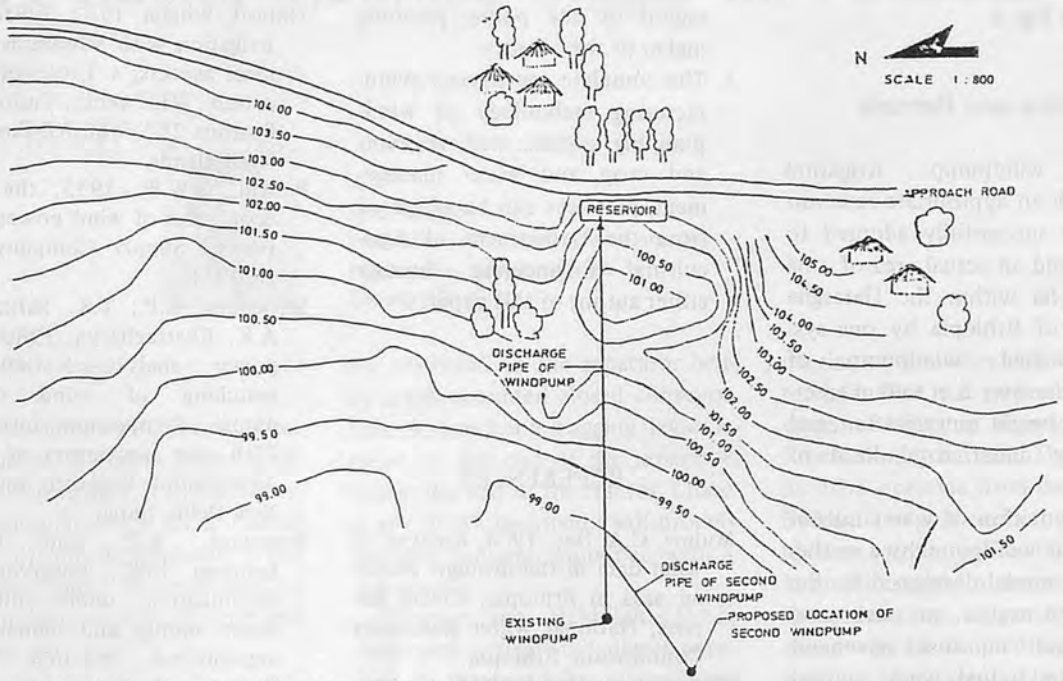


Fig. 5 Windpump site at Tinikie Farmers' Cooperative, Alemaya.

Fig. 6 Whole view of the reservoir.

Fig. 7 Part of reservoir and the windpump in the background.

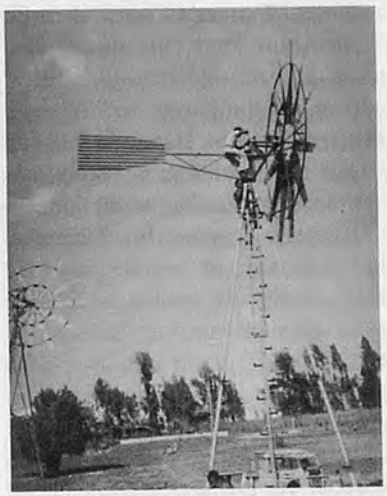


Fig. 8 Second windpump being installed. First windpump and reservoir are seen in the background.

tion has a relatively poor output but with a windpump of rotor diameter 5 m, working at 14 m of total head and erected at a height of 8.5 m at Tinikie Farmer's Cooperative in Alemaya provided a daily withdrawal of 60 m^3 of water through the regulation of a reservoir having net capacity of 88 m^3 **(Figs. 1 and 6)**. Thus, with 60 m^3 of water available per day throughout the year, an area of 1.5 ha can be irrigated under one crop or combinations of crops whose evapo-transpiration value together, does not exceed 4 mm /day. Considering a very realistic water application efficiency of 68% under rotational irrigation plan, the actual area which can be commanded is 1.5 x 0.65 ha, is approximately 1 ha. The output of the model for the station Alemaya was tested against the windpump output erected at Tinikie Farmer's Cooperative for the months February and May, and is found to be in close agreement with a variation of ±4% only.

Table 2 shows the required reservoir sizes for meeting different daily demand levels at different stations (excepting Alemaya) within the Hararghe region, which are to be coupled with a windpump of rotor diameter 6 m, working under total head of 14 m are erected at a height range of 8-10 m. As is seen from the table that stations Gode, Grawa and Hamaro require a reservoir of minimum size, that is 75% of the daily demand 120 m^3, which is 90 m^3. And, thus in those areas around double of the area commanded by the windpump in Alemaya can be put under irrigation by one windpump. The field of Tinikie Farmer's Cooperative at windpump site **(Fig. 5)** is having an area of 2.5 ha, and the present installed windpump can command an area of 1 ha only, therefore, to cover whole 2.5 ha for irrigation by windpump, another windpump is being installed **(Fig. 8)** at the place

shown in Fig. 5.

Conclusions and Remark

1. The windpump irrigation through an appropriate reservoir can be successfully adopted to command an actual area of 1 ha to 2.5 ha within the Hararghe region of Ethiopia by one system-matched windpump of rotor diameter 5 m to 6 m erected at a height range 8-10 m, and working under total head of 14 m.
2. The prediction of water output from the windpump by a mathematical model developed for the Hararghe region, on test, gave the result in close agreement with the actual water output from the windpump installed at Tinikie Farmer's Cooperative in Alemaya. Thus, the model can be used to predict water output from a windpump for different places in the Hararghe region, and the result can be safely utilised for planning windpump irrigation systems for Hararghe region by the policy planning maker of the country.
3. The complete appropriate manufacturing technology of windpumping systems with reservoir and crop and water management practices can be obtained from the Department of Agricultural Engineering through either author of this paper.

REFERENCES

Munoz, C.A. Dec. 1974, Analysis of wind data in the drought affected area in Ethiopia, UNDP Report, National Water Resources Commission, Ethiopia.

Munoz, C.A. March 1974, Analysis of wind data in the drought affected area in Ethiopia, UNDP, Report, National Water Resources Commission, Ethiopia.

Nathan, K.K. and K.P. Srivastava, July 1982, Feasibility of Wind Electric Pump for Uttar Pradesh, Indian Journal of Power and River Valley Development, 112-116, India.

Nijhoff, Willem, 1982, Syllabus for Irrigation with Windmills, Technical aspects, a Tool/wot publication, TH Twente, Vnijrof 152, Postbus 217 7500 AE Enschede, Netherlands.

Pontin, G.W.W, 1975, the bland economics of wind power, Wind Energy Supply Company, Red Hill, U.K.

Srivastava, K.P., T.K. Sarkar and A.K. Bhattacharya, 1980, Wind power analysis-selection and matching of wind electric pumps, Symposium during the 75th year anniversary of Indian Agricultural Research Institute, New Delhi, India.

Srivastava, K.P. and Fikadu Lemessa 1982, Reservoir size optimization under different water supply and demand, an unpublished research work, Department of Agricultural Engineering, College of Agriculture, Addis Ababa University, Ethiopia.

Van de Ven, Neik, 1982, construction manual of 12 Pu 350 and 12 Pu 500 Windmills, a Tool/Wot publication, TH Twente, Vnijrof 152, Postbus 217 7500 AE Enschede, Netherlands. ■■

A Tractor-Mounted Digger for Potatoes

by
G.C. Misener
Research Station, Agriculture Canada
Fredericton, New Brunswick
Canada E38 4Z7

Abstract

The development and evaluation of a small-scale potato digger is described. The digger is mounted on the three-point-hitch of a tractor and is driven hydraulically. The digger was found to work satisfactorily under varying soil type and moisture contents.

Introduction

Improved harvesting technology suited for small units of potato production would alleviate the high labour requirements during harvest. Minimizing mechanical injury during harvest is also a critical factor when considering the storage capability of the product. This consideration is often neglected during the harvest season.

Although several types of harvesters are available these machines are large and expensive and are only suitable for large farms. McRae (1978) describes these harvesters with options that include stone-potato separation, mud and clod removal, haulm removal and self-leveling controls for hillsides.

Several plot harvesters have been developed in order to reduce labor required for harvest. Dijkstra (1976) describes a machine developed for harvesting potatoes in experimental plots. The potato lifting section which includes the digging share, depth control wheels, rod link elevator, haulm separator and cross conveyor is located at the front of the tractor. The potatoes are conveyed to the separator belt by a side-mounted closed conveyor belt. A detachable bagging device is fitted to the end of the separator belt at the rear of the tractor. Chase *et al* (1978) described a self-propelled plot harvester equipped with a sizing table.

Misener and McMillan (1982) developed a single-hill digger capable of digging hills of potatoes spaced at 75 cm and depositing them on the soil with the vines while not mixing tubers from adjacent hills. This machine was required by the potato breeding program at the Fredericton Research Station which grows about 50000 single hill plots of material in its first field generation. The use of the digger improved the effectiveness and efficiency of the harvest crew. The potatoes are cleanly separated from the soil and individual plants remain well separated which makes it easier for the selectors to do their job. This paper reports on the use of this digger for harvesting potatoes for commercial use.

Construction Details

The digger is three-point-hitch mounted which allows quick turn around and ease of transportation. The digger is offset on the tool bar in order that the tractor can straddle two rows of potatoes while digging only one row. This arrangement and details of the digger are shown in **Fig. 1**.

A hydraulic drive was chosen for the digger bed because it allows maximum flexibility in the speed of the bed. This is an important factor when considering damage of the tubers during harvest. The hydraulic drive operates from the tractor's hydraulic supply and requires a fluid flow of up to 36.0 *l*/min. If a hydraulic supply is not available on the tractor, an external hydraulic pump can be coupled to the PTO shaft of the tractor. The hydraulic motor used in the study is a Char-Lynn 2000 series motor with 100 cc displacement per revolution.

The digger bed operates at an angle of 15° with respect to the horizontal. Some variation in this angle can be achieved by adjustment of the top link of the three-point-hitch. The low angle of the bed was chosen to minimize roll back of the tubers. The digger chain is made of 12.7 mm diameter rods with a 40 mm pitch. The width of the digger chain is 711 mm with a one up and one down configuration of the rods. Depth wheels with haulm cutting coulters are located opposite the digging share. The depth wheels are adjustable by means of a screw jack assembly. The coulters are required to cut away haulms that would otherwise catch on the sides of the digger. There are no castings required for construction of the digger. All the parts are off-the-shelf which enables construction by a machine shop.

During operation, the weights of the digger rests on the depth control wheels. By adjusting the wheels, the depth of digging can be controlled. Small undulations in the ground contour can be accommo-

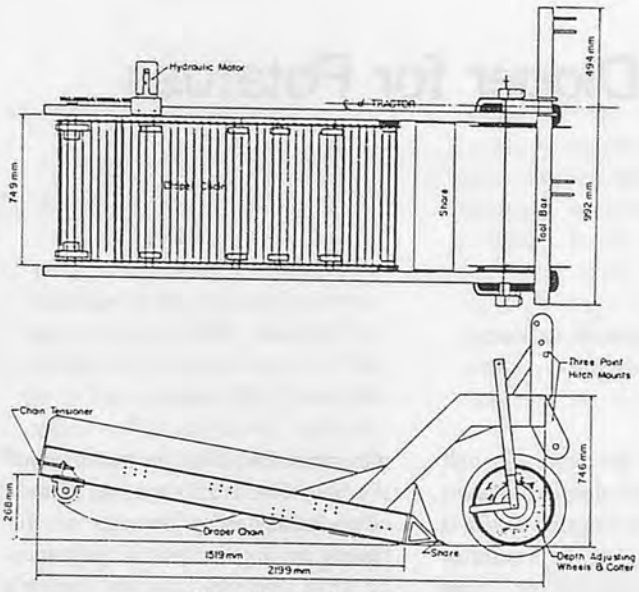


Fig. 1 Potato digger.

Fig. 2 Side view of potato digger working in field.

Fig. 3 Rear view of potato digger working in field.

dated by the digger because the depth wheels are adjacent to the digging blade.

Evaluation of Digger

The digger has been evaluated for the past three years to determine its capability to dig potatoes with a minimum of damage. The digger was operated with a variety of soil types with varying moisture contents. Figs. 2 and 3 show a digger in the operational mode.

Tuber damage was determined by peeling with an ordinary potato peeler that removed a slice approximately 1 mm thick with each stroke. The damage was classified as follows (Thornton, 1969):

Undamaged; scuffed or skinned –skin only broken, or flesh damage by a 1 mm deep stroke of the peeler; and slightly to severely damaged –damage to flesh which cannot be removed by a 1 mm deep stroke of the peeler. The weight and number of tubers in each classification were recorded.

Results and Discussion

The digger was found to perform very well under varying soil conditions. The coulters were able to effectively cut the haulms adjacent to the digging share. This action prevented the haulms from dragging along the side of the digger which would have displaced the tubers on the chain. Blade length was found to be critical with respect to the flow of material onto the digging bed. A straight blade of width 21.6 cm was found to allow an even flow of soil under a wide range of soil moisture content. The distance between the blade and digging chain was made adjustable to accommodate varying soil conditions. The forward speed of the digger can vary up to 3 km/h depending upon the desired output.

Very little mechanical injury of the tubers was recorded during the study. During the past season the average percentage of slightly to severely damaged tubers was 3.2 %. An average of 30.8 % of the tubers were partially skinned. This is considerably lower than the damage level of the commercial harvesters.

Conclusion

A potato digger was designed and constructed which is capable of digging potatoes with a minimum of injury. The digger which is equipped with a hyrdraulic drive was found to be very flexible and could accommodate variable harvest conditions.

Detailed plans are available from the author at the above address.

REFERENCES

1. Chase, R.W., Thompson, N.R., Ledebuhr, R.L., Hansen C.M. and R.B. Kitchen. Plot harvester for potatoes. Am. Potato J. 55: 235, 237, 1978.
2. Dijkstra, J. Some aspects of experimental field mechanization in the Netherlands. Proceedings of the Fourth International Conference on Mechanization of Field Experiments, pp.314-320, 1976.
3. McRae, D.C. Potato harvesting and transport. Survey Paper. 7th Triennial Conference. EAPR, Warsaw, Poland: 79-94, 1978.
4. Misener, G.C. and McMillan, L.P. A single-hill potato digger. Am. Potato J. 59(11): 551-553, 1982.
5. Thornton, R.E. Problems and situations on bruising of potatoes in harvesting and handling. Presentation at the 1969 Annual Meeting of the Pacific Northwest Section of ASAE, 1969. ■■

Design, Development and Field Evaluation of Vertical Conveyor Reaper Windrower

by
R.S. Devani
Head, Farm Machinery Dept.
Central Institute of Agricultural Engineering
Nabibagh, Berasia Road
Bhopal, India

M.M. Pandey
Scientist S-2, Electro Mechanical Div.
Central Institute of Agricultural Engineering
Nabibagh, Berasia Road
Bhopal, India

Abstract

Two models of reaper windrowers for harvesting crops such as wheat and rice based on the principle of vertical conveying were designed and developed. The 1.6 m cutting width, which equalled to the seven rows at 22.8 cm was selected for use with a power tiller and a similar size unit and later on a 2.05 m cutting width models were developed for operation with the tractor. The operations performed by the reaper windrower include guiding of the standing crop towards cutter bar with the help of row dividers and star wheels, cutting of crop, conveying of cut crop under control to the right side of machine and laying it on ground in the form of a windrow with ears on one side. The performance studies showed that the cost of operation and labour requirements for reaper windrowers were lower than the conventional method. The average field capacity values of 0.38 ha/h were higher than so far achieved by the other harvesters developed in India. The designed reaper windrowers would contribute in the mechanization of cereal harvesting under the prevalent socio-economic-techno conditions and help in increasing production and productivity of the farmers in the country.

Remark: Reaper normally refers to a machine used for harvesting the grain crop. Windrower is normally used for harvesting fodder crops. The windrower normally cuts the crop and leaves the harvested crop in a windrow for curing and drying in the field. Reaper windrower term is used here to clarify and emphasize that the machine cuts the grain crop and lays the crop in the form of a windrow with the panicles on one side for easy manual picking and collection.

Acknowledgements: The authers acknowledge with thanks the support, encouragement and guidance received from Dr. T.P. Ojha, Director, CIAE, Bhopal during the development of the vertical conveyor reaper windrower and of Prof. A.C. Pandya, Ex-Director of CIAE and Mr. D.F. Howson, RNAM Expert on Cereal Harvester stationed at CIAE Bhopal. The assistance and cooperation of the Coordinating Centre staff of ICAR Coordinated Scheme on Farm Implements and Machinery and Electro Mechanical Engineering Division are highly appreciated.

Introduction

Grain harvesting has since involved the hand cutting with a sickle and threshing by treading of animals or by flailing and separating the threshed grain by hand raking, winnowing or sieving. The mechanical harvesting of grains such as wheat, rice, barley includes (a) direct combining, (b) windrowing and combining, (c) binding and stacking followed by threshing at a threshing floor, (d) windrowing, picking up the crop and stacking and threshing in a stationary machine.

The stationary threshing of grain was introduced in India in 1960 and at present in most of the grain raising areas, stationary thresher is still widely practiced. This is because the farmer is interested to accummulate straw as animal feed. The direct combining and windrow combining involves least labour and in some areas the combine harvesters are used but because of high cost of self-propelled combine harvesters, low wages of labour and low price of grain, the use of harvesters has been very limited. In Punjab the shortage of local labour for field jobs has resulted in the migration of labour from the economically weaker regions of Rajasthan, U.P. and Bihar during harvesting seasons.

The direct combining and windrow combining help in reducing the weather hazards to the standing grain crop, because in direct combining the grain can be harvested at slightly higher moisture and in windrow combining the harvest can also be started earlier by several days to permit curing of crop before threshing. However, these methods are not prevalent in the country.

The stationary threshing has reached the level of 100% mechani-

zation in states like Punjab and Haryana and parts of other states. The most appropriate method of mechanization of grain crop would be binding and stacking. The field evaluation of reaper-binders indicated that the cost of twine for binding the bundles is more than the manual gathering and tying in conventional method. The reaper-binder uses the precision-built binding mechanism and therefore the cost of a reaper-binder of tractor-operated or self-propelled is quite high for a small farmer to own it.

The use of the reaper-windrower type for harvesting the grain, manual collection of windrows and stationary threshing of grain crop will be most appropriate from the socio-economic point of view. As a step towards appropriate mechanization of the harvesting operation for cereal crops a few self-propelled, tractor and power tiller mounted cereal harvesters were evaluated on wheat and rice crops at CIAE, Bhopal (4). This included reaper-binders and reapers. The field performance of the selected prototype indicated that those which were functionally acceptable were economically not viable. The cost of operation of binders were high because of the high cost of twine in the total cost of operation per unit area. The fixed cost component for all the machines was high because of either high initial cost of machine and their low field capacity. On the basis of the above studies, it was concluded that under the prevailing socio-economic conditions, harvesting with a reaper-windrower, coupled with manual collection and tying, will be a viable proposition. Considering these, a power tiller-mounted reaper-windrower of high capacity and a tractor-mounted reaper-windrower were designed, developed and their field performance evaluated on wheat at the Central Institute of Agricultural Engineering, Bhopal during 1981-84. The tractor mounted and power tiller mounted vertical conveyor reaper-windrowers are shown in **Figs. 1 – 4.**

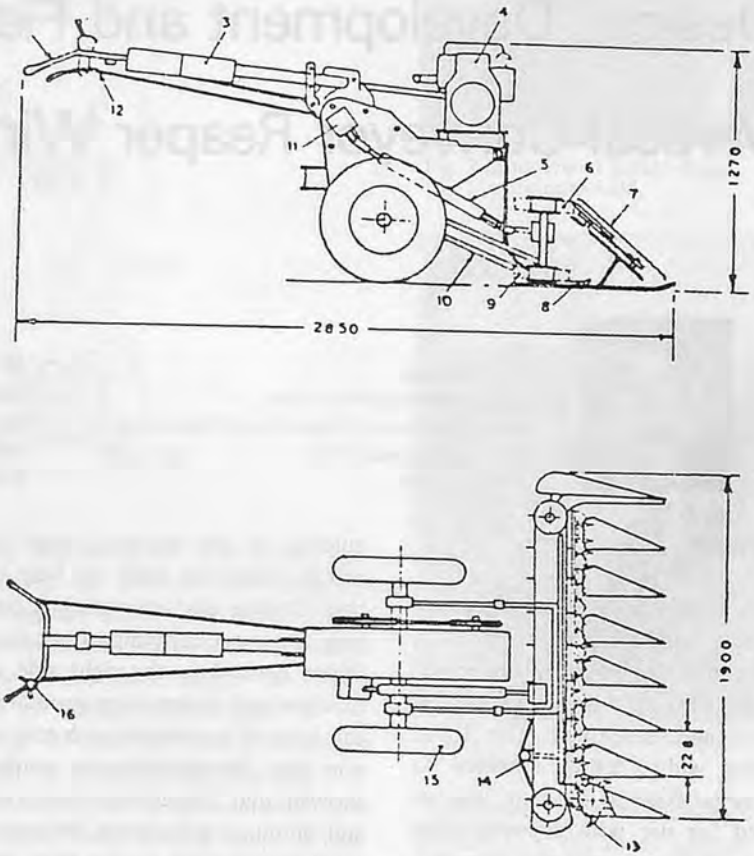


Fig. 2 Main parts of vertical conveyor reaper windrower (power tiller type).

Fig. 1 Power tiller operated vertical conveyor reaper windrower.

Fig. 3 Tractor-operated vertical conveyor reaper windrower (Model I).

Advantages of Vertical Conveyor Windrower

A vertical conveyor of reaper windrower has the following features which enable it to have an edge over other harvesters.

i) The plants are conveyed in the vertical position and the gath-

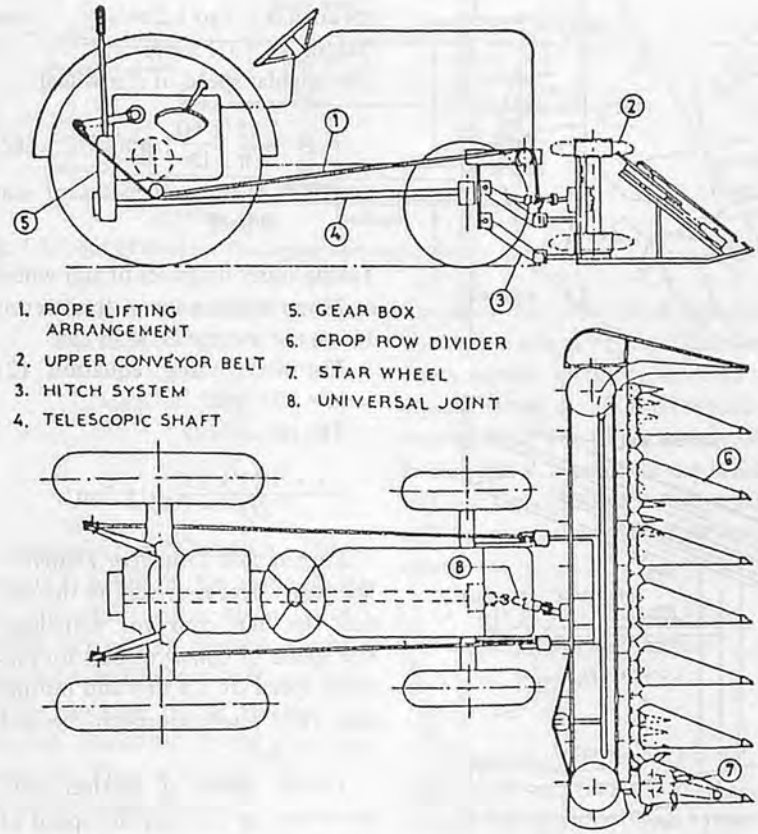


Fig. 4 Details of power transmission system of tractor-operated windrower.

ering and collecting of standing crop towards the machine is achieved without the panicles coming into contact with the moving parts of the machine. This helps in minimizing the shattering loss.

ii) The crop is conveyed in vertical position and is under control and is laid on the ground in a clear windrow maintaining the direction of tillers perpendicular to direction of travel. This also provides ease in manual collection and tying of crop.

iii) The machine is small in size due to compact design. This results in better manoeuvrability in the field.

iv) The weight of machine per unit length of machine is less and therefore the cost of unit is low and thus the cost of harvesting operation is low.

v) For paddy crop where soil conditions are poor for trafficability, the light weight power tiller unit can be operated easily.

Description of Machine

The vertical conveyor reaper-windrower is a front-mounted, hand-guided, walking type light-weight, compact machine. It has a 1.6 m long cutter bar and cuts seven rows of crop with 22.8 cm row spacing. It cuts the crops and lays it in a windrow which can be easily picked up by the farm labourers. The crop is cut by the cutter bar, the cut plants are held in vertical position by means of pressure springs and are guided by the star wheels to the lugged conveyor belt. The cut plants are transferred in the vertical position until discharged at the outer end into a windrow at right angle to the direction of motion. The main parts of the reapers are: lifting and gathering mechanism, lugged belt conveyor and cutter bar.

The main parts of windrower are shown in **Figs. 1 – 4**. The windrower was designed for operation with a power tiller and later it was adopted for operation with a tractor. The design of windrower includes the analysis of width of cut of the unit, the design of main parts and further check on the size of i) power unit, ii) mechanism of windrower and power tiller, iii) power transmission system.

Lifting and Gathering Mechanism – The lifting and gathering mechanism consists of a row crop divider fitted with a lugged V-belt, pressure springs and the star wheel. These are shown in **Fig. 5**. The star wheels for each row are driven by the lugs attached to the vertical conveyor belt thus guiding the plants to the cutter bar. The speed of star wheels or lugged V-belt depends upon the forward speed of machine as they handle the plants to be cut. The star wheel and lugged V-belt do the job similar to that of a reel in case of conventional header units. The star wheel is inclined at an angle "α" with ground and therefore the velocity component of the star wheel which is responsible for guiding the crop will be $V_s \cos\alpha$, where V_s is the peripheral velocity of star wheel along its plane. The angle α, *i e*, angle of inclination of star wheel depends upon the length of the row divider. In order to have a compact machine "α" should be as large as possible. Therefore, α selected for the machine was 18°. The velocity of star wheel is $V_s \cdot \cos\alpha$ and this should be greater than the forward velocity of machine in order to have the gathering action on crop towards the cutter bar by the star wheel.

The speed ratio of 1.026 between $V_s \cos\alpha$ and forward speed is recommended for the proper operation. Similarly, if the ratio between lugged V-belt and machine forward speed is lower than unity will result

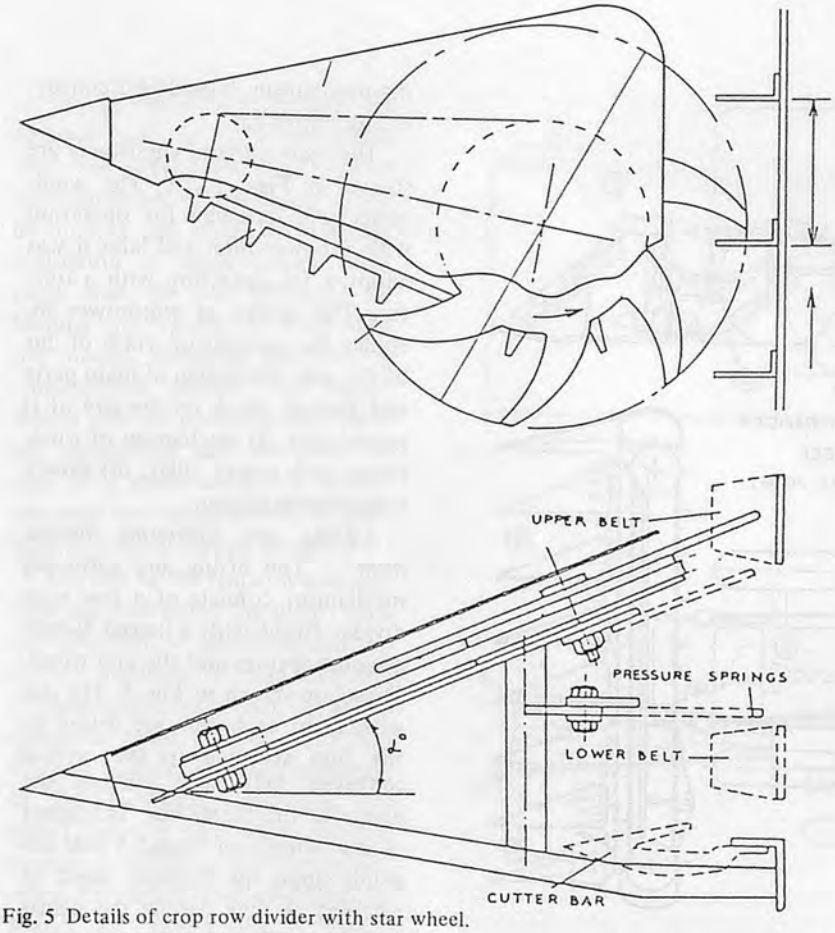


Fig. 5 Details of crop row divider with star wheel.

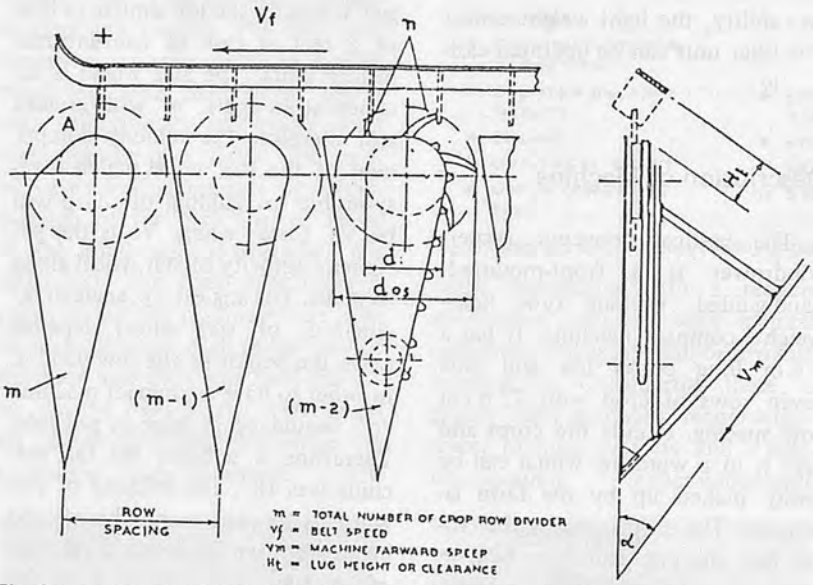


Fig. 6 Arrangement of crop row dividers and clearance at outermost unit.

in pushing of crop away from the cutter bar. When the crop is erect, the lugged V-belt can be removed during operation.

The high velocity of star wheel results in shattering loss. Therefore, the star wheel speed should take into account the crop varieties to be handled by the machine.

$$\frac{Vs \cos\alpha}{Vm} = 1.026 \quad \ldots\ldots (1)$$

$$Vs = 1.07 \text{ m/s}$$

The normal value of Vs recommended is 1.1 to 1.2 m/s.

Taking Vs = 1.15 m/s

The angular speed of star wheel

$$N = \frac{1.15 \times 60}{\pi \times Ds} \text{(rpm)} \ldots\ldots (2)$$

Ds = Average diameter of star wheel.

Taking outer diameter of star wheel as 21 cm and the inner diameter as 11 cm the average Ds = 16 cm.

Therefore using equation (2) N = 137 rpm.

The tip velocity

$$= \frac{\pi \times 0.21 \times 137}{60} = 1.5 \text{ m/s}$$

Lugged Belt Conveyor Design – The star wheel is driven by the vertical flat belt conveyor with lugs. The speed of conveyor belt for machine speed of 1.0 m/s and normal crop yield levels should be around 1.5 - 1.6 m/s.

Taking speed of vertical conveyor belt as 1.5 m/s the speed of drive pulley and the pitch of lugs and number of arms on the star wheels are determined as follows:

i) The pitch of lugs on the flat conveyor belt and number of arms on the star wheels is given by the simple relationship (Fig. 5).

$$\pi \, Dos = P \times Ns \ldots\ldots\ldots (3)$$

where, Dos = Outer diameter of star wheel, Ns = No. of arms on star wheel.

P = Pitch of lugs on conveyor belt.

Assume Ns = 16, Dos = 21 cm

P = 10.9 or say 11.0 cm.

ii) Speed of flat belt pulley

$$V_p = \frac{\pi \, Dp \, Np}{60} \ldots\ldots (4)$$

Where Dp = diameter of pulley, m

Np = Speed of pulley, rpm

and Vp = Peripheral speed of pulley = 1.5 m/s

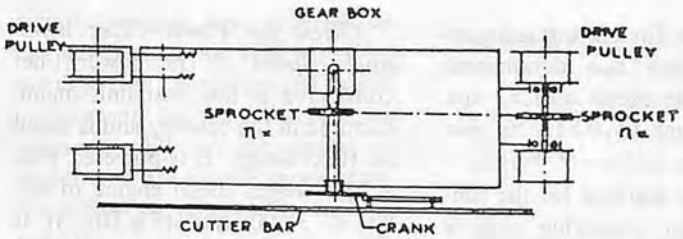


Fig. 7 Layout of drive for flat lugged belt conveyors.

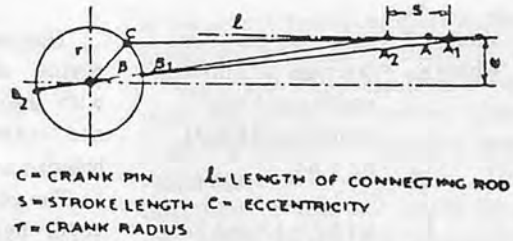


Fig. 8 Crank drive arrangement for cutter bar movement.

When the diameter of pulley is 0.12 m

$$Np = \frac{1.5 \times 60}{0.12 \times \pi}$$

$$= 239.7$$

say 240 rpm.

Lug Height and Clearance – This method is based on the assumption that the entire cut crop is to be moved out of the machine at the outermost end. Hence there should not be blockage of the material at this end. Referring to the diagram shown in **Fig.6** and using the following nomenclature.

P_1 = Star wheel annulus lost due to spikes, %

P_2 = Belt length lost to lugs thickness, %

Ht = Gap needed between belt and pulley to avoid blocking, m

P_3 = Star wheel speed compared to belt speed, %

Reaper total output = W.Vm m^2/s

The total cross sectional area of plant material to be handled by the reaper at outermost end = W.Vm. Sd m^2/s.

The capacity of machine to dischange the cut crop at outermost plant = $H_t.V_f\,(1-P_1)(1-P_2).\,P_3$ . . . . . (5)

To avoid blockage

$W.Vm.Sd = H_t\,V_f\,(1-P_1)\,(1-P_2).\,P_3$ . . . . . (6)

The value of $P_1.P_2$ and P_3 can be easily determined or assumed without causing much deviation in the results.

Assuming

$P_1 = 20\%, P_2 = 2\%$ and $P_3 = 90\%$

Consider the best crop condition for either wheat or rice. The maximum number of tillers expected per square meter in the field would be around 500. The tiller diameter will be around 4–5 mm. Hence if Sd is 0.02 m^2/m^2 (200 sq cm) the value will be more than sufficient for all cases.

i e $H_t.V_f\,(0.8)\,(.98)\,(0.9) =$ W.Vm.Sd. putting values of V_f, W, V_m, Sd

$H_t = 3.2$ cm

Hence taking $H_t = 4.0$ cm will be similar for most of the conditions for the 1.6 m width of cut reaper.

The value of H_t puts the limitation on the width of vertical conveyor reaper, because to utilize the full power of tractor the size of windrower could be made very large, but because of crop yield levels machine design factors and manoeuvrability of machine the lengths would be limited to about 3 m. Furthermore, the machine capacity can be increased only by increasing the forward speeds upto 6.0 km/h.

Flat Belt Lugged Conveyor Drive – The power for the flat belt drive is transmitted by means of a chain and sprocket drive. The speed of the drive shaft which also drives the cutter bar is kept as 612 rpm.

The flat belt speed V_f is to be maintained at 1.5 m/s. Assume the diameter of the flat belt pulley as 12 cm.

$$i\,e\ \frac{\pi\,DNp}{60} = 1.5 \text{ m}$$

$$i\,e\quad Np = \frac{1.5 \times 60\ \ 1.5}{\pi \times 0.12} = 238$$

i e, for chain drive the sprocket was taken with 15 teeth, *i e*, no. of teeth on the driven sprocket = 38.

For the roller chain of 9.52 mm pitch above size sprockets were used.

Cutter Bar Design – The cutter bar used is the conventional reciprocating type cutter bar with stroke length of 76.2 mm. The cutter bar is driven by the crank mechanism directly from the gear box provided on the reaper.

The recommended speed ratio of average cutter bar, a speed to the forward speed of machine is 1.3 – 1.4. The average cutter bar speed

$$V_c = Vm \times 1.4$$

$$= 1.4 \text{ m/s}$$

$$V_c = \frac{S \times Nc}{30} \quad \ldots\ldots\ldots\ldots (7)$$

S = Stroke length, N_c = rpm of crank

$$i\,e\,N_c = \frac{V_c \times 30}{S}$$

$$= 550 \text{ rpm}$$

The speed of crank Nc through the designed gear box

$$Nc = 3\,200 \times \frac{6}{68} = 685 \text{ rpm}$$

Assuming belt slippage as 10%, Nc 1 680 x 0.9 = 612 rpm

Hence the actual average cutter bar speed for cutting will be

Vc = 1.54 m/s

Absolute velocity of kinife

Vmax = r.w. . . . . (8)

= 2.35 m/s

Minimum velocity of cutter bar

$Vmin = w/(S-bo)b^2$

Where w = angular velocity of crank, rad/s

r = crank length

Vmin = 1.9 m/s

Where bo = average of knife tip width and knife guard base (**Fig.9**).

$$= \frac{b2 + b4}{2} = 19.5 \text{ mm.}$$

let b2 = 13 and b4 = 26mm.

The maximum acceleration and inertia force of knife bar are given by

$$a_{max} = \frac{S\,w}{2}\left(1 + \frac{\pi}{(1/r)}\right) \quad . \quad (9)$$

Where l = length of connecting rod.

Max. inertia force = m a_{max}

where m = mass of cutter bar knife. The mass was approximately 4 kg for 1.6 m long cutter bar.

i e Maximum inertia force = 900 kg m/s²

This balancing is done to minimize vibration. The balancing is recommended for about 50% of maximum value *i e*, for half the inertia force = 450 kg/m/s.

Check for size of prime mover – The windrower power requirement will be the total power consumed in cutting and conveying of the crop in the form of windrow, in propelling the machine and the power transmission losses.

The power for cutting and conveying of crop was determined with the knife speed of 1.52 m/s and cutter bar of 0.513 hp per length.

The power required for the conveyor belt for conveying crop is assessed at 50% of cutting power. Therefore, the power for cutting and conveying will be

$$0.82 + 0.41 = 1.23 \quad \ldots\ldots \quad (10)$$

The power required to propel the machine is estimated thus:

Power = Rolling resistance x speed.

Let the coefficient of rolling resistance be 0.2

Power for propelling of the unit = 240 x 0.2 x 1

$$= \frac{40}{75} \text{ kg} = 0.53 \text{ hp}$$

Total power = 1.23 + 0.53 = 1.76 = 1.8 hp . . . . . (11)

Assume 90% power transmission efficiency at each stage and three reductions in case of power tiller, the average efficiency will be = 0.72. Therefore, the power requirement will be

$$= \frac{1.8}{0.72} = 2.5 \text{ hp} \quad \ldots\ldots \quad (12)$$

Which is well within the limits of power tiller and tractor units.

Check for Power Tiller Windrower Speed – The power tiller considered as low cost unit manufactured in the country and is based on IRRI design. It is powered with a light weight diesel engine of 6.5 hp at 3 600 rpm (**Fig.10**). It is fitted with pneumatic wheels with outer diameter "Dw", 59 cm. The engine pulley size was 6 cm and driven-pulley diameter of 28 cm. The transmission speed ratio is 15.5 and total speed reduction of 72.3. Therefore, the theoretical speed of power tiller

$$Vm \times 60 = \frac{\pi \times 58 \times 3\,200}{60 \times 100 \times 72.3}$$

$$= 1.34 \text{ m/s}$$

Assuming 15–25% wheel slippage during motion, the speed of reaper windrower can be taken as

Vm = 1.0 m/s

Mounting of Reaper Windrower and Balancing – The unit was designed for operation, first with power tiller and, afterwards, with tractor. It is a front-mounted type. The front-mounted unit has the advantage of better visibility during operation. The windrower was balanced to avoid the problem of making the front end heavy. The

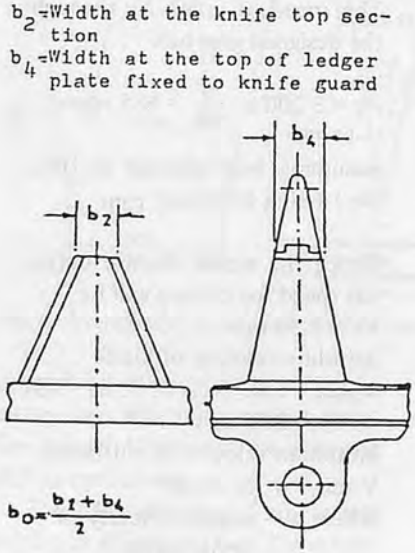


Fig. 9 Knife and guard details.

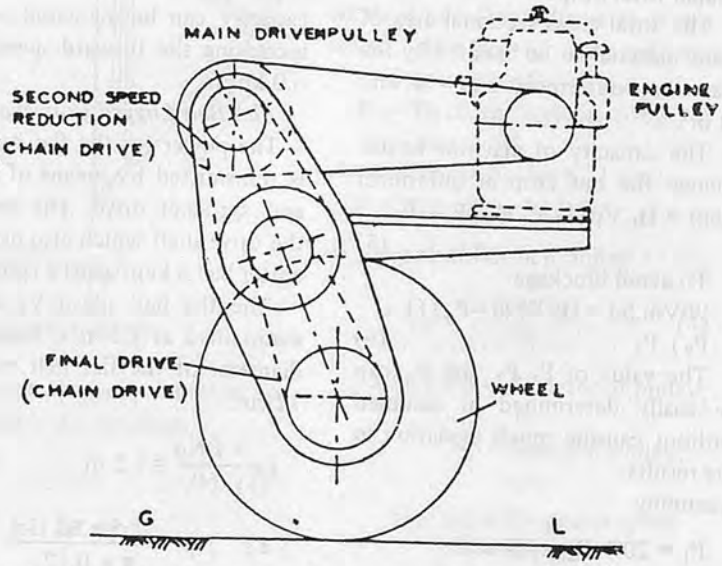


Fig. 10 Schematic of power tiller transmission (IRRI design).

counter weights were provided on the handle bar side (**Fig.11**). Considering the condition of static balance and assuming that the unbalance is due to the weight of reaper and taking the movements, the following relationship was obtained:

$$W_R \times 60 = W_c \times 85 + P^1 \times 165 \quad \ldots\ldots\ldots\ldots (13)$$

Where W_R = Weight of reaper (87 kg)

W_C = Counter weight (40 kg)

and P^1 = Effort at the handle = 11 kg

Thus for static balance the effort on the handle was 11 kg. During operation the centre of gravity of the complete unit will shift slightly in front and thus the effort at the handle will be further reduced.

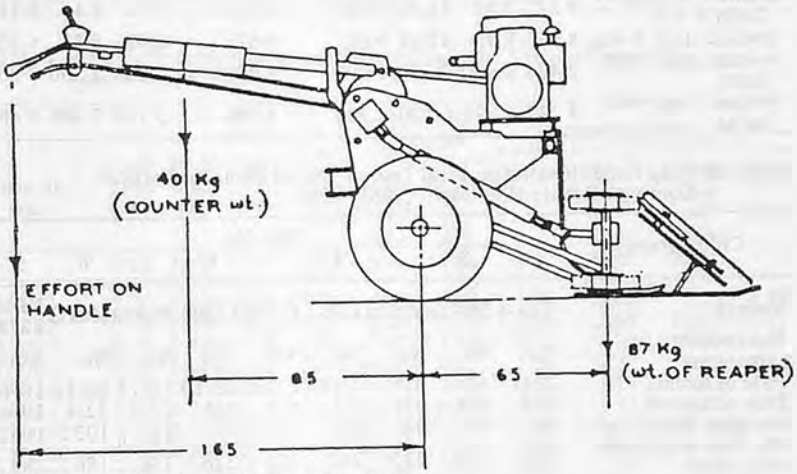


Fig. 11 Static balancing of reaper windrower.

Table 1 Specifications of the Reaper Windrowers Developed and Evaluated at Bhopal

Item	Tractor operated Model-I (1982)	Power Tiller Model (1981)	Tractor operated Model-II (1983)	Tractor operated Model-II improved (1984)
	Developed at Coordinating Centere of FIM Scheme, CIAE, Bhopal.			
Estimated cost, Rs.	6 000	6 000	7 000	7 000
Dimensions:				
Width of cut, m	1.6	1.6	2.05	2.05
Width of machine, m	–	–	2.2	2.2
Length of machine, m	0.84	0.84	0.84	0.84
Height of machine, m	0.61	0.61	0.61	0.61
Weight of machine, kg	87	87	164	164
Suitability for crops	Wheat, rice and barley			
Suitable crop height	70-120 cm			
Power source	Tractor, 20 hp	Power tiller	Tractor, 25 hp	Tractor, 25 hp
Gathering unit				
No. of row dividers	7	7	9	9
Row spacing, cm	22.8	22.8	22.8	22.8
Star wheel diameter, cm	21	21	21	21
Pressure springs/row	2	2	2	2
Cutter bar	Conventional reciprocating type			
Length of stoke, mm	76.2	76.2	76.2	76.2
Cutter bar speed, m/s	1.54	1.54	1.96	1.96
Stokes/min	1 224	1 224	1 550	1 550
Vertical belt convevor				
No. of belt used	2	2	2	2
Size of belt, mm	50	50	50	50
Size of lugs, mm	48x50	48x50	48x50	48x50
Lug spacing, cm	11.0	11.0	10	10
Speed of conveyor blet, m/s	1.5	1.5	1.42	1.75-2.0
Method of attachment	Parallel links with four-point support. The unit can be detached easily from the power source.			

The data thus calculated were used to design the power tiller reaper windrower. The unit was fabricated and evaluated. The operation of this unit in the field was found greatly felt because of greater number of tractors are in use on farms as compared to power tillers. Therefore, the tractor models were developed. The first model had 1.6 m wide cutter bar. It was further improved and the width was increased to 2.05 m to cover nine rows, which matched the nine row seed drills used in the country. The specification of reapers developed and evaluated are given in **Table 1**.

Test Procedure

The tractor Model-I and power tiller units were evaluated during April 1982 at the CIAE farm. Four ha of wheat were harvested covering 17 field trials with two units following the test code developed under the scheme. The wheat varieties harvested are normally recommended for the central region of Madhya Pradesh for irrigated and rainfed agriculture. The crop parameters are reported in **Table 2**. The test data are reported in **Tables 3** and **4**. The crops yield levels were in the range of 7.4 to 11.5%. The test periods extended to three weeks.

The tractor operated Model-II with 2.05 m width of cut was field evaluated during April, 1983. The crop parameters are reported in **Table 2** and test observation and results in **Table 5**. **Figs.13** and **14** show the method used for operation of machines in the field. The shaded area on head lands indicate the crop harvested and removed manually by labour.

The performance evaluation of the modified tractor reaper windrower was conducted during 1984.

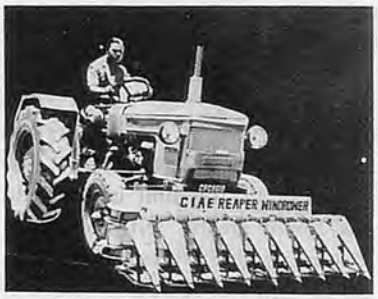


Fig. 12 Tractor-operated vertical conveyor reaper windrower (Model II).

Six ha of wheat were harvested. Five field tests were conducted covering 3.5 ha for which data were recorded. The remaining area was harvested to conduct the field demonstrations before farmers, manufacturers and government officials. Each test was made for a period of 2 to 3 h. The machine was evaluated on three varieties of wheat. The data regarding labour (unskilled) requirements were not recorded for the tests. But during field demonstration 10 persons were employed to pick up the crop as it was harvested by the machine.

Results and Discussions

The field performance data was analysed to determine the field capacity, field efficiency, fuel consumption, labour requirements, losses and cost of operation. These are presented in **Tables 3 – 7**.

Field Performance Results – The average field capacity of the tractor-operated Model-I during 1982 was 0.255 ha/h and for power tiller it was 0.269 ha/h with an average field efficiency of 67.9 and 77 %, respectively. The higher field capacity for power tiller unit was because of less time taken by it in making the turns as compared to the other machine. The forward speed of the windrowers ranged from 36 to 48 m/min. This was below the design speed of 60 m/min and therefore the observed field capacity values were propor-

Table 2A Crop Conditions during Field Test on Power Tiller-Mounted Vertical Conveyor Reaper Windrower, (1981–82)

Crop parameter	Trial No. 1	2	3	4	5	6	7	8
Variety	Swati	Swati	KSLM 3	Narmada-4	Narmada-4	N-112	Sona-lika	Sona-lika
Susceptibility to shattering	Yes	Yes	Yes	No	No	No	Yes	Yes
Date of sowing	24/10	24/10	14/11	14/11	14/11	26/10	13/11	13/11
Date of harvest	13/4	13/4	14/4	16/4	16/4	26/4	20/4	19/4
Average plant height, cm	98	98	82	94	94	98	86	86
Tiller population Ave. No./Sq.m	205	205	178	121	121	160	213	213
Moisture content, Grain % w.b.	9.82	9.82	11.53	10.20	10.20	7.76	8.16	8.16
Average straw % w.g.	8.96	8.96	12.15	9.67	9.67	8.47	6.33	6.33
Average grain yield, kg/ha	2 430	2 430	2 750	1 090	1 090	2 260	2 300	2 300
Average crop yield, kg/ha	5 320	5 320	6 120	2 900	2 900	5 120	5 480	5 480

Table 2B Crop Conditions during Field Test on Tractor-Mounted Vertical Conveyor Reaper Windrower, (1981–82)

Crop parameter	Trial No. 1	2	3	4	5	6	7	8	9
Variety	Lok-1	Mukta	Mukta	Lok-1	C-306	C-306	Mukta	Mukta	HDM 2278
Susceptibility to shattering	No	No	No	No	Yes	Yes	No	No	Yes
Date of sowing	7/11	6/11	6/11	7/11	23/10	23/10	10/11	10/11	16/10
Date of harvest	5/4	6/4	6/4	7/4	9/4	9/4	22/4	22/4	29/4
Av. plant height, cm	68	94	94	68	73	73	103	103	105
Av. tiller population No./sq.m	242	310	310	242	226	226	186	186	282
Av. moisture content Grain % w.b.	9.56	10.85	10.85	9.56	10.12	10.12	8.47	8.47	7.36
Straw	8.32	9.69	9.69	8.32	10.27	10.27	6.55	6.55	6.82
Grain yield, Average kg/ha.	2 200	2 780	2 780	2 200	2 230	2 230	2 280	2 260	2 860
Crop yield kg/ha	4 800	5 920	5 920	4 800	4 850	4 850	5 120	5 120	6 360

Table 2C Crop Conditions during Field Test on Tractor-mounted Nine-row Vertical Conveyor Reaper Windrower Model-II, (1983)

Crop parameter	Trial No. 1	2	3	4	5	6
Variety	Narmada	Lok-1	Mukta	HD-2578	HD-2378	Mukta
Susceptibility of shattering	No	No	No	Yes	Yes	No
Date of sowing	12/11/82	28/10	17/10	15/11	15/11	27/10
Date of harvesting	13/4/83	15/4	27/4	27/4	28/4	10/4
Average plant height, cm	82.5	125.5	73.8	73.3	82.7	75.6
Tiller population Average No./sq.m	312	269	299	299	276	289
Moisture content Average grain % w.b.	11.72	10.23	8.26	8.26	7.57	6.87
straw % w.b.	10.52	9.87	8.63	8.63	7.40	7.95
Grain yield kg/ha	2 410	2 360	3 120	3 120	2 000	2 260
Crop yield kg/ha	5 180	5 750	5 590	5 590	4 500	4 900

Table 2D Crop Conditions during Field Test on Tractor-mounted Vertical Conveyor Reaper Windrower Model-II, (1984)

Crop parameters	Trial No. 1	2	3	4	5
Variety	Sonalika	Sonalika	WH 146	WH 146	Narmada-4
Susceptibility to shattering	No	No	No	No	No
Date of harvest	11/4/84	12/4/84	13/4/84	14/4/84	17/4/84
Average plant height, cm	96.7	96.0	71.8	73.0	142.0
Tiller population No./sq.m	233	238	160	193	243
Moisture content grain % w.b.	8.6	7.8	8.0	8.7	8.5
Grain yield, kg/ha	4 200	3 400	2 300	3 270	2 770
Crop yield, kg/ha	9 480	8 050	5 130	5 920	7 680

Table 3 Field Performance Results of Power Tiller-Mounted Vertical Conveyor Reaper Windrower

Date of test	Grain yield	Field capacity	Field efficiency	Fuel consumption	Labour requirement		Harvesting losses			
					Unskilled	Skilled	Header	Discharge	Collection and binding	Total % of yield
	t/ha	ha/h	%	1/ha	man-h/ha	man-h/ha	g/m²	g/m²	g/m²	
13/4/82	2.43	0.241	72.4	1.80	43.39	4.13	1.84	2.63	10.81	6.28
13/4/82	2.43	0.280	84.9	1.66	40.42	3.53	1.62	3.16	8.80	5.58
14/4/82	2.75	0.235	67.7	1.68	43.02	4.25	4.40	4.10	13.70	8.07
16/4/82	1.09	0.307	76.7	1.42	35.25	3.22	0.34	0.00	3.00	3.80
16/4/82	1.09	0.277	67.9	1.50	37.57	3.50	0.29	0.00	4.18	4.10
26/4/82	2.26	0.272	85.1	1.54	37.86	3.70	1.58	0.68	7.99	4.53
29/4/82	2.30	0.275	82.5	1.66	40.13	3.58	1.15	2.60	6.40	4.41
29/4/82	2.30	0.268	80.6	1.59	41.22	3.70	2.35	1.35	8.29	5.21
Average:	2.08	0.269	77.2	1.61	39.86	3.71	1.70	1.81	8.60	5.25

Table 4 Field Performance Results of Tractor Mounted Vertical Conveyor Reaper Windrower

Date of test	Grain yield	Field capacity	Field efficiency	Fuel consumption	Labour requirement		Harvesting losses			
					Unskilled	Skilled	Header	Discharge	Collection and binding	Total % of yield
	t/ha	ha/h	%	1/ha	man-h/ha	man-h/ha	g/m²	g/m²	g/m²	
5/4/82	2.20	0.270	63.9	4.25	44.14	3.68	1.85	0.32	7.73	4.50
6/4/82	2.78	0.244	74.2	4.71	46.29	4.08	3.86	2.55	10.59	6.11
6/4/82	2.78	0.256	77.8	4.58	43.50	3.88	2.72	1.75	8.09	4.51
7/4/82	2.20	0.243	54.3	4.60	45.76	4.15	1.56	0.37	4.23	2.80
9/4/82	2.23	0.246	62.1	4.72	44.54	4.08	2.85	3.15	4.61	4.75
9/4/82	2.23	0.248	61.1	4.65	42.77	4.00	4.15	2.37	5.88	5.56
22/4/82	2.26	0.270	69.9	4.21	42.30	3.69	1.32	0.16	6.30	3.44
22/4/82	2.26	0.269	69.6	4.16	42.93	3.72	1.08	0.29	7.09	3.74
29/4/82	2.86	0.252	78.06	4.48	44.76	3.98	2.25	1.76	8.70	4.44
Average	2.42	0.255	67.9	4.49	44.11	3.92	2.40	1.41	7.02	4.43

Table 5 Field Performance Results of Tractor Front Mounted Vertical Conveyor Reaper Windrower (1983)

Date of test	Grain yield	Field capacity	Field efficiency	Fuel consumption	Labour requirement		Harvesting losses			Total % of yield
					Unskilled	Skilled	Header	Discharge	Collection and binding	
	t/ha	ha/h	%	1/ha	man-h/ha	man-h/ha		g/m²		
13-4-83	2.41	0.321	76.2	4.35	40.88	3.11	2.77	0.00	5.93	3.61
15-4-83	2.36	0.263	75.3	4.95	45.60	3.81	1.92	1.52	7.22	4.52
27-4-83	3.12	0.320	73.9	4.21	39.34	3.12	0.90	1.74	10.08	4.08
27-4-83	3.12	0.318	70.6	4.49	40.10	3.17	1.50	0.80	9.71	3.85
28-4-83	2.00	0.319	73.6	4.33	44.31	3.14	3.87	1.85	5.34	5.53
30-4-83	2.26	0.318	75.0	4.31	43.55	3.14	2.72	3.05	7.97	6.08
Average	2.54	0.310	74.1	4.44	42.30	3.25	2.28	1.49	7.71	4.61

Table 6 Field Performance Results of Tractor Front Mounted Vertical Conveyor Reaper Windrower, Model-II

Date of test	Grain yield	Field capacity	Field efficiency	Fuel consumption	Skilled labour requirement	Harvesting losses			Total % of yield
						Header	Discharge	Collection binding	
	t/ha	ha/h	%	1/ha	man/h-ha	g/m²	g/m²	g/m²	
11-4-84	4.20	0.336	62.7	3.7	2.97	1.8	1.30	13.5	3.9
12-4-84	3.40	0.39	72.5	4.3	2.56	1.8	1.26	13.6	4.9
13-4-84	2.30	0.40	56.0	4.84	3.33	6.16	2.02	7.6	6.8
14-4-84	3.27	0.368	69.0	4.4	2.71	5.4	1.07	10.0	5.2
17-4-84	2.77	0.294	59.8	4.5	3.40	6.11	2.02	12.0	7.2
Average	3.188	0.337	64.0	4.4	2.96	2.90	1.53	11.34	5.6

tionately low. Further average working width of the machine was 1.53 m. The power tiller windrower had one forward speed and the engine was operated at 80% of full throttle and forward speed was controlled to achieve proper cutting of the crop. For the tractor forward speed control was possible and it was operated in low fourth gear. The engine throttle lever was set at 80-85% of its fully opened position. Further increase in forward speed resulted in uneven cutting of crop. The fuel consumption values for tractor and power tiller units were 4.49 l/ha and 1.61 l/ha. The fuel consumption values were low for the tractor-operated unit.

The field performance tests during 1983 indicated that the average field capacity of the tractor-operated Model-II was 0.31 ha/h with an average field efficiency of 74%. The field efficiency was low because of time lost during turning and small field plots. The average forward speed during operation was 36.4 m/min. This was achieved by operating the tractor in low 4th gear. The effective working width of the machine during operation was 1.91 m. Increasing the forward speed resulted in greater cutter bar losses and uneven cutting. The average fuel consumption value of tractor windrower reported was 1.37 l/h and it averaged to 4.44 l/ha.

The field performance tests during 1984 indicated an average field capacity of 0.337 ha/h with field efficiency of 64% when the tests were conducted on larger size plots and test duration was 2 to 3 h. The highest value achieved was 0.39 ha/h. The high field capacity was due to higher forward speed. The low field efficiency was due to time losses in turning. The tractor was operated in first high gear with engine at 85% full throttle. The average fuel consumption was 4.4 l/ha.

Labour Requirements – The skilled labour requirements by trac-

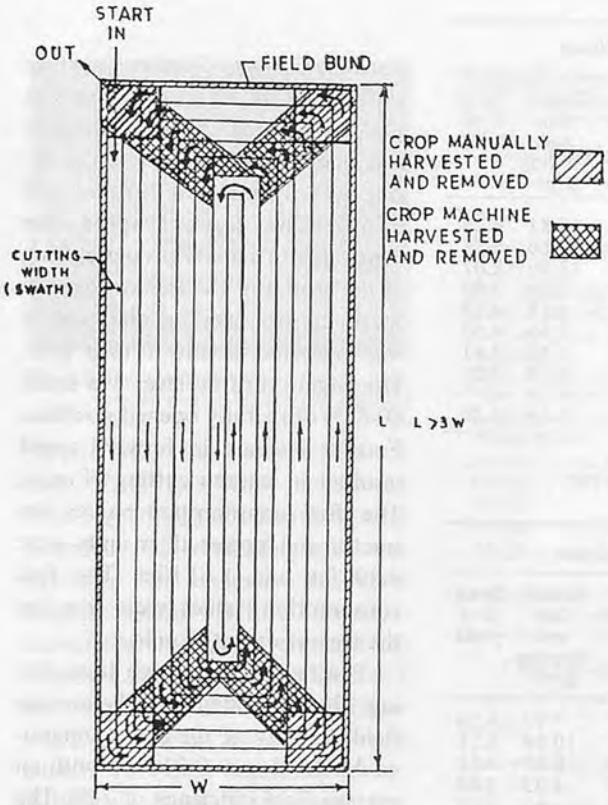


Fig. 13 Method of operating power tiller reaper windrower in the field.

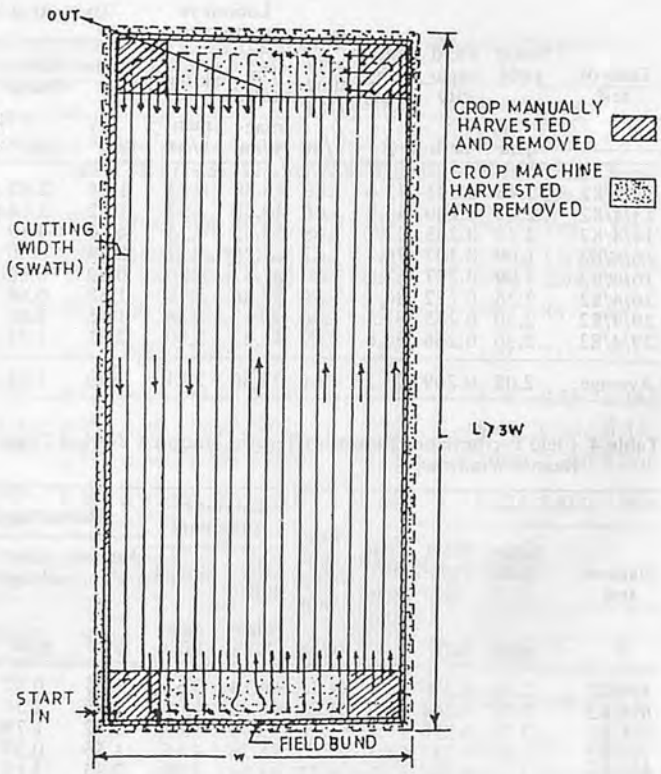


Fig. 14 Method of operating tractor-mounted reaper windrower in the field.

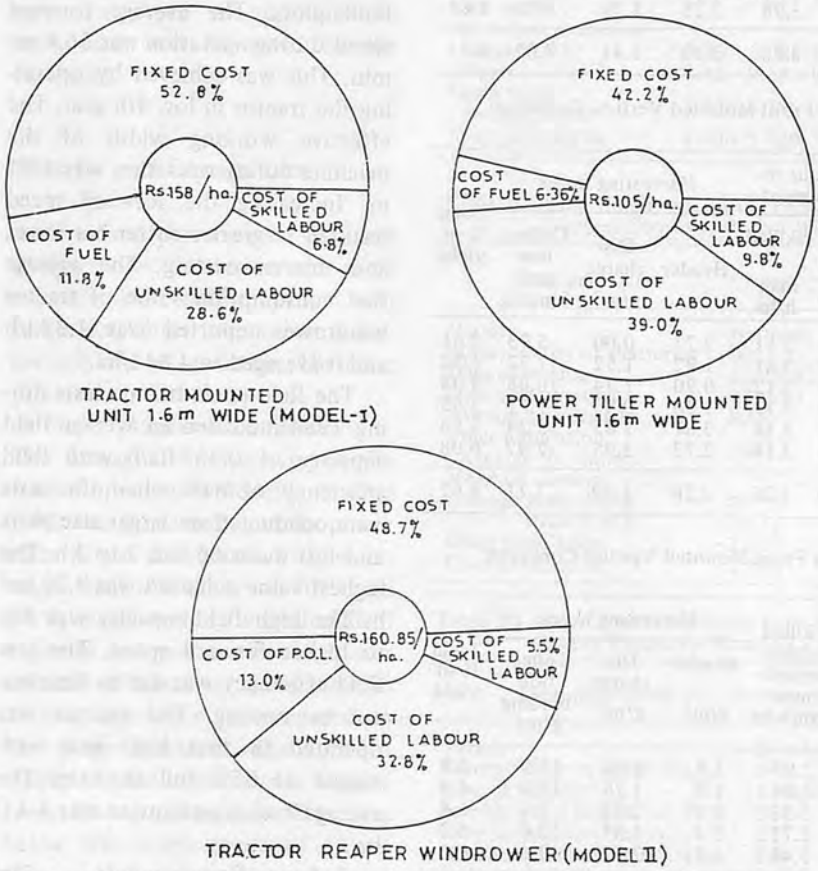


Fig. 15 Distribution of cost of operation for different models of vertical conveyor reaper windrowers.

tor Model-I and power tiller unit were 4.49 and 3.71 man-h/ha, respectively. The unskilled labour required for preparing the field before operation, removal of the crop during the beginning of operation and for collection and binding of the crop bundles after the windrowing was completed. The average values reported were 44.11 and 39.86 man-h/ha, respectively. The labour wages for unskilled labour were Rs 45.43 and 41.05/ha for tractor and power tiller units, respectively. Two labourers were engaged during the machine operation to remove the harvested crop and sometimes plants left uncut at the corners during the turn.

The average labour requirements for the tractor-operated vertical conveyor reaper windrower Model-II were 42.3 man-h/ha for unskilled and 3.25 man-h/ha for skilled labour. The unskilled labour is mostly required for cutting of crop from the corners of test plots and collection and tying of the material after

Table 7 Range of Cost of Operation for a Tractor and Power Tiller Operated CIAE Reaper Windrower

Item	Tractor Model-I (1.6 m)			Power Tiller Model (1.6 m)			Tractor Model-II (2.05 m)			Tractor Model-II improved ***		
	Min.	Max.	Av. (1982)	Min.	Max.	Av. (1982)	Min.	Max.	Av. (1983)	Min.	Max.	Av. (1984)
Fixed cost Rs/ha	78.13	88.62	83.2	41.40	53.11	47.71	74.84	91.61	78.12	61.59	81.80	71.45
Variable cost:												
Fuel cost Rs/ha	13.05	14.83	14.07	4.45	5.64	5.04	14.86	17.47	15.67	13.06	17.26	15.53
Oil cost	4.35	4.94	4.68	1.48	1.88	1.68	4.95	5.82	5.22	4.31	5.70	5.17
Cost of labour												
Cost, Rs/ha	43.57	47.68	45.43	36.30	44.69	41.05	50.12	57.00	52.87	52.87	52.87	58.72
Cost, Rs/ha	10.12	11.41	10.76	8.85	11.35	10.20	8.55	10.48	8.93	7.04	9.35	8.16
Total variable cost, Rs/ha	71.33	78.62	74.95	51.08	63.56	58.24	57.75	67.48	63.07	77.28	85.18	81.58
Cost of harvesting, Rs/ha	149.67	165.24	158.0	92.48	117.69	105.55	152.68	182.39	160.85	138.87	166.98	145.11
Grain yield 14% m.c. t/ha	2.386	3.15	2.63	1.165	1.896	2.398	2.140	3.300	2.666	2.30	4.20	3.18
Cost of harvesting, Rs/t	50.81	68.51	60.62	39.75	86.54	52.00	56.50	71.0	60.50	34.14	71.77	45.63
Cost of sickle harvesting, Rs			164.0			164.0			200.0			
Cost of harvesting manual with sickle Rs/t			62.3*			62.30			79.50**			

Remarks: 1 US$= Rs 12 (Approx.) *Labour wages Rs 8.20/day. **Labour wages Rs 10/day. ***Costs taken at 1983 levels

winnowing was completed. The skilled labour was used for operating the windrower. Because of the good quality windrowing labour requirements were less. The labour wage rates increased from Rs 8.20/day to Rs 10/day during 1983.

The skilled labour requirement for trials conducted during 1984 averaged 2.92 man-h/ha as compared to 3.25 reported during 1983. The minimum of 2 unskilled labourers were used during machine operation. The crop was not simultaneously picked during the test but during demonstration 10 labourers were used to pick up the crop, each covering the field length of about 25 m. Thus the unskilled labour requirements may be considered as similar to that reported during 1983 tests, *i e*, 40-42 man-h/ha.

Harvesting Losses – The total harvesting losses constituted the header loss, discharge or conveyor loss and losses due to collection and tying of bundles. The total grain losses during 1982 were 4.43 and 5.25% of the crop yield for tractor and power tiller operated units, respectively. The machine losses were in the range of 1.5 to 1.6%. The collection losses were 61 to 66% of the total losses for the tractor and power tiller operated units, respectively. The collection losses were high because of low moisture content of crop, high ambient temperature (35-43°C) and the manual collection of harvested crop.

The harvesting losses for the tractor-operated windrower Model-II, during 1983, were in the range of 3.6 to 6.0% with average of 4.61 % of the total grain yield. The losses due to machine were only 1.5% and maximum loss noted was during the gathering and collection of the crop. The gathering moisture content was in the range of 6.9 to 11.7% and the ambient temperatures in the range of 40°C. The losses would be low when harvesting is carried out at the recommended 14 % grain moisture content. The high gathering losses were recoverable up to 50% without incurring the extra cost, because in this region, the farm labourers pick up the ears after machine operation and share the picked up crop on 50% basis. Hence the total losses can be brought to low level of 2.0 to 3.0%.

The losses during 1984 tests were in the range of 3.7 to 7.2%, these were mostly due to collection of crop. The crop was not collected at the same time but after a day or two and this resulted in greater losses due to collection as the shattered ears were left in the field. The average loss reported was 5.6% of yield or 157 kg/ha.

The Cost of Operation – The cost of operation with tractor-mounted and power tiller units were calculated from the test results and making the assumptions for machine life, hours of operation, rate of interest and cost of machine, etc as per standard procedure. The working hours for reapers were assumed as 300 h/year and these are also recommended as per ISI standards. The cost of operation values were Rs 158 and Rs 105/ha for the two machines (1982). The various cost components for the machines are shown in **Table 7**. As compared to the manual sickle method the cost of harvesting based on 20 man-days per ha works out as Rs 164. Hence the power tiller unit was cheaper by 38% and the tractor operated unit only 5% comparable to manual sickle method. This was because of low field output and the fixed cost of the tractor was high, as compared to the power tiller unit.

During the 1983 trials the cost of operation was calculated taking into account the costs of labour and materials at 1983 rates. These

were high as compared to 1982. The labour wage rates increased by Rs 1.80/man-day *i e* from Rs 8.20/jman-day to Rs 10.00/man-day. Thus the cost of operation with the 2.05 m size windrower was Rs.161/ha. The fixed cost for the machine and tractor were 50% of total cost. The labour costs were 34%. The increase in cost of operation with manual sickle harvesting method taking 20 man-days for harvesting 1 ha was calculated as Rs 200 **(Table 7)**. Thus there was a net saving of 20% by harvesting with the tractor-operated Model-II as compared to manual method.

The cost of operation during 1984 are reported based upon the rates of labour, fuels, etc. on 1983 basis. Because of an increase in the field capacity of the machine the cost of operation averaged to Rs 145/ha. This was about 9% less as compared to the value reported during 1983.

Conclusions

i) The vertical conveyor reaper windrower was a suitable machine for harvesting wheat as it makes a clean windrow ears on one side and plants laid perpendicular to the direction of travel. The field capacity achieved with 1.6 m wide unit was 0.269 ha/h and for 2.09 m tractor unit 0.337 ha/h.

ii) The costs of operation with tractor and power tiller models were low as compared to manual method by 20 to 38%.

iii) The total harvesting losses were in the range of 4 to 6% of grain yield when grain mositure content was 7 to 11%. One-third of these losses were due to machine. The other two-thirds were due to collection and tying of crop bundles, but are recoverable type. The low machine losses indicate the effectiveness of vertical conveying system.

iv) Increasing field capacity of windrower can reduce the total cost of operation because the fixed costs were around 50% of total cost of operation.

v) The labour requirements are reduced to 40-42 man-h/ha, *i e*, one third of the manual harvesting method. Thus windrower can eliminate the peak demand of labour during harvesting season.

REFERENCES

D.F. Howson and Devnani, R.S. (1981). A Width of Cut Analysis of a Vertical Conveyor Cereal Reaper for Indian Farms. Agricultural Mechanization in Asia, Vol.XII(4), pp.19-23.

Devnani, R.S. and Pandey, M.M. (1981). Evaluation of Field Performance of Reaper Binders for Harvesting of Wheat Crop. Journal of Indian Society of Agricultural Engineers. Vol. XVII (1), pp.97-110.

Pandey, M.M. and Devnani, R.S. (1981). Development of improved CIAE sickle for harvesting cereals. Agricultural Mechanization in Asia. Vol.XII(2), pp.54-58.

Devnani, R.S. and Pandey, M.M. (1980). Testing and Field Performance Evaluation and Adaptation of Cereal Harvesters. CIAE Technical Bulletin No. CIAE/9/80. Presented at Second Annual Workshop on Cereal Harvesters, August 5-8 at University of Philippines, Los Banos, Philippines.

Pandya, A.C. & Howson, D.F. (1981). Coordinator's report on testing, adaptation and evaluation of harvesting machines presented at the 2nd Sub-network Workshop, August, 1980.

Devnani, R.S. Harvesting equipment developed in India. CIAE Technical Bulletin No.CIAE/78/4, CIAE, Bhopal.

Proceedings of the Second Sub-Network on Cereal Harvester. 5-8 August, 1980, Los Banos. Organized by the Institute of Agricultural Engineering and Technology, University of Philippines at Los Banos and Regional Network for Agricultural Machinery.

Annual Report of 1981-82 of Bhopal Centre of FIM Scheme on All India Coordinated Project on Farm Implements and Machinery, Prototype Manufacturing Workshop and Feasibility Test Centres for Testing Improved Agricultural Implements under Actual Field Conditions, presented during eleventh annual workshop, at Birsa Agri. University, Ranchi.

Annual Report of Bhopal Centre 1982-83 presented during the twelfth annual workshop of All India Coordinated Scheme on Farm Implements and Machinery, Jan. 20-22, 1983 at HAU, Hissar.

Annual Report of Bhopal Centre 1983-84, presented during the Thirteenth annual workshop of All India Coordinated Scheme on Farm Implements and Machinery, 2-4 Feb., 1984 at IISR Lucknow. ■■

Measurement of Properties of Rice Husk Boards:

Part II Thermal Properties

by
B.D. Shukla
Post Doctoral Fellow
Agricultural Engineering Dept.
International Rice Research Institute
P.O. Box 933, Manila, Philippines

T.P. Ojha
Director
Central Institute of Agric. Engineering
G.T.B. Complex, T.T. Nagar
Bhopal-462003, India

C.P. Gupta
Professor
Agric. Engineering Dept.
Indian Institute of Technology
Kharagpur 721302, India

Introduction

Three successful processes for the production of rice husk boards were developed at the Indian Institute of Technology (IIT), Kharagpur, India (Shukla, 1976). Various engineering properties of the rice husk boards were measured and studied (Shukla *et al,* 1983). The tests indicate that the husk boards, depending on their density and strength, can be used like insulation boards, particle boards and hard boards. Procedures and apparatus for the measurement of physical and mechanical properties of rice husk boards are described in Part I of this paper (Shulka *at al,* 1983). Therefore, the procedures and development of apparatus for measuring the air permeability, thermal conductivity and specific heat of rice husk boards are described in this paper. The results are compared with the recommendation of the Indian Standard Institution (ISI) and other published literatures and the suitability of rice husk boards for insulation purposes have been studied.

Acknowledgments: The authors wish to acknowledge with thanks the efforts and care taken by Ms. Ellen Suñaz in typing the manuscript of this paper.

Theoretical Considerations

The basic theory involved in the measurement of air permeability, thermal conductivity and specific heat of rice husk boards are briefly described below:

Air Permeability

According to Muskat (1946), the permeability of porous medium may be stated as the volume of a fluid of unit viscosity passing through a unit cross section of the 'medium' in unit time under the action of unit pressure gradient, and can be expressed as:

$$k \text{ (permeability of porous medium)} = \frac{\text{(Volume of fluids)/(area of medium)}}{\text{(time) (pressure gradient)}} \quad \ldots\ldots\ldots\ldots (1)$$

If the whole mass of rice husk board is considered as porous medium then its air permeability can be determined by the modified Darey's equation (Muskat, 1946) as follows:

$$k = \bar{Q}\mu t/A\Delta P \quad \ldots\ldots\ldots (2)$$

where, k = coefficient of air permeability, cm^2

Q = volumetric air flow rate, cm^3/sec

μ = viscosity of air, poise (g/cm-sec)

t = thickness of husk board specimen, cm

The permeability of rice husk board was calculated by equation (2) with the following assumptions:

1. Air flow through the board specimen was laminar and isothermal and, the Darey's law was applicable.
2. Pressure gradient was considered to be uniform as the observation was recorded when the air flow rate through the board attained a steady state.
3. Board specimen was supposed to be acting as an undeformable homogeneous porous medium.
4. There was no change in the moisture content within the porespaces of the board.

Thermal Conductivity

The following equation given by Fourier for steady state conductive heat transfer was used to determine the thermal conductivity of the rice husk board:

$$K = Qt/A\Delta t \quad \ldots\ldots\ldots (3)$$

where, K = thermal conductivity of rice husk board, K cal/h-m-°C

Q = heat flow rate, K cal/h

t = thickness of board, m

A = surface area of board, m^2

ΔT = temperature difference between the hot and cold

surfaces of the board, °C.

The following assumptions were made in using Equation (3) for the calculation of the thermal conductivity of the rice husk board.

1. The heat transfer due to convection and radiation was negligible, hence, it was not considered in the final calculation of thermal conductivity of rice husk boards.
2. Heat losses from the side of the apparatus were not accounted for in the final calculation of thermal conductivity of the boards as the apparatus was insulated from all sides.
3. Linear heat flow through the husk board was assumed.

Specific Heat

The method of mixture was used to determine the specific heat of the rice husk boards. At an equilibrium temperature, the quantity of heat given by the board specimen is equal to that received by the calorimeter and liquid. Therefore, the specific heat of the rice husk board is given by the following equation:

$$Cp = \frac{wS(T - t_1) + \dot{m}s(T - t_1)}{M(t_2 - T)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where, Cp = specific heat of rice husk board

S = specific heat of calorimeter and stirrer metal

s = specific heat of liquid

M = weight of test specimen

$\dot{m}$ = weight of liquid

w = weight of calorimeter with stirrer

t_1 = initial temperature of liquid

t_2 = temperature of heated rice husk board test specimen

T = temperature of mixture

The following assumptions were made in the determination of specific heat of rice husk baord:

1. The heat losses during the transfer of test specimen from hot air oven to calorimeter, and from the side of calorimeter were not accounted for in the calculation of specific heat as it was negligible.
2. There was no evaporation of liquid during the equilibrium period.

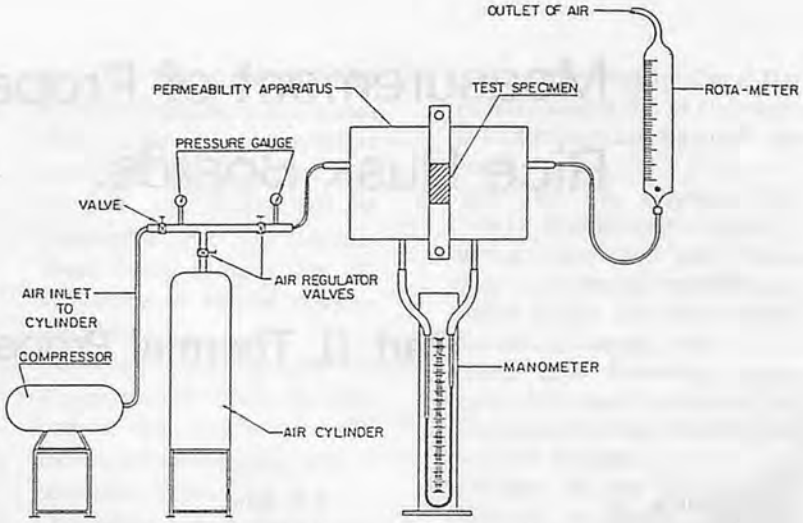


Fig. 1 Air permeability apparatus.

Experimental Procedures

The rice husk boards were prepared with the use of phenol formaldehyde (PF) resin binder. The procedures for the preparation of the boards have been described by Shukla (1976) and Shukla *et al* (1983). The air permeability, thermal conductivity and specific heat of these boards were determined by the following apparatus and procedures.

Air Permeability

The apparatus used in measuring the air permeability of the rice husk board was designed, fabricated and was based on the Darey's principle (described by Muskat, 1946) of flow through a porous medium with the following components:

Compressed Air Cylinder Assembly – The line diagram of the permeamility apparatus is shown in **Fig. 1**. A cylinder of 0.086 m^3 internal volume was filled with air at about 6.5 kg/cm^2 pressure by a compressor. The air pressure in the cylinder was indicated by a pressure gauge (0-7 kg/cm^2 pressure range) attached to the opening of the cylinder. The air flow from the cylinder (according to the requirement of the experiment) was controlled by means of a valve fitted in the air outlet pipe of the cylinder.

Permeability Apparatus – The apparatus consists of inlet and outlet pipes for air, two air holding boxes, a fixture to hold the test specimen of rice husk board and a glass manometer to measure the differential pressure head. The details of the apparatus are shown in **Fig. 2**.

The two air holding boxes of 12 x 12 x 6 cm each in dimension, were fabricated using copper sheet. A U-tube glass manometer of 1 m length and 6 mm diameter was attached to the apparatus to record the difference in pressures of incoming and outgoing air through the board specimen. At the opening of each copper box, a brass plate of 18 x 18 cm size with a circular hole of 8 cm diameter at the center, was welded. Thus, both boxes have equal size circular openings for air passage.

The rice husk board, specimen of 125 x 125 mm size, was fixed to fixture made of perspex sheet of 18 x 18 x 1.2 cm thick. The fixture along with the test specimen was fixed in between two copper boxes

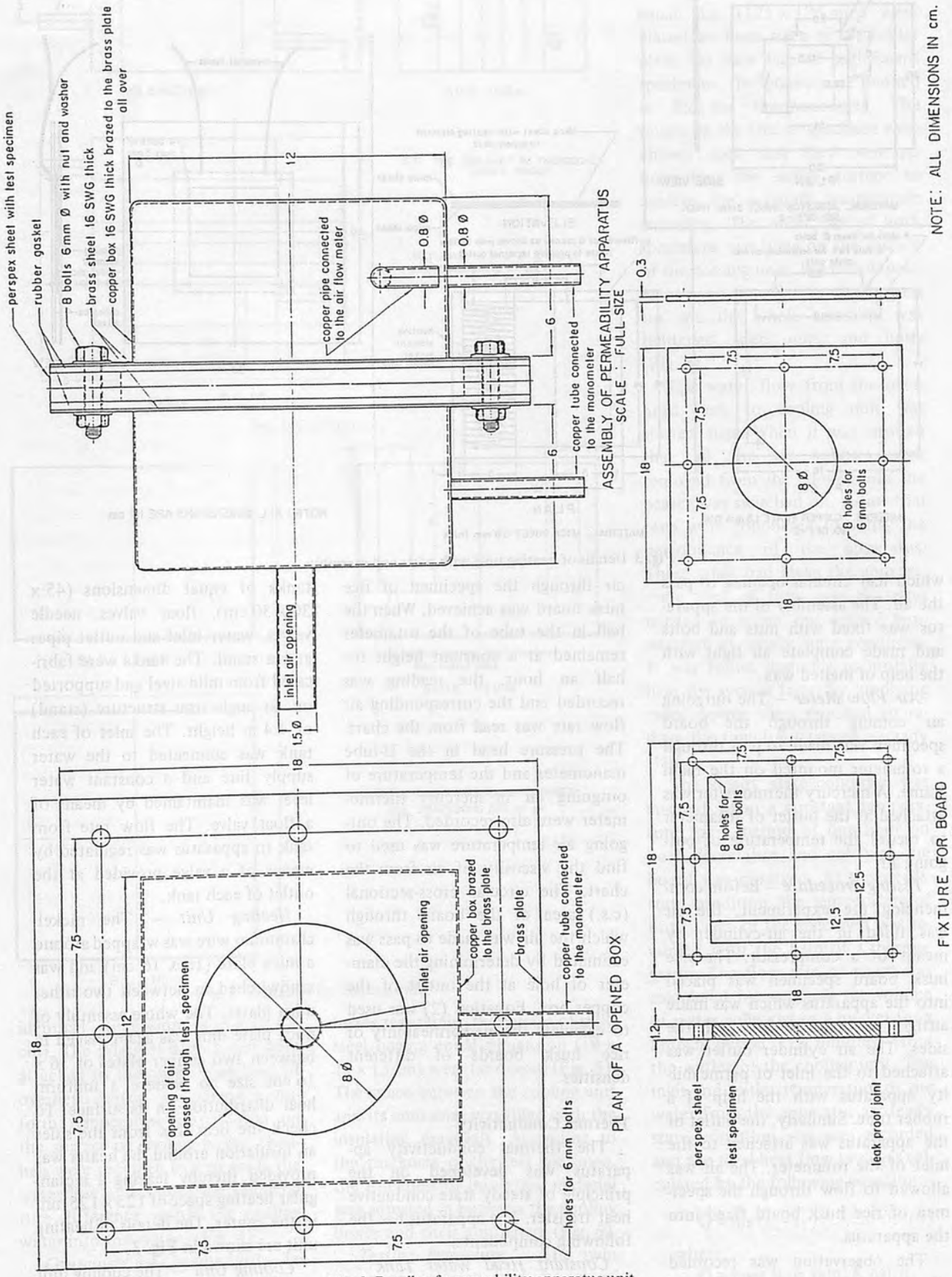


Fig. 2 Details of permeability apparatus unit.

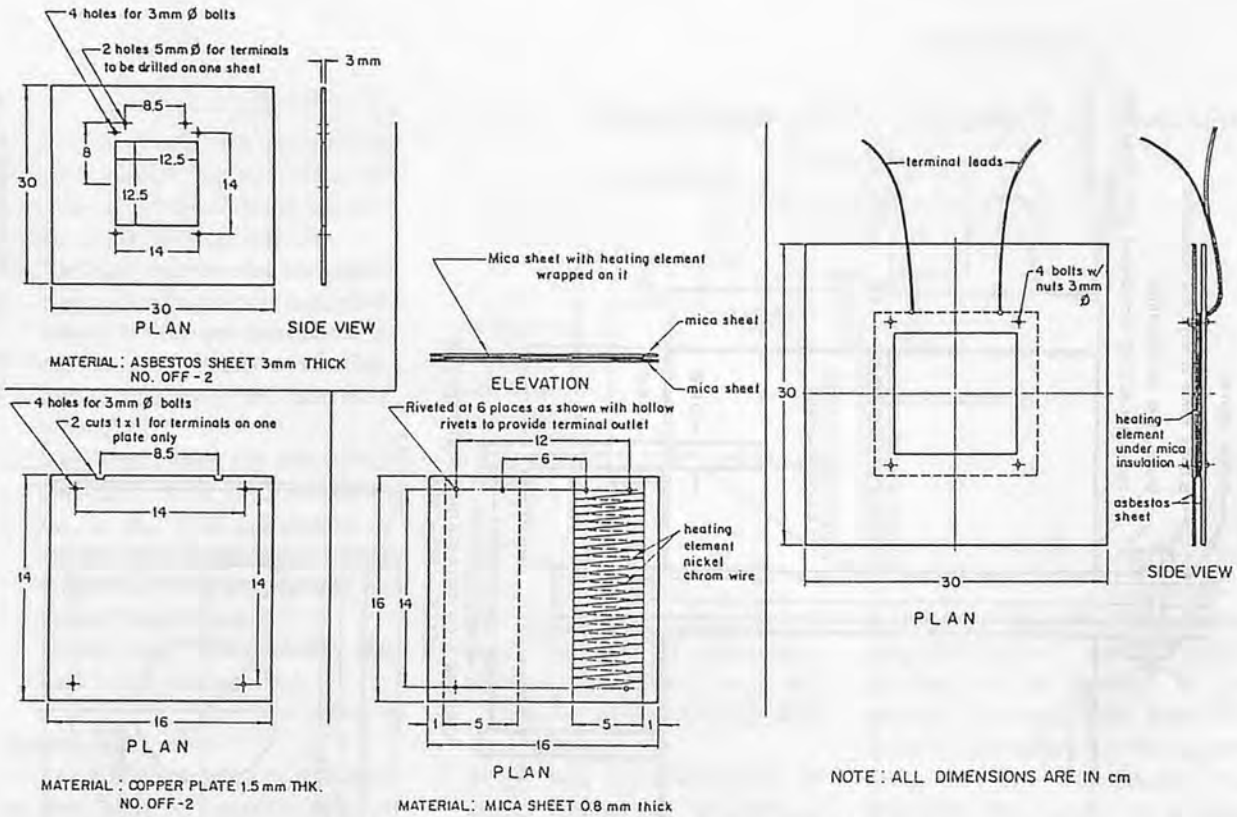


Fig. 3 Details of heating unit with parts and assembly.

which had circular opening to pass the air. The assembly of the apparatus was fixed with nuts and bolts and made complete air tight with the help of melted wax.

Air Flow Meter – The outgoing air coming through the board specimen was made to pass through a rotameter mounted on the main frame. A mercury thermometer was attached at the outlet of rotameter to record the temperature of outgoing air.

Testing Procedure – Before commencing the experiment, the air was filled in the air-cylinder by means of a compressor. The rice husk board specimen was placed into the apparatus which was made airtight completely from all the sides. The air cylinder outlet was attached to the inlet of permeability apparatus with the help of a rubber tube. Similarly, the outlet of the apparatus was attached to the inlet of the rotameter. The air was allowed to flow through the specimen of rice husk board fixed into the apparatus.

The observation was recorded when a steady state in the flow of air through the specimen of rice husk board was achieved. When the ball in the tube of the rotameter remained at a constant height for half an hour, the reading was recorded and the corresponding air flow rate was read from the chart. The pressure head in the U-tube manometer and the temperature of outgoing air in mercury thermometer were also recorded. The outgoing air temperature was used to find the viscosity of air from the chart. The circular cross-sectional (c.s.) area of the board through which the air was made to pass was estimated by determining the diameter of hole at the outlet of the copper box. Equation (2) was used to calculate the air permeability of rice husk boards of different densities.

Thermal Conductivity

The thermal conductivity apparatus was developed on the principle of steady state conductive heat transfer. The apparatus has the following components:

Constant Head Water Tank – The unit consists of two overhead tanks of equal dimensions (45 x 30 x 30 cm), float valves, needle valves, water inlet and outlet pipes and a stand. The tanks were fabricated from mild steel and supported on an angle iron structure (stand) of 1.4 m height. The inlet of each tank was connected to the water supply line and a constant water level was maintained by means of a float valve. The flow rate from tank to apparatus was regulated by means of a valve provided at the outlet of each tank.

Heating Unit – The nickel-chromium wire was wrapped around a mica plate (16 x 16 cm) and was sandwitched in between two other mica plates. The whole assembly of mica plate unit was again placed in between two copper plates of 16 x 16 cm size to achieve a uniform heat distribution on its surface. To check the heat loss from the sides an insulation around the heater was provided thereby leaving a rectangular heating space of 125 x 125 mm in the center. The details of heating unit are shown in **Fig. 3**.

Cooling Unit – The cooling unit consists of two wooden boxes of

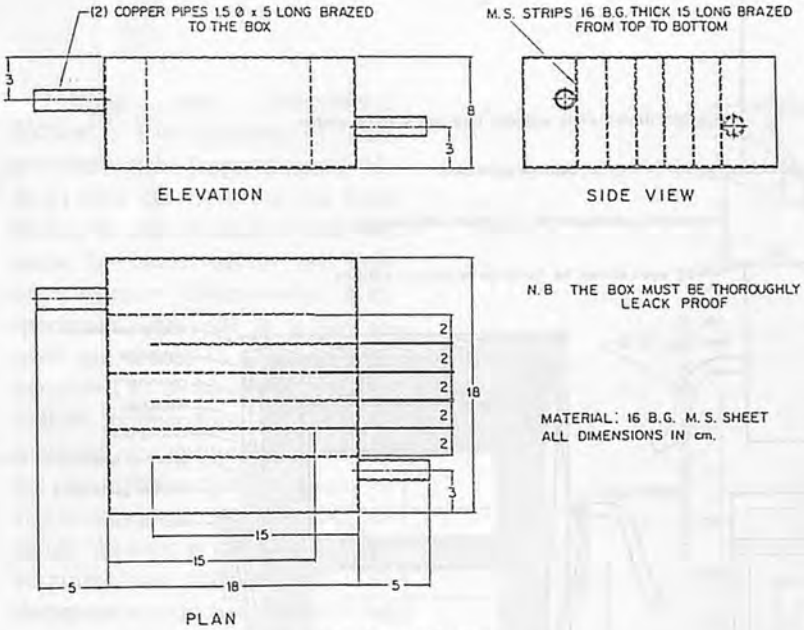


Fig. 4 Cooling unit.

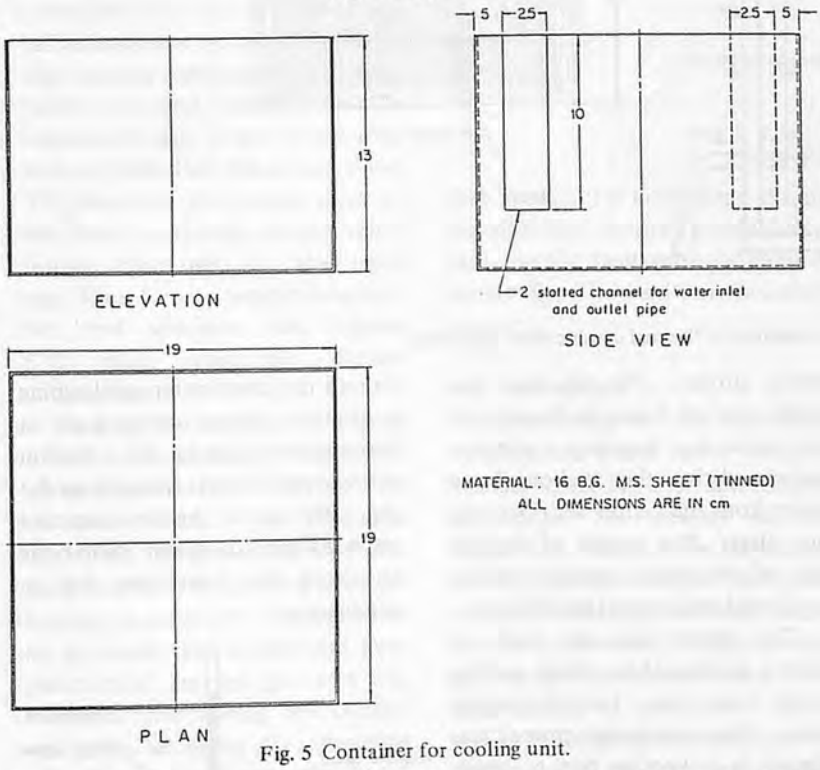


Fig. 5 Container for cooling unit.

identical dimensions (18 x 18 x 8 cm). The inlets of both boxes were attached to the outlet pipe lines of overhead tanks. To achieve a uniform temperature distribution on the surface of cooling boxes, channels were provided in it to guide the waterflow and reduce the temperature difference within the cooling water into the system (Fig. 4).

Containers for Cooling Unit – To accommodate the two cooling boxes separately, two boxes of mild steel having equal dimension (19 x 19 x 13 cm) were fabricated (Fig. 5). The space between the cooling unit and its container was filled with the insulating materials. According to the thickness of the test specimen, the thickness of insulation material was adjusted in between the cooling boxes and their containers (Fig. 6).

Testing Procedure – The twin specimens of rice husk board of equal size (125 x 125 mm) were placed on both sides of the heater plate. On each face of both board specimens, five points were marked to fix the thermocouples. The points on the face of specimen were chosen such that they were representing the entire surface to achieve the accurate temperature recording. The other face of both specimens was lying on the surface of the cooling unit. The board specimens were placed into the apparatus and the whole assembly was tightened with nuts and bolts (Fig. 6).

The water flow from the overhead tank to cooling unit was started first. When it was ensured that all the air bubbles were removed from the cooling unit the heater was switched on. A few trial tests were conducted to verify the performance of the apparatus. These trials had given the approximate idea of flow rate of water needed to attain the desired temperature at steady state condition. It was found desirable to initially heat the system faster by supplying more power than required to reduce the time for attaining a steady state.

The steady state condition was ensured when a constant temperature for a period of one hour on both faces (hot and cold) of the board was observed. At the steady state condition, the temperature of both faces of the specimen was recorded with the help of a thermograph. The flow rate of water was calculated by weighing the volume of water collected in a bucket for a known period (15 minutes) from the outlet of the cooling unit. The inlet and outlet temperature of the water from the apparatus at steady state condition was also recorded and the total heat flow rate was calculated by the following equation:

$$Q = \dot{m}s\,(t_2 - t_1) \quad \ldots\ldots\ldots \quad (5)$$

where,

Q = heat flow rate, K cal/h

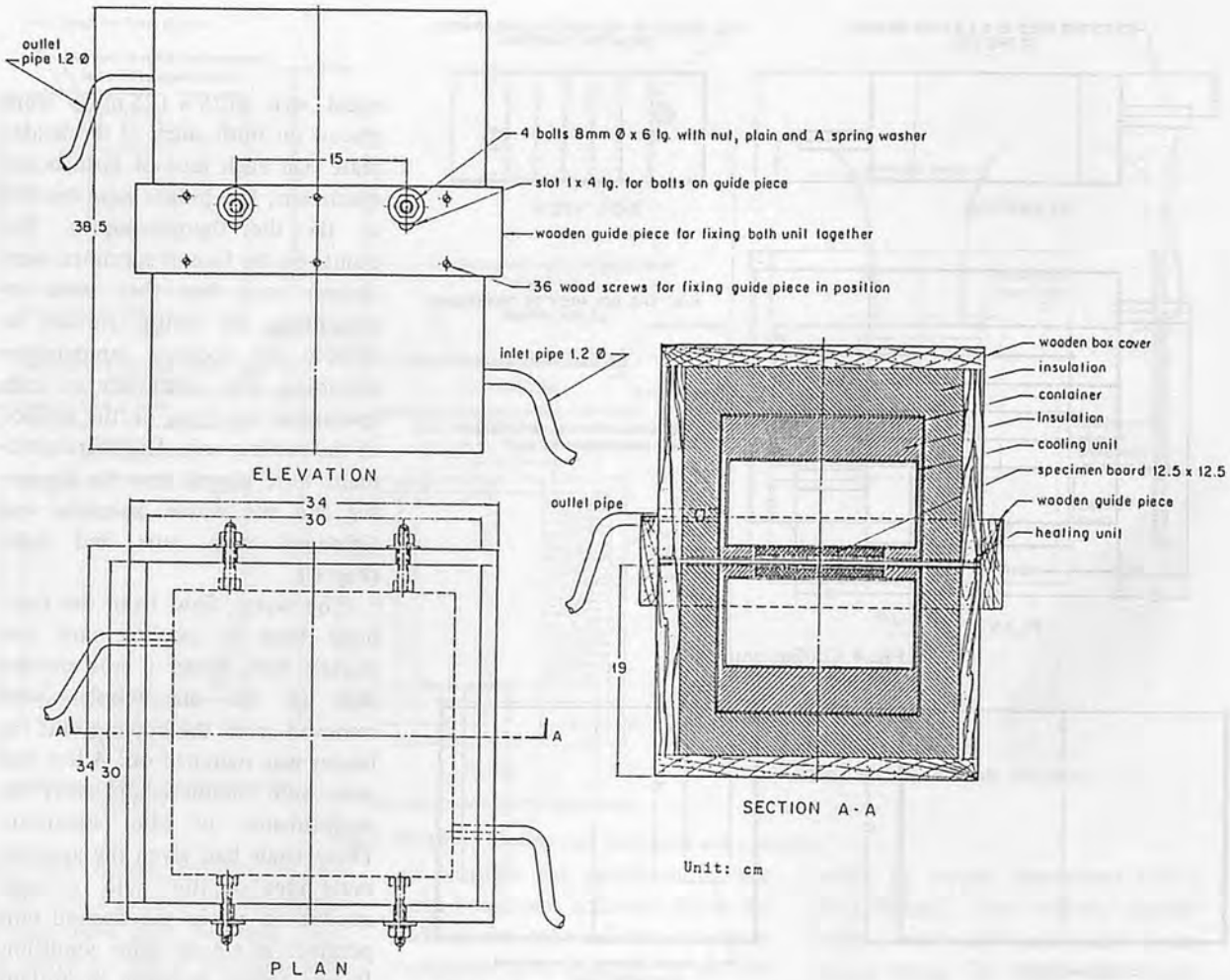


Fig. 6 Assembly of thermal conductivity apparatus.

$\dot{m}$ = mass flow rate of water, kg/h

s = specific heat of water, K cal/kg °C

t_1 = inlet temperature of water, °C

t_2 = outlet temperature of water, °C

The thermal conductivity of the rice husk board was calculated by the Equation (3).

Specific Heat

The apparatus is described as follows:

Calorimeter Proper and Accessories – The calorimeter proper (Fig. 7) is a copper cup having internal diameter of 50 mm, length of 75 mm and wall thickness of 1 mm. A copper lid, which sealed the cup during the experiment to eliminate the chance of evaporation of liquid is placed on the top of the calorimeter proper. The lid had two holes; one of 7 mm in diameter at its center for inserting a thermometer and the other at about 3 mm away from the center for operating the stirrer. The weight of the full unit of calorimeter proper (including the lid and stirrer) was 80 g.

The stirrer was also made of copper and has three blade paddles made from two twisted copper wires. The calorimeter proper was placed in a wooden box of inside dimensions of 102 x 85 x 85 mm height made of 1.2 cm thick plank. The box was screwed on to a wooden stand to support the mercury thermometer (0-50°C) placed into the center of the calorimeter.

Insulation – Adequate insulation was provided around the calorimeter proper to check the heat losses. A highly polished aluminium shield was provided around the calorimeter cup keeping a distance gap of about 1 cm in between to minimize the radiation and convection heat losses from the top. The rest of the box was also provided with sufficient insulations to check the heat loss due to conduction.

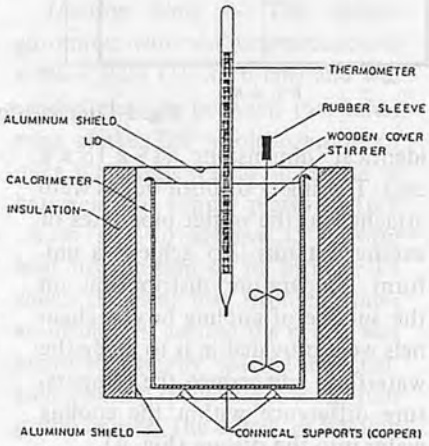


Fig. 7 Experimental set-up of calorimeter for the determination of specific heat.

Heating and Transferring Method – Two specimens of equal size and weight (approximately 10-12 g) were cut from the rice husk board. In one of them a hole was made to insert tightly the bulb of a mercury thermometer. Both specimens were put in a hot air oven and heated to a desired temperature (50 or 80 or 100°C). The desired temperature of the test specimen was ensured by determining the temperature of specimen attached with a mercury thermometer. As soon as the required temperature was indicated by the thermometer attached to one of the specimen, it was assumed that the other specimen also attained identical temperature in the oven. Hence, the second specimen piece was taken out and dropped in the calorimeter cup. It was found after several trials that there was about 5°C drop in the temperature of the board specimen during transferring from oven to calorimeter cup. Therefore, to compensate that, the test specimen was heated 5°C more than the desired temperature.

Testing Procedure – About three-fourth volume of the calorimeter cup was filled with a liquid of known specific heat (kerosene oil). Two specimens of the rice husk boards were already placed for heating to a desired temperature in an air oven. The weight and temperature of the test specimen was recorded. The stirring was continued after dropping the specimen into the cup and temperature of equilibrium state between the liquid, cup and hot husk board was recorded. Equation (4) was used to calculate the specific heat of rice husk board.

Results and Discussions

Rice husk boards of different densities were prepared by the procedures described by Shukla (1976) and Shukla *et al* (1983) and the air-permeability, thermal conductivity, and specific heat were determined separately. The results are discussed below:

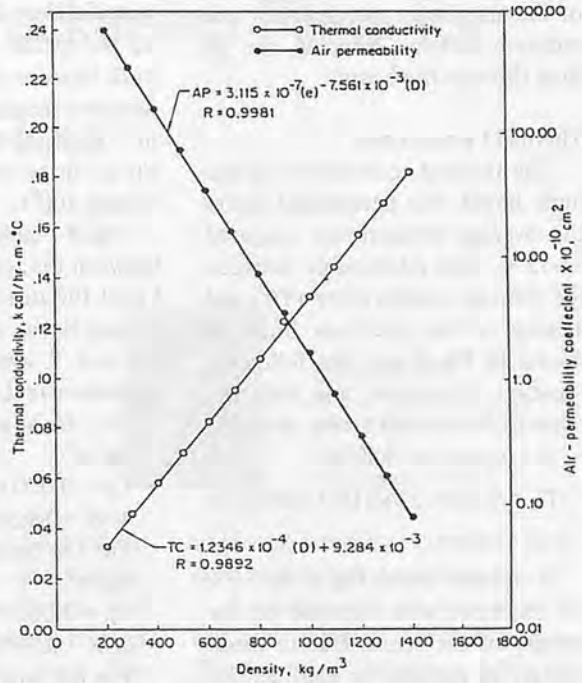


Fig. 8 Relationship between thermal conductivity and air-permeability coefficient with density of the boards.

Table 1 Thermal Conductivity and Air-Permeability of Rice Husk Baords

Density (kg/m³)	Air-permeability ×10⁻¹⁰ (cm²)	Thermal conductivity (K cal/h-m-°C)
200	686.600	0.0339
300	332.300	0.0463
400	151.300	0.0586
500	71.050	0.0709
600	33.360	0.0833
700	15.660	0.0956
800	7.353	0.1080
900	3.452	0.1203
1 000	1.620	0.1327
1 100	0.761	0.1450
1 200	0.357	0.1573
1 300	0.167	0.1697
1 400	0.078	0.1820

Air Permeability

The density of the rice husk board is the prime factor which is related to its physical and thermal properties. The density of the board was found to be dependent on the platen pressure of the press, adhesive content in rice husk board, and to some extent, on the particle size of the rice husk (Shukla, 1976 and Shukla *et al* 1983). **Fig. 8** shows the relationship between the density (D) and air permeability (AP) of rice husk board. Applying the technique of regression analysis, the following exponential equation with the correlation coefficient (R) of 0.9981 was obtained:

$$AP = 3.115 \times 10^{-7} e^{-7.561 \times 10^{-3}} (D) \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

The calculated values of AP at different densities of the rice husk board are given in **Table 1**. The lowest and highest values of AP were found as 7.8×10^{-12} and 6.86×10^{-8} cm², respectively, against the highest and lowest densities of board as 1 400 and 200 kg/m³, respectively. Hence, the AP was observed higher at lower density of rice husk board and vice-versa. It appears that the permeability was influenced by the number and size of the interparticle capillaries rather than anatomical features of rice husk particles. Hence, in low density board, due to the presence of large number of air spaces, the permeability was high. In the high density board, the air spaces were reduced due to higher compression

of the mat, hence, permeability was reduced thereby reducing the air flow through the board.

Thermal Conductivity

The thermal conductivity of rice husk board was determined under the average temperature range of 51-55°C. The relationship between the thermal conductivity (TC) and density of the rice husk board is shown in **Fig. 8** and the following equation of straight line with the value of R = 0.9892, was obtained by the regression analysis:

$$TC = 0.00012346(D) + 0.009284 \quad \ldots\ldots (7)$$

It appears from **Fig. 8** that the TC increases with increase of the density of the board. Due to closer contact in particles of high density board, the heat transfer due to conduction was faster in comparison to lower density board, when more air spaces retarded the heat flow, hence, reduced the thermal conductivity. These observations support the views of Lewis (1967). Hence, it may be stated that apart from other factors, the density of rice husk board also affects its thermal conductivity to a great extent. The values of TC at different densities of board are given in **Table 1**.

The boards of density less than 600 kg/m^3 satisfy the requirements of the ISI for insulation boards. At 400 kg/m^3 density the TC should not exceed the limit of ISI as 0.07 K cal/h-m-°C in the case of particle boards used for insulation purposes (IS:3129-1965) and 0.056 K cal/h-m-°C in the case of fiber insulation boards (IS:3348-1965). It is clear from **Table 1**, that at 400 kg/m^3 density, the rice husk boards have the value of TC, 0.0586 K cal/h-m-°C, which is within the limit recommended by the ISI. Hence, the rice husk board is suitable for insulation purposes also.

Specific Heat

The specific heat (Cp) of the rice husk board was determined at three densities ranging from 600-1 300 kg/m^3. Each sample was tested for its Cp at three temperatures, *i e,* 50, 80 and 100°C.

Fig. 9 presents the relation between the temperature (T) and Cp of the rice husk board. The following linear relationship between Cp and T was obtained using the regression analysis technique:

For the board density of 613.25 kg/m^3

$$Cp = 0.0001\,(T) + 0.3258 \quad \ldots (8)$$

at R = 0.9286

For the board density of 895.60 kg/m^3

$$Cp = 0.0001\,(T) + 0.4338 \quad \ldots (9)$$

at R = 0.9993

For the board density of 1250.72 kg/m^3

$$Cp = 0.002\,(T) + 0.5479 \quad \ldots (10)$$

at R = 0.9173

It appears (**Fig. 9**) that Cp depends mainly on the temperature of the husk board. Due to non-availability of published literature on specific heat of rice husk board, the obtained result could not be verified. Some work on the specific heat of dry wood has been reported by Marks (1941) and according to him, the specific heat values were high on the addition of resin in dry wood. The specific heat of the rice husk board was found somewhat higher than those of drywood due perhaps to the resin content of the board.

Conclusion

The apparatus designed and developed for measuring the air permeability, thermal conductivity and specific heat of rice husk boards, were simple, inexpensive and worked satisfactorily. Thermal conductivity and air permeability were

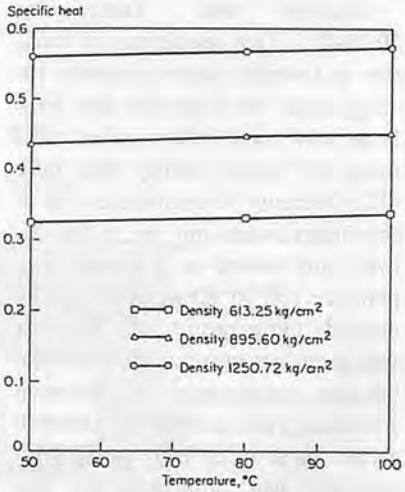


Fig. 9 Relationship between specific heat and temperature at various densities of rice husk boards.

dependent on the density of rice husk boards whereas the specific heat was mainly dependent on the temperature of the board. The rice husk boards satisfied the requirements of insulation boards as recommended by the Indian Standard Institution.

REFERENCES

1. Indian Standard Institution: IS: 3129-1965 and IS: 3348-1965.
2. Lewis, W.C. 1967. Thermal conductivity of wood base fibre and particle panel materials. USDA Forest Service Research Paper No. FPL77.
3. Marks, L.S. 1941. Mechanical engineering handbook. 4th Ed. McGraw Hill Book Co., Inc., New York and London.
4. Muskat, M. 1946. The flow of homogeneous fluid through porous media. 2nd Ed. McGraw Hill Book Co., Inc., New York.
5. Shukla, B.D. 1976. Processes for developing rice husk boards and determination of their engineering properties. Ph. D. Thesis. IIT, Kharagpur, India. ■■

Suitability of Flexible Packaging Films for Rice, Dal and Wheat Flour

by
Mridula Bhattacharjee
Junior Research Officer (Biochemist)
Harvest and Post Harvest Technology (ICAR) Scheme
PHTC, Indian Institute of Technology
Kharagpur, India

Surya Nath
Senior Research Officer
HPHT (ICAR) Scheme
PHTC, IIT
Kharagpur, India

Abstract

The study is aimed at identifying suitable consumer packages among polythene (PLY, 400 μ), polythene impregnated jute bag (PIB) and jute bag (JUB) for milled rice (MR), parboiled brown rice (PABR) and parboiled milled rice (PAMR), mung dal (*Phaseolus aureus*) and wheat flour. The observations show that i) PLY was the best packaging system; ii) outer bran coating of PABR and the gelatinized starch of PAMR have a protecting effect on moisture ingress within the grain; iii) dal and wheat flour are much more susceptible to moisture absorption and quality deterioration (moisture change was parallel to relative humidity); iv) the total and viable micro-organisms increased as storage period advanced in each type of food commodity stored; v) microbial infestation was least in PABR and highest in MR. The PLY was suitable for storing PABR, PAMR and MR in their acceptable range up to 120 days; dal up to 85 days and wheat flour for 4 weeks. (The JUB was useless for any type of food item); and vi) the loss in dry matter, though not very significant, was least in PLY and highest in JUB for rice, dal and wheat flour. The maximum loss was observed with MR, followed by PAMR and PABR. Dry weight loss, in the case of wheat flour, was much higher than that in dal and rice due to severe infestation during storage.

Acknowledgements: The authors are very grateful to Mr. K.K. Mishra, Junior Laboratory Assistant for his valuable assistance throughout the experiment. Sincere thanks go to Prof. N.G. Bhole, Head, PHTC for providing the facilities in Post Harvest Technology Centre and to the I.C.A.R. for providing grants to undertake the study.

Introduction

There is always a time-lag between production and consumption of rice. The expected shelf-life of the fresh food material is highly variable on the part of consumers since it has to pass through several operations like processing, transportation, distribution and marketing before it reaches the ultimate users. Storage, therefore, is an inevitable stage between production and consumption of food which involves a change in the physical and chemical properties of the product as affected by processing, cooking, eating and nutritional qualities. The keeping quality of the processed food depends heavily on the nature of packaging. A large section of the consumers are interested to purchase small quantity of food materials instead of bulk, mainly to avoid handling expenses, large investments and storage losses.

A considerable amount of work has been done on food packaging. The sorption behaviour of food products and the permeability of the packaging material are the essential constraints in designing and developing functional packages (Anandaswamy and Iyenger, 1980). A moisture content higher than 15% is critical for mold growth and discolouration of red pigment formation of chilli during storage (Mahadevaiah *et al*, 1976). Water-vapour-transmission rate, tensile and bursting strengths, tearing resistance and elongation of a variety of indigenously manufactured flexible plastic films have been determined and reported by Kumar *et al*, 1976. Improper packaging of *asafetida* causes loss of flavour, volatile oil and absorption of moisture. Moisture level between 14 and 17% corresponding to an equilibrium relative humidity about 65% is critical for various physico-chemical and microbial spoilage in *asafetida* (Balasubrahmanyam *et al*, 1979). Biscuits with initial moisture content of 2% became soft at or above a moisture level of 4%. The longevity of the product can be increased to some extent by wrapping the biscuits with wax paper, cellophane, vinyl coated aluminium foil packages (Kumar and

Balasubrahmanyam, 1978). Similarly, a moisture level of 3.5% is critical with respect to the crispness of fried potato chips (Balasubrahmanyam and Anandaswamy, 1979). In a separate type of observation, pouches of the laminate of paper/aluminium foil/polythylene and aluminium collapsible tube were found suitable for packaging mango jam and tomato ketchup (Gowramma *et al*, 1981).

There is an increasing interest in extending the shelf-life of food in sealed plastic packages through nitrogen or other gaseous condition and use of vacuum (Christopher *et al*, 1979; Kaffezakis *et al*, 1969; Kantter *et al*, 1981). Vacuum packaging of pork, beaf or lamb and use of modified gaseous conditions that limit microbial growth of meat during storage and thereby checking the deterioration of quality of food have been reported in several reports (Scideman *et al*, 1979; Scideman *et al*, 1980; Taylor, 1972). Recently, sandwitches packed under nitrogen followed by sealed in gas-impervious-plastic pouches have appeared in the market which remain in satisfactory condition for about 30 days, if kept in refrigerator (Kantter *et al*, 1981). The brown rice and milled rice after packaging in laminated film bags when stored under water was almost similar to that of rice stored at a low temperature under controlled conditions (Mitsuda and Yamamoto, 1971; Ory *et al*, 1980).

The present investigation was carried out for rice, pulse (dal) and wheat flour stored in various types of small flexible packages to identify the right packaging film capable of retaining the shelf-life of the product.

Materials Used

The raw milled rice (MR) of Ratna variety was collected from the Agricultural Engineering Department of Indian Institute of Technology, Kharagpur. PAMR and PABR were procured from a private rice mill at Balichak in the district of Midnapore, West Bengal. The green gram *(Phaseolus aureus)* was bought from the market in split form and locally called 'Mung dal'. For the wheat flour, the Sonalika variety was used in the study.

Methodology

A 2-kg sample of each of the commodities was stored in PLY, PIB and JUB packages. PAMR and PABR were stored for 150 days while MR and mung dal were stored at room temperature (34±2°C) for 120 days; wheat flour was stored only for 56 days. The duration of storage period was selected depending on the acceptabilities of the respective commodities. The bags were sealed and kept on elevated wooden platform. The room as well as the bags were disinfected with malathion (1:15 by volume) 3 *l* each per 300 m^2 surface area before packaging the materials. Moisture content, microbial count and dry matter loss were separately determined in order to identify the extent of food deterioration for each commodity during ageing.

Moisture Content – A sample of 25 g each was kept in an oven at 130 ± 2°C for 1 h in a moisture box, dried, cooled in a desicator and weighed (AOAC, 1970).

Microbiological Analysis – A 10 mℓ of sterile distilled water was added asceptically to 1 g of powdered sample in sterile test tube. This gave the stock sample solution. Microbial analysis was performed from this stock in two different steps:

i) Total microbial count: A stock solution of 0.02 mℓ was taken asceptically in the haemocytometre stage and covered with a coverslop. The numbers of living and dead organisms were counted under microscope.

ii) Viable microbial count: The agar plates were prepared by pipetting out 15 mℓ of the sterilized tryptone-glucose-agar medium into the respective Petri dishes of 11 cm dia. While the agar plates were prepared with the stock sample solutions, the colonies formed were much too crowded which is why 1 mℓ of sample solution from the stock was diluted to 10 mℓ (10^{-1}) in another sterile test tube in order to obtain the colony readings within the proper range. Sometimes one more dilute sample solution was made with 10 mℓ of water.

Tryptone-glucose-agar medium constitutes:

Tryptone	: 5 g
Yeast extract	: 2.5 g sterilized at 15 lbs
Glucose	: 1 g pressure for 15 min
Agar	: 15.0 g (ISI, 1962)
Distilled water	: 1.0 litre
pH	: 7.1 ± 0.1

The plates were incubated at 37 ± 2°C for 24 h and the colonies formed were counted in a colony counter.

Dry Weight – A sample of 100 sound grains were weighed at one month interval on dry basis and the loss in dry matter was calculated from the difference in respective weights at particular storage interval with respect to the initial weight.

Results and Discussions

Moisture Content – The moisture content of all types of rice samples increased with the storage period irrespective of packaging materials (Figs. 1-3). The extent of such increase, however, was relatively low in the PLY bags. The gelatinized starch in PAMR and the outer bran layer in PABR have a

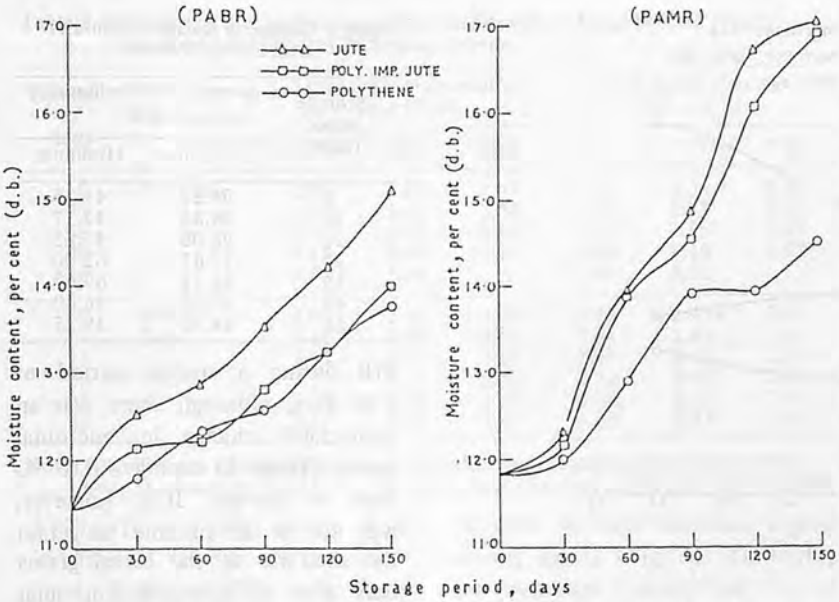


Fig. 1 Moisture variation of parboiled brown rice (PABR) and parboiled milled rice (PAMR) stored in different packaging systems.

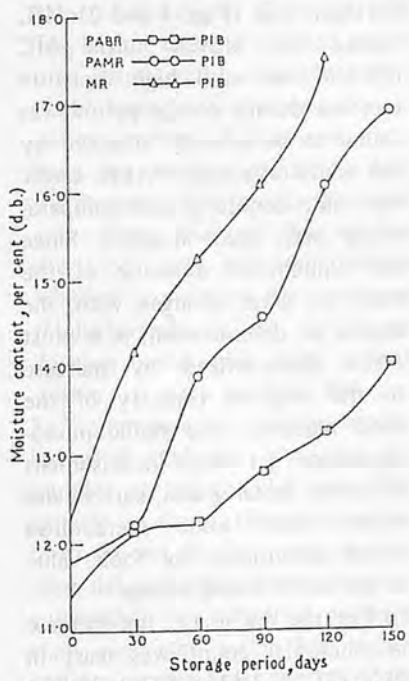


Fig. 2 Variation of moisture content of milled rice (MR) stored in different packaging systems.

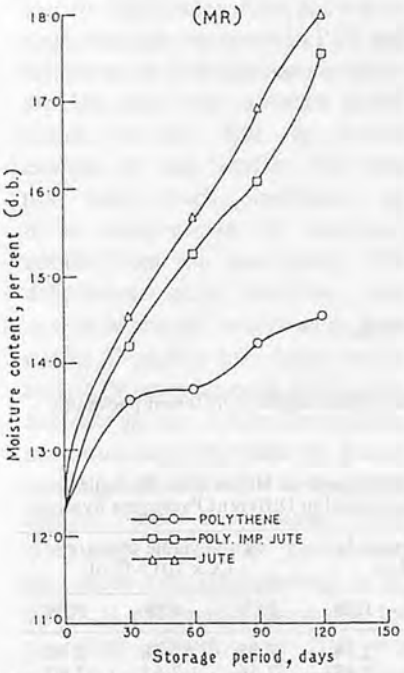


Fig. 3 Moisture variation of PABR, PAMR and MR stored in Polythene-impregnated jute bag.

protecting effect (Fig. 3) towards ingress of moisture. Similar results were also reported by Indudharswamy *et al*, 1971. MR with no kernel protection was found to indicate maximum moisture increase than PAMR (Fig. 3). The moisture changes took place at a relatively low rate in PABR during rice ageing. The relative effectiveness of moisture absorption by PABR, PAMR and MR was shown in all packaging materials.

Changes in moisture content (MC) of Mung dal and wheat flour followed the same increasing trend along with storage period (Fig. 4) as was observed in rice samples. The increase in MC for dal grains was highest in JUB, (18.21%) and least in PLY (16.05%) after 120 days of storage indicating relatively moisture-proof nature of PLY during storage. In the case of wheat flour, the moisture rise in wheat flour stored in PLY and PIB was in the acceptable limit for 21 days of storage (about 11.5 and 13%, respectively), but it crossed the safe moisture limit in wheat flour stored in JUB (about 14%). After about a month the moisture change in flour stored in PLY was lower (12.5%), but the same was found to be in high range (14-15%) for samples in PIB and more so in JUB (16%). This range is favourable for microbial growth. The rise in moisture content of stored wheat flour was parallel to that of the relative humidity (RH) (Table 1). The highest RH of 97-98% within 28 days of storage was the point where deterioration of flour started. It has been observed that 14% is the critical moisture content suitable for microbiological spoilage according to Mahadevaiah *et al*, 1977.

Microbiological Analysis – Due to lack of proper knowledge and sometimes failure of the packaging system, an appreciable amount of fresh food material is lost during storage. The losses and degradation of the food products occur due to the activities of several macro- and micro-organisms and their moisture content (Schroeder and Calderwood, 1972). The organisms developed during storage include mainly fungi, bacteria and insects. The appearance and growth of micro-organisms have been observed by total microbial count (living + dead organisms) and viable count (living organisms only). Both of these counts increased with increase of storage period irrespective of packaging systems as well as the food products. In the case of rice, PLY was found to be the best packaging system for all the commodities (MR, PAMR and PABR) following

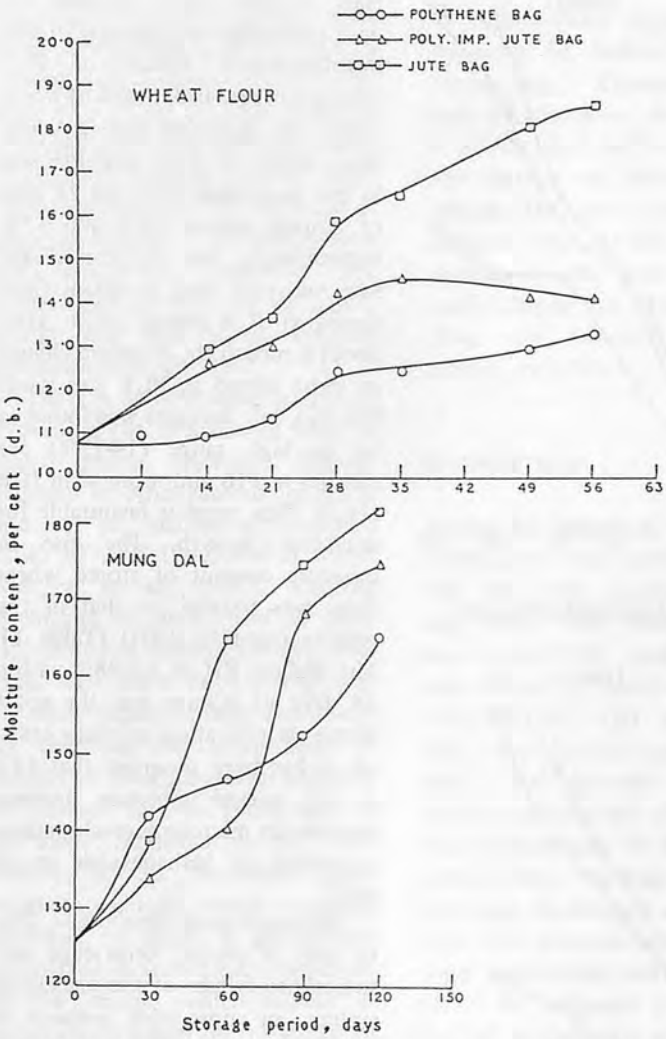


Fig. 4 Moisture variation of *mung dal* and wheat flour stored in different packaging systems.

Table 2 Influence of Storage Time on Microbial Growth of Milled Rice, Parboiled Milled Rice and Parboiled Brown Rice Stored in Different Packaging Systems

No. of days	Type	Total microbial count/g (5y x 10) = P of			Total viable count/g (X x 10) = Q of		
		PLY	PIB	JUB	PLY	PIB	JUB
0	Milled rice	2.74	2.74	2.74	2.08	2.08	2.08
30		2.81	2.84	2.98	2.56	2.53	2.62
60		2.87	3.10	3.13	2.75	2.78	2.94
90		2.93	3.15	3.54	3.04	3.18	3.08
120		3.52	3.20	–	3.30	3.41	–
0	Parboiled milled rice	2.54	2.54	2.54	2.40	2.40	2.40
30		2.74	2.74	2.87	2.60	2.73	2.85
60		3.00	3.11	3.18	2.81	2.91	2.97
90		3.19	3.27	3.53	3.00	3.06	3.22
120		3.43	3.48	–	3.40	3.41	–
0	Parboiled brown rice	2.54	2.54	2.54	2.34	2.34	2.34
30		2.70	2.70	2.74	2.53	2.56	2.63
60		3.04	3.06	3.11	2.62	2.71	2.87
90		3.02	3.13	3.43	2.60	3.00	3.36
120		3.30	3.43	3.62	2.86	3.25	–

Note: Overall mean dilution plate counts of viable micro-organisms expressed as Log_{10} (colonies/g).

Table 1 Change in Relative Humidity with Storage Period

Storage period (days)	Average relative himidity (%)	
	Maximum	Minimum
0	94.25	41.25
14	94.83	42.17
21	96.00	47.83
28	97.67	62.00
35	98.17	67.67
49	87.20	36.80
56	84.75	39.25

PIB during a storage period of 120 days, although there was an appreciable change in microbial count (**Table 2**) during 60 to 90 days of storage. JUB, however, was not at all suitable to retain the shelf-life of the cereal grains only after 60 days. The microbial deterioration of the cereal grain was parallel to its moisture change during storage (**Figs. 1 and 2**). MR, having the highest initial MC (12.3%) and with high moisture increase during storage period was found to be severely attacked by the micro-organisms. PABR, under the same condition had comparatively been least attacked. Since the equilibrium moisture of the bulk of grain changes with the degree of deterioration, it is most often characterized by increase in the sorption capacity of the food material. The viable micro-organisms get their nourishment from the cereal grains, survive and secret some toxic metabolites which deteriorate the food value of the cereal during storage.

For the dal grains the increase in microbial count was least in PLY (TC = 3.43/g, VC = 3.00/g) after 90 days of storage and was highest in JUB (TC = 3.57/g, VC = 3.47/g) (**Table 3**). The shelf-life of the stored product was found to remain almost intact up to 90 days (MC = 15.21%) in PLY while the same in PIB and JUB deteriorated only after 60 days (MC = 14.01% and 16.05%, respectively).

The proliferation of microflora, in wheat flour was found to be severe (**Table 3**) in JUB (VC =

Table 3 Influence of Storage Time on Microbial Growth of Mung Dal and Wheat Flour Stored in Different Packaging Systems

Number of days	Commodity	Total microbial count/g (5y x 10) of			Total viable count/g (X x 10) of		
		PLY	PIB	JUB	PLY	PIB	JUB
0	Nung dal	2.87	2.87	2.87	2.36	2.36	2.36
30		2.95	3.02	3.04	2.74	2.77	2.83
60		3.20	3.32	3.45	2.88	2.85	2.93
90		3.43	3.49	3.57	3.00	3.40	3.47
120		3.63	3.68	–	3.40	3.50	–
0	Wheat flour	3.06	3.06	3.06	2.43	2.43	2.43
14		3.11	3.08	3.13	2.54	2.61	2.75
21		3.11	3.13	3.18	2.60	2.68	2.79
28		3.20	3.25	3.22	2.86	2.92	2.97
35		3.35	3.45	3.47	3.04	3.22	3.24
49		3.57	3.68	3.64	3.28	2.33	3.47

Note: Overall mean dilution plate counts of viable micro-organisms are expressed as Log_{10} (colonies/g). X and Y are the numerical values of viable and total colonies.

2.97/g, TC = 3.24/g) during 28 to 35 days of storage. On the other hand, PLY and PIB were fairly acceptable indicating thereby the safe limit of wheat flour up to 28 days of storage in PLY and PIB. The higher number of dead organisms (total count – viable count) might have been observed due to the production of dead microflora from the viable ones during their metabolism whereas only the viable count were the one that spoiled the food. *Atta* and *maida* stored in *Kraft* paper have been reported (Mahadevaiah *et al*, 1977) to develop mold and fungi growth within 10 days at 92% RH, and 38°C temperature. These results indicated that the rice and dal samples stored in PLY and PIB are safe for storing the commodities upto 60 and 90 days, respectively. Also dal and wheat flour are more susceptible to microbial spoilage than rice, the latter has higher inclination towards the development of micro-organisms. This is perhaps due to their higher tendency of moisture absorption.

Dry Matter Loss – There was a general decreasing trend in dry matter with the storage period for all the food commodities stored during this experiment. For rice samples the extent of decrease was higher with MR than that of PAMR and PABR, respectively, (Table 4). This trend is parallel to that of their moisture ingress during ageing (Fig. 3). MR having no protective coating like that of PABR absorbed maximum moisture from the atmosphere and as such lost its dry matter. Also, the loss in dry solids was minimum in PLY and maximum in JUB packages indicating the relatively moisture proof nature of PLY. But the overall changes in dry matter loss was not very much significant, as it is compensated by moisture uptake from the atmosphere. The deteriorated grain, therefore, may not show enough reduction in total weight though it may loose in dry matter (Mazumdar *et al*, 1973). The decrease in dry matter for dal was maximum in JUB (Table 5) due to very high development of moisture content within the packages at the later stage of storage period. An MC about 14% (Mahadevaiah *et al*, 1977) is extremely favourable for microbial growth. The JUB was attacked severely by microbes and insects which invaded the solid matters from the grain. The wheat flour in each type of packages was much more susceptible to infestation than dal or rice. This is because a high rate of moisture absorption was associated with a high amount of solid loss during storage (Table 5). As such the longevity of fresh wheat flour in the best type of packaging system (PLY) was only 5 weeks.

Table 4 Influence of Storage Time on the Dry Matter Loss of Milled Rice, Parboiled Milled Rice and Parboiled Brown Rice Stored in Different Packaging Systems

Number of days	Variety	Loss of weight, % (d.b.)		
		Polythene bag	Pol-lmp. jute bag	Jute bag
0	Milled rice	–	–	–
30		1.15	1.68	1.97
60		1.23	2.57	2.91
90		1.68	3.26	3.93
120		1.95	4.46	4.77
0	Par-boiled milled rice	–	–	–
30		0.91	0.75	0.46
60		1.18	1.57	1.73
90		1.68	2.39	2.67
120		1.88	3.27	4.16
150		2.43	4.12	4.43
0	Par-boiled brown rice	–	–	–
30		0.82	0.66	1.12
60		0.87	0.98	1.43
90		1.13	1.25	1.89
120		1.64	1.69	2.42
150		2.17	2.29	3.16

Table 5 Influence of Storage Time on dry Matter Loss of Mung Dal and Wheat Flour Stored in Different Packaging Systems

Number of days	Commodity	Loss of weight, % (d.b.)		
		Polythene bag	Pol-lmp. jute bag	Jute bag
0	Mung dal	–	–	–
30		1.38	1.42	1.53
60		1.72	1.87	3.12
90		2.26	3.34	4.08
120		3.25	4.03	4.71
0	Wheat flour	–	–	–
14		0.16	1.63	1.92
21		0.57	1.96	2.55
28		1.46	2.52	4.18
35		1.63	3.08	4.92
49		1.96	3.37	6.03

All the observations in the entire experimentation infer that PLY (400 μ) is the best flexible film for packaging rice, dal and wheat flour in small quantities (2 to 5 kg). Moreover, rice whether it is MR, PAMR or PABR, can remain in the acceptable range to the consumers for 120 days. Dal stored in PLY was suitable up to 85 days, provided the initial moisture was safe to begin with and no initial infestation was there whereas wheat flour (initial MC = 12%) could be stored safely for a

maximum of 5 weeks only. JUB was a useless package for storing any of the food commodities. PIB, however, was suitable enough for storage of rice for 90 days, dal for 60 days and wheat flour for 28 days.

REFERENCES

Anandaswamy, B., Iyengar, N.V.R. 1980. Food Packaging Research Development in India. J. Food Sci. Technol., Vol. 17, No. 1 and 2, 1980, pp 59-65.

AOAC, 1970. Determination of moisture content (ed. William Horowitz). AOAC, Washington D.C., p 211.

Balasubrahmanyam, N., Abraham, K.O., Raghavan, B., Shankaranarayana, M.L. and Natarajan, C.P. Asafetida VI. Packaging and storage studies on asafetida products. Indian Food Packer, vol. 33, No. 3, 1979, pp 15-22.

Balasubrahmanyam, N., Anandaswamy, B. Packaging requirements for fried potato chips. Indian Food Packer, vol. 33, No. 3, 1979, pp 3-7.

Christopher, F.M., Vanderzant, C., Carpenter, Z.L. and Smith, G.C. Microbiology of pork packaged in various gas atmospheres. J. Food. Sci. 34, 1969, pp 426-429.

Gowramma, R.V., Mahadevaiah, M., Naresh, R; Dwarakanath, C.T. and Anandaswamy, B. Preliminary studies on suitability of flexible packaging materials for packing processed food products. Indian Food Packer, vol. XXXV, No. 2, 1981, pp 55-61.

Indian Standard Institution. Indian standard method of test for dairy industry – Part III, Bacteriological analysis of milk, IS: 1479 (Part III), 1962, pp 10.

Kaffezakis, J.G., Palmer, S.J. and Kramer, A. Microbiology of fresh apple and potato plugs preserved by gas exchange. J. Food Sci. 34, 1969, pp 426-429.

Kantter, D.A., Lynt, R.K., Lilly, T., Solomon, J.R. and H.M. Evaluation of the Botalism Hazard from nitrogen packed sandwitches. J. Food Protection, 44, 1981, pp. 1-84.

Kumar, K.R., Mahadevaiah, B. and Anandaswamy, B. Physico-chemical properties of some flexible packaging materials used in food packaging. Indian Food Packer, vol. XXX, No. 1, 1976, pp. 34-39.

Kumar, K.R., Balasubrahmanyan, N. Package profile for biscuits. Indian Miller, vol. IX, 1978.

Mahadevaih, B., Chang, K.S. and Balasubrahmanyam, N. Packaging and storage studies on dried ground and whole chillies *(capsicum annum)* in flexible consumer packages. Indian Food Packer, vol. XXX, No. 6, 1976, pp. 33-40.

Mahadevaiah, B., Kumar, K.R. and Balasubrahmanyam, N. Packaging and studies on pulses and cereal flours in flexible films. INdian Food Packer, 1977, pp. 1-7.

Mitsuda, M.F. Kawai and Yamamoto, A. Hermetic storage of cereal and legumes under the water and ground. Memoirs of the college of Agriculture. Kyoto Univ., No. 100, Nov., 1971, pp. 49-69.

Ory, R.L., Delucca II, A.J., Angelo, St. and Dupuy, H.P. Storage quiality of brown rice as affected by packaging with and without carbon-dioxide. J. Food Prot., 43, 1980, pp. 929-932.

Scideman, S.C., Carpenter, Z.J., Smith, G.C., Dill, C.W., and Vanderzant, C. Physical and sensory characteristics of pork packed in various gas atmosphere. J. Food Prot., 42, 1979, pp. 317-322.

Scideman, S.C., Vanderzant, C., Smith, G.C., Dill, C.W. and Carpenter, Z.L. Appearance of beef, pork and lamb stored in vacuum or modified gas atmosphere. J. Food Prot., 43, 1980,

■■

Combustion Process of Rice Husk for Amorphous Silica Production

by
H.D. Banerjee
Assistant Professor
Materials Science Centre
Indian Institute of Technology
Kharagpur, India

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

A.K. Mahapatra
P.H.T.C., I.I.T.
Kharagpur, India

P. Nishra
Research Scholer
P.H.T.C., I.I.T.
Kharagpur, India

Introduction

In India most of the modern rice mills are facing a problem of rice husk disposal. The rice mills with a parboiling unit are using this by-product partly as fuel but for rice mills located in such areas where raw rice milling is common, there is no way to utilize rise husk and, consequently, its disposal becomes a problem.

On the other hand extensive efforts are being devoted for the development of a high volume, low cost technology for manufacturing solar grade silicon materials.

Rice husk is a potential source of pure amorphous silica which has been shown to be an attractive source for manufacturing silicon material of reasonable purity (purer than 99.99%) (1-3).

Keeping the above points in view, the present study was undertaken with the following major objectives: 1 – To study the effects of various physical and chemical treatments of rice husk on the combustion process to produce white ash for commercial application; 2 – X-ray diffractometry and scanning electron microscopic studies of pure amorphous silica produced by burning rice husk subjected to various chemical treatments under different burning conditions.

Materials and Methods

Characterization of White Ash

The physico-chemical and structural nature of white ash obtained by burning rice husk, subjected to various physical and chemical treatments, has been studied by using X-ray diffraction, thermogravimetric and scanning electron microscopic techniques. The rice husk was obtained from Suprya variety of paddy.

The thermogravimetric analysis (TGA) of rice husk was carried out using a thermogravimetric balance made in the Fertilizer Coorporation of India. Various rice husk samples, unground and ground to fine particles (60 mesh) were digested with HCl at different concentrations and subjected to thermogravimetric analysis.

Apparatus and Experimental Procedure

Various samples of rice husk were taken in a small platinum crucible (10 cc) and loosely packed to allowing complete combustion of the husk to take place. The crucible was suspended freely inside a tubular furnace with the help of a very thin platinum wire below a sensitive chemical balance.

The sample inside the furnace was heated at a constant rate of heating (2°C/min) by controlling the input power with the help of a variac. During the entire heating operation the weight loss of the sample was determined by taking successive readings of the weight of the material at various time intervals. Simultaneously, the temperatures of the sample were recorded with the help of a Chromel-Alumel thermocouple in conjunction with a D.C. microvoltmeter.

To ensure complete combustion of the husk and to produce white ash the material was kept at maximum firing temperature further for about 18 h and then the furnace was put off.

An X-ray analysis of the burnt husk was carried out to determine structure of the rice husk ash. Diffraction strip-chart records were taken with a continuous strip-chart recorder for determining the 'd' values. The samples were rotated at a speed of 2°/min. Nickel filtered MOKα radiation was obtained from a general purpose X-ray diffractometer (Type POH-1, operated at 30 KV, 10mA), for all the above experiments.

Scanning Electron Microscopy (SEM)

The SEM studies of the different ash samples were conducted using a ISI 60 SEM apparatus (Magnification 480).

Results and Discussion

The thermogravimetric analysis of various samples under investigation have been carried out for different physical and chemical treatments. The overall nature of the TGA records indicate that the decrease in weight with the rise of temperature takes place in a number of stages: i) removal of moisture ii) removal of volatile matters; and iii) oxidation/removal of carbon.

As indicated in **Figs. 1 and 2** the TGA records of unground husk consists of three distinct stages whereas for ground husk there are five distinct stages. The average temperature region (25-150°C) and the time needed for drying operation in both cases are almost identical, hence the drying operation is essentially independent of the particle size of the husk. The second stage in weight loss in both cases is the intermediate stage, region of inappreciable weight loss. The sublimation of volatile matters, however, took place in the third stage as indicated in **Figs. 1 and 2.** The essential difference in the third stages of these two cases is that the rate of sublimation of the volatile matters was comparatively faster and distinct when husk of smaller particle size is taken. This shows that the reduction in the particle size of the husk is obviously more helpful in augmenting the rate of sublimation of the volatile matters. It is also clear from **Fig. 2** that within the temperature range 30-475°C there are two additional stages as indicated by IV and V. Apparently, stage IV is another intermediate stage of inappreciable weight loss whereas stage V is mainly due to removal of carbon arising out of its oxidation. Furthermore, it has also been observed that for husk of smaller particle size (60 mesh) the removal of carbon took place at a lower temperature (**Fig. 2**) as compared to that for unground husk. Eventually, in the above two cases, the total time taken for the combustion are 5 h-5 min and 5 h-10 min respectively.

The TGA analysis of the various acid leached samples were recorded to examine the effect of different chemical treatments on the burning characteristics of husks treated with HCl of different concentrations and digested them at an elevated temperature between 50 and 80°C for about 1 h. Moreover, the effects of the chemical treatment were also studied with unground and ground husk for understanding the combined effect of particle size and chemical treatment on the combustion characteristics. In the present study three different concentrations of HCl were taken namely 1N, 5N and 11.3N.

Ground rice husk, chemically treated with 1(N) HCl exhibits different TGA characteristics compared to that of untreated husk. There exists an intermediate decay stage between drying and escape of volatile matters which exhibits a sharp fall in weight immediately after the completion of drying. Afterwards a region of inappreciable weight loss occurred. However, this two-stage intermediate region is not very prominent when acids of higher concentrations were

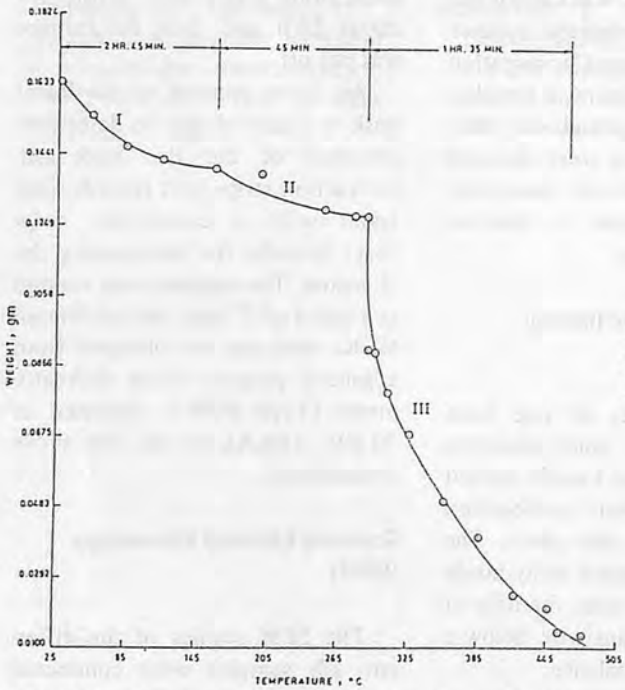


Fig. 1 Thermogravimetric analysis (TGA) of rice husk. Heating rate 2°C/min.

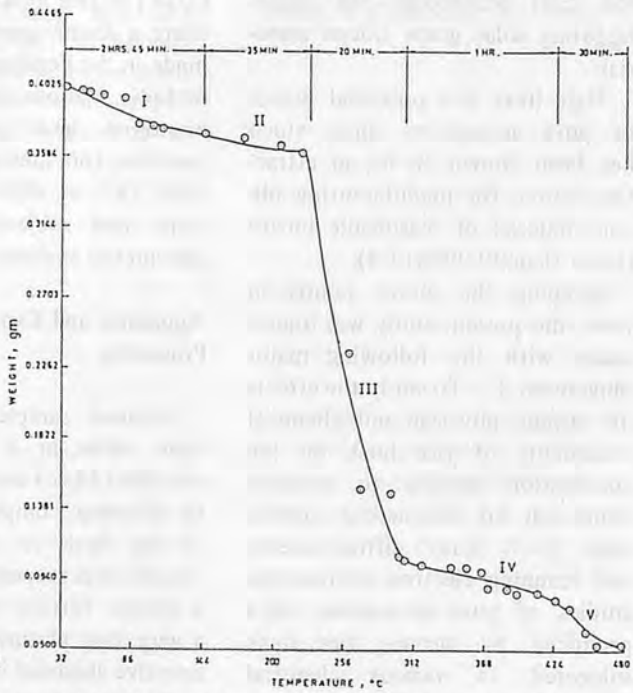


Fig. 2 TGA of ground rice husk (60 mesh). Heating rate 2°C/min.

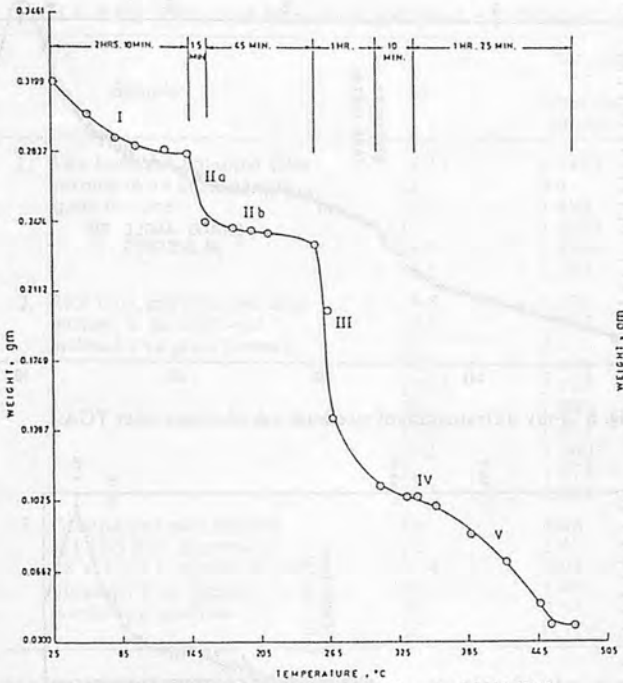


Fig. 3 TGA of ground (60 mesh) and acid leached (1N HCl digested at 50°C for 1h) rice husks. The material was heated upto 475°C for about 5-3/4 at the rate of 2°C/min.

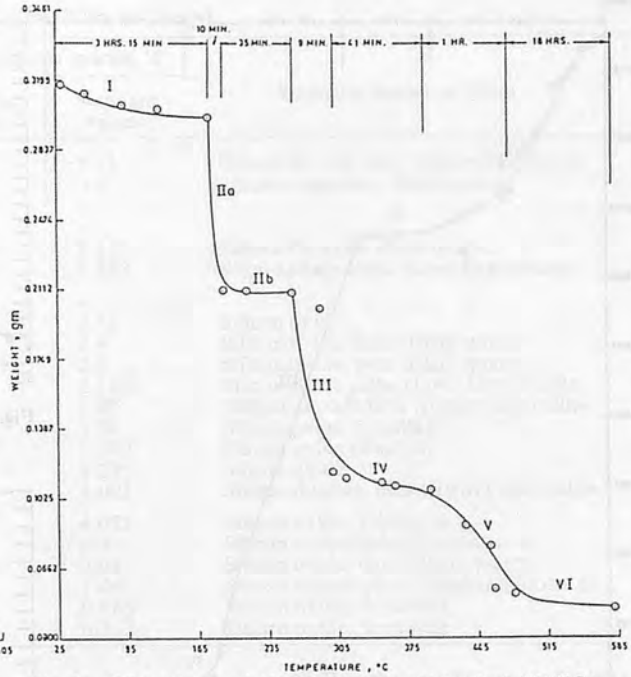


Fig. 3a TGA of ground (60 mesh) and acid leached (IN HCl digested at 50°C for 1 h) rice husks. The material was heated upto 480°C for 503/4 h at the rate of 2°C/min and then kept at 580°C for about 18 h.

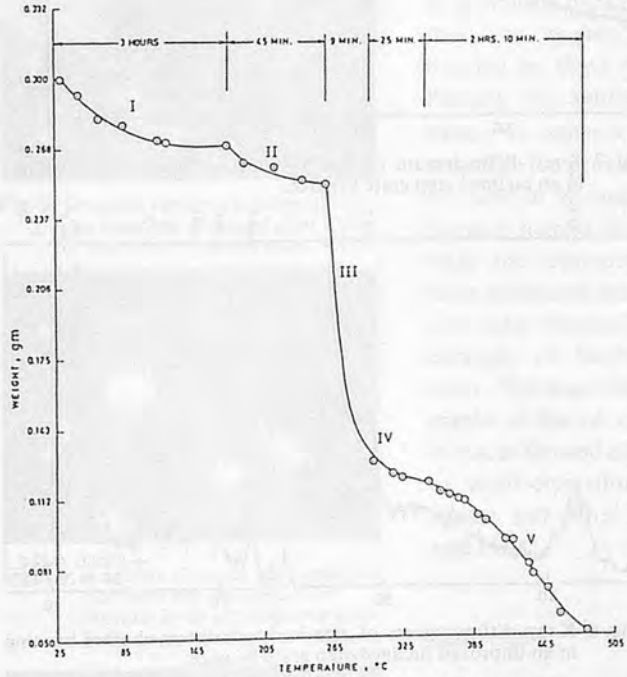


Fig. 4 TGA of ground (60 mesh) and acid leached (5H HCl digested at 98°C for 1 h) rice husk. The material was heated upto about 475°C for 6.5 h at the rate of 2°C/min.

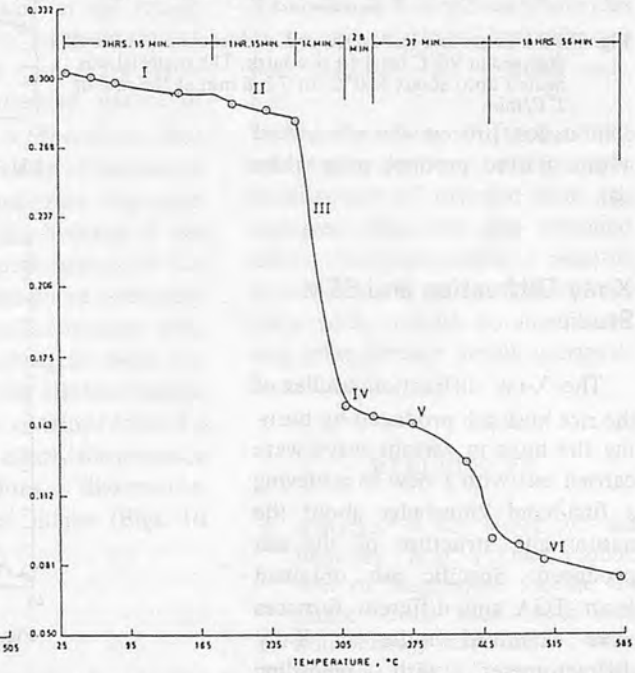


Fig. 4a TGA of ground (60 mesh) and acid leached (5H HCl digested at 98°C for 1 h) rice husk. The material was heated upto 460°C for about 5 h 50 min at the rate of 2°C/min and then kept at about 580°C for 18 h 56 min.

used for purification as shown in Figs. 3-5. The major part of the weight loss that took place as a result of the escape of volatile matters from the husk is indicated in Figs. 3-5. It also appears from these figures that irrespective of all physical and chemical treatments of the husk the removal of volatile matters was completed at around 300°C.

The subsequent stages of combustion were due to removal of carbon in the husk by oxidation. The major amount of carbon loss during combustion (in oxidation) took place in the temperature range of 350 to 450°C. The last trace of carbon was removed at a very slow rate at temperatures between 450 to 590°C for a long time (around 18 h) for the production of white ash. But this prolonged heating of the material was not necessary in the case of the husk leached with 11.3(N) HCl (concentrated). It is interesting to note that the whole

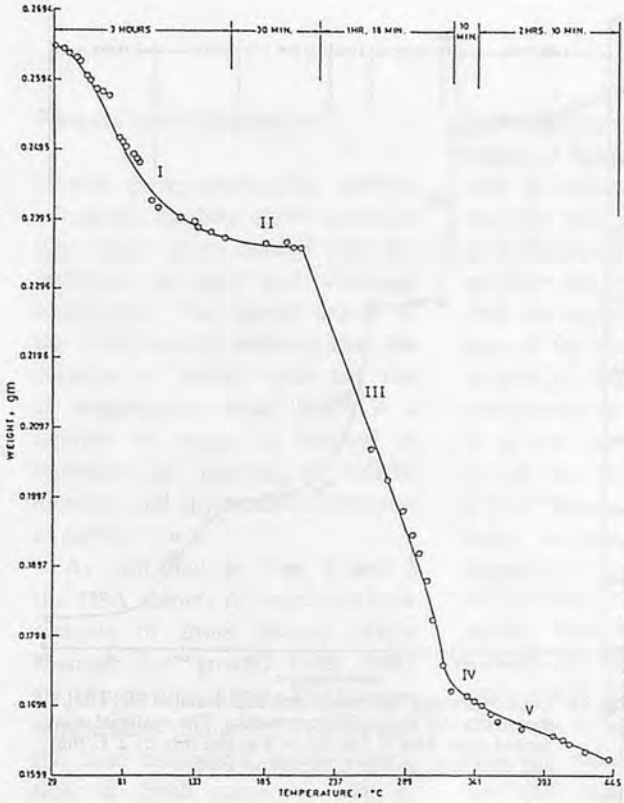


Fig. 5 TGA of ground (60 mesh) and acid leached (11.3N HCl digested at 98°C for 1 h) rice husk. The material was heated upto about 450°C for 7 h 8 min at the rate of 2°C/min.

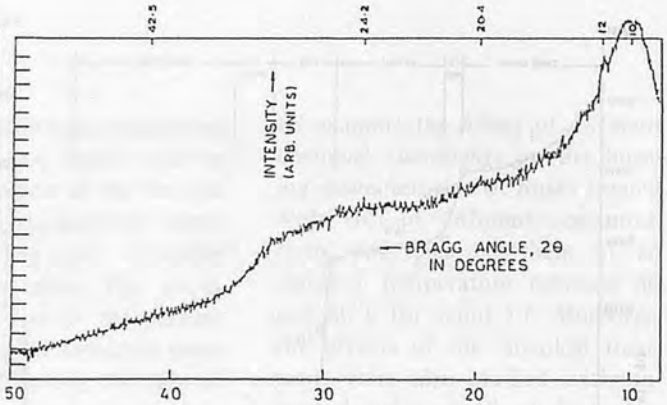


Fig. 6 X-ray diffratogram of rice husk ash obtained after TGA.

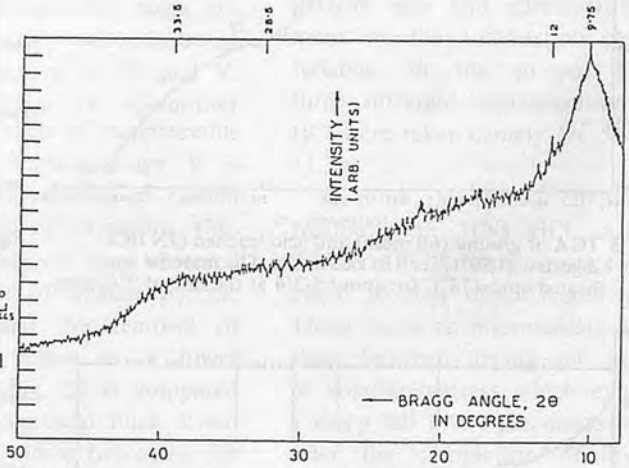


Fig. 7 X-ray diffractogram of rice husk ash obtained after burning in an inclined step grate furnace.

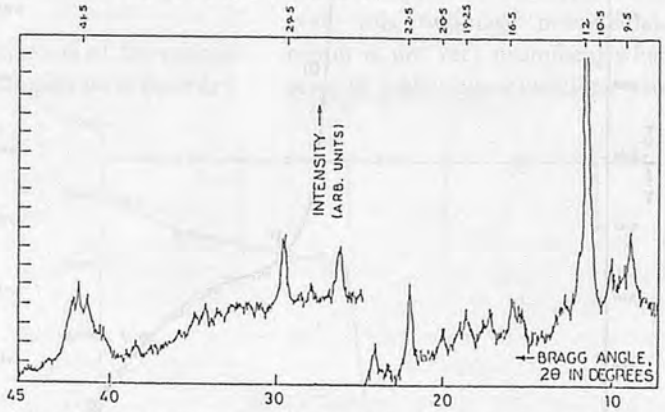


Fig. 8 X-ray diffractogram of rice husk ash obtained after burning in an improved inclined-step grate furnace.

combustion process was completed within 8 h to produce pure white ash.

X-ray Diffraction and SEM Studies

The X-ray diffraction studies of the rice husk ash produced by burning the husk in various ways were carried out with a view to achieving a first-hand knowledge about the nature and structure of the ash produced. Specific ash obtained from TGA and different furnaces were examined under an X-ray diffractometer with recording attachment and their X-ray diffractograms are shown in **Figs. 6-8**. The ash produced after thermogravimetric analysis clearly exhibits broad diffraction patterns indicating the amorphous nature of the white ash. On the other hand, presence of crystalline silica was white ash. on the other hand, 4.08 and 3.4, respectively. The different forms of amorphous and crystalline silica, obtained from a thermogravimetric set up, a step grate furnace (at about 800°C) and improved step grate furnace (at about 1 000°C) are shown in **Table 1**. The presence of some crystalline silica in the ash obtained after TGA may be due to prolonged heat treatment at a higher temperature of 480°C compared to the temperature required for production of amorphous silica at around 380°C (2). The presence of both amorphous and crystalline silica is also shown by the SEM picture of the ash (**Fig. 9**).

The X-ray diffraction and SEM studies of the rice husk ash produced after burning the husk at a still higher temperature (above 800°C) in an inclined step grate as well as in an improved step grate furnace (about 1 000°C) showed no such amorphous nature of the silica, on the contrary they exhibit-

Table 1 X-ray Diffraction Data of the Rice Husk Ash Obtained from Different Sources

Sample	2θ	Interplanner spacing 'd' Observed values	Standard values	Structural nature of Silica
1. Rice husk ash obtained after burning in an inclined step grade furnace	9.75	4.1499	4.15	Silicon dioxide beta (High) Criotobalite
	12	3.4	3.4	Silicon oxide beta (High) quartz
	19.5	3.494	–	–
	27	1.5218	–	–
	28.5	1.4358	1.453	Silicon IV oxide alpha quartz
	33.5	1.233	1.233	Silicon oxide alpha (Low) Criotobalite
2. Rice husk ash obtained after burning in an improved inclined step grate furnace	9.5	4.291	–	
	10.5	3.885	3.72	Silicon oxide
	12	3.4	3.4	Silicon oxide, beta (High) quartz
	16.5	2.479	2.5	Silicon oxide, beta (High) quartz
	19.25	2.122	2.118	Silicon oxide alpha (Low) Criotobalite
	20.5	1.988	1.99	Silicon dioxide beta (High) Criotobalite
	22.5	1.821	1.84	Silicon oxide (Coesite)
	26.5	1.5609	1.562	Silicon oxide (Keatite)
	29.5	1.374	1.275	Silicon oxide
	41.5	1.001	1.001	Silicon dioxide, beta (High) Criotobalite
3. Ground and acid leached (11.3N) HC1 digested at 98°C for 1 h) rice husk ash obtained after thermo-gravimetric analysis	10	4.08	4.075	Silicon oxide, Tridymite
	12	3.4	3.4	Silicon oxide, beta (High) quartz
	20.4	2.01	2.01	Silicon oxide, beta (High) quartz
	28.2	1.46	1.46	Silicon dioxide, beta (High) Criotobalite
	42.5	0.98	0.985	Silicon oxide, Stishovite
	55	0.77	0.792	Silicon oxide, Stishovite

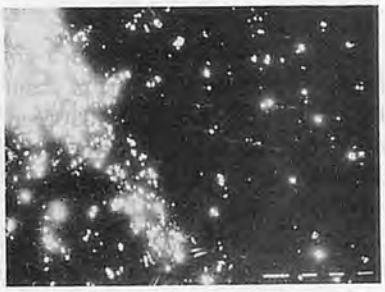


Fig. 9 Scanning electron micrograph of rice husk ash obtained after TGA of the husk (magnification: 480).

Fig. 10 Scanning electron micrograph of rice husk ash obtained after burning in an inclined-step grate furnace (magnification: 480).

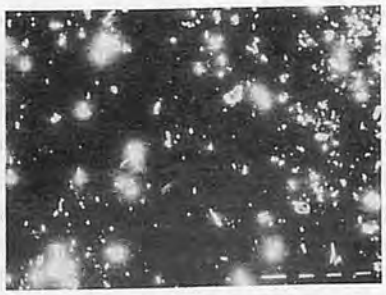


Fig. 11 Scanning electron micrograph of rice husk ash obtained after burning in an improved inclined-step grate furnace (magnfication: 480).

ed clearly the presence of crystalline silica in various phases and forms as shown in **Table 1**. This is obviously because of the reason that the higher temperature of burning in these cases have transformed the amorphous nature of silica. It appears, therefore, that although the provision of secondary air flow in an improved step grate furnace helped the burning of the husk the structural nature of the silica produced remained essentially the same because of its high temperature of burning in both the cases. The scanning electron micrographs of the ash obtained from the furnaces showed clearly the presence of small crystallites - like needle, square and other shapes **(Figs. 10 and 11)**.

Summary

Results of the studies of TGA, X-ray diffraction and SEM analysis of different rice husk ash are reported. The important conclusions drawn are as follows:

(1) The thermogravimetric analysis records of rice husk subjected to various physical and chemical treatments exhibit decay in different stages: drying, transition, removal of volatile matters and removal of carbon.

(2) For the production of white ash generally in the case of unground rice husk, prolonged heating for about 24 h is necessary whereas in the case of ground husk digested with 11.3(N) HCl it took only 8 h.

(3) The X-ray diffraction and scanning electron micro-scopic examination of the rice husk ash indicates that the ash obtained after thermogravimetric analysis produces more or less amorphous silica while the ash obtained from step grate furnace produces crystalline silica.

REFERENCES

1. Acharya, H.N.; Datta, S. and Banerjee, H.D. (1980) Production of Magnesium Silicide and Silane from Rice Husk Ash. Solar Energy Materials, 3 : 441.
2. Banerjee, H.D; Sen, S. and Acharya, H.N. (1982) Investigations on the production of silicon from rice husk by the magnesium method. Materials Science and Engineering. 52 : 173-179.
3. Benerjee, H.D.; Sen, S. and Acharya, H.N. (1980) Production of solar grade polysilicon by zinc reduction of silicon tetrachloride. Indian Journal of Technology. 18 : 84-85. ■■

Results of an Opinion Poll on Safety Features of Tractors in India

by
N.S. Sandhar
Assistant Engineer
Dept. of Farm Power and Machinery
Punjab Agricultural University
Ludhiana, India

J.P.S. Malhotra
Engineer Trainee
Danfoss (India) Ltd
New Delhi, India

Abstract

The study was undertaken with the objective of assessing the need for providing safety features on tractors used in India. The opinion of the individuals were recorded on each of the identified safety features. The study sample comprised of 46 persons from educational institutions, 25 from tractor manufacturers, dealers and suppliers and 35 tractor operators. The χ-square test was applied to the data and the safety features were classified into three distinct categories, namely; essential safety features with 100% positive opinion; features required but with 25% differences in opinion and the features with different opinion.

Introduction

The farm tractor is one of the basic sources of mechanical power performing agricultural operations. Tractor population is estimated about 500 000 in India. Tractor accidents do happen on farms and roads. Accidents result in fatality, serious injury, property damage, medical attention, time loss, hired help and permanent disability. Most accidents are due to the "Negligence of the operator, faulty repairs, improper construction, lack of safety provision, inadequate operator comfort, overturning on uneven field, sharp turns on roads and unshielded power take off shaft" (5, 7, 8. 9, 11).

In America the data for the tractor accidents on farms and roads show that approximately 60% of tractor fatalities are the result of overturning accidents and 25% while travelling on public roads (1). To reduce accidental deaths and provide comfort to the operator many safety features have been added to the tractor.

Accidents do happen on Indian farms and roads but neither statistics nor the accident analysis are available. Accident reports based on newspaper clippings indicate that they are due to overturning of tractor, trolley, collision between tractor and scooter, car, bus, trucks, etc, failure of brake and negligence of the operator (3).

Based on the accident data information a need was felt to study the opinion of persons concerned with safety in agriculture on safety features of the tractor.

Acknowledgement: The authors are grateful to Dr. R.K. Jindal, Assistant Statistician, Department of Farm Power and Machinery for helping in the data analysis.

Review of Literature

The National Safety Council (7) stated that tractor accidents claim the lives of an estimated 1000 persons annually in the United States. A rate of about 2.2 deaths per 10 000 tractors is indicated.

Schnieder (10) stated that the leading cause of accidents in the U.S. seemed to be improper operation of the tractor and equipment, which included excessive speed, chasing cattle, carelessness and loosing control of the tractor.

Knapp (5) reported that in a PTO study, 61% of the accidents investigated show that almost all shields in the tractor were missing. Power takeoff accidents are part of the tractor machine sub-system and thus indirectly related to tractor safety.

The important safety items of general interest include:

"The shielded power takeoff drive to implements, the hydraulic control for integral as well as for towed implements, three-point hitch system, electric starting, hydraulic power steering and brakes, roll over protective structure, slow moving vehicle (S.M.V.) emblem, training to the operator, quick coupler for the three-point hitch system, safety switch to prevent starting the engine while the tractor in gear, nonskid head for steps, foot pedals etc.,

proper hand holds for mounting, shields on the moving parts, hydraulic remote controls for towed implements, spark arresters for internal combustion engines and safety chains for towed vehicles (1, 2, 6)".

Material and Methods

The present study on safety features of tractor was divided into parts: i) selection of the safety features on tractors; and ii) opinion of various people on the safety features.

Selection of Safety Features

The safety features selected for the study were based on the literature available and personal experience. These are as follows:

Front side – Dipper; head light for field and highway; muffler provided; and shield for fan and alternator.

Middle side – Foot-operated accelerator (i); hand-operated accelerator (ii); and combination of (i) and (ii); hydraulic brakes and mechanical brakes; controls conveniently located; emergency brake; fenders (mud-guards); gear marking (1, 2, and R) below the gear shifting lever and for L and H gear; hand holds for mounting; hazard warning decals; horn; ignition key; and instrument panel. For the instrument panel, the following were taken into account: ammeter; charging circuit indicator; engine rpm. meter; hour meter; oil pressure gauge; PTO rpm meter; speedometer-cum-engine rpm; and temperature gauge. Other safety features considered were: neutral start switch with safety interlock to prevent starting while in gear; optimum visibility; panel light; posture designed seat with position control and shock absorbing; protective frame or protective enclosure; provision for self start; PTO engaged and disengaged lever position marking; roll over protective structure; seat belt; seat for the person other than driver; skid resistance platform steps and pedals; steering (hydraulic or mechanical); and turn signals and flashing amber lights for highway travel.

Rear side – The following features were considered: three point hitch system; latches on 3-point hitch system (secure or release implements); parking light; protective PTO shaft cap; PTO shield; red brake light; red tail lights and red reflectors; slow moving vehicle (S.M.V.) emblem; vital instruction plate; and work light.

Opinions Regarding Safety Features of Tractor

An assessment proforma for studying the opinion of various persons on the safety and operator comfort features of the tractor was prepared. These persons were classified into three professional categories, *viz*, educational institutions, 46; manufacturers, tractor dealers and suppliers 25; tractor drivers 35.

The proforma consisted of 38 safety features and a four-choice scales: strongly needed, needed, not needed and strongly not needed. The opinion of each individual on different safety features was sought through personal interview. Because of the ordinal nature of the data and the fact that the data did not meet the requirement for parametric statistics, the χ-square test was used. The level of significance was established at 1%.

Results and Discussion

The results of this study are discussed under three main headings, namely; essential safety features, safety features required but with 25% response difference and safety features with different opinion.

Essential Safety Features

For some of the safety features, the χ-square analysis did not apply because the observed frequencies were less than 5. As such it can be concluded that the safety features are red tail light and red reflector, fenders, skid resistant platform, head lights for field and highway, posture designed seat, provision for self start, control conveniently located, gear marking (1, 2 & R) below the gear shifting lever and for low and high gear, P.T.O. engaged and disengaged lever position marking, muffler, optimum visibility, instrument panel, ignition key, horn, panel light, three-point hitch system, brakes, and accelerator.

Required Safety Features with 25% Response Difference

For the safety features mentioned in **Table 1** on the basis of analysis, the calculated value of χ-square was less than the table value of 1% level of significance. The result is non-significant at the tested level of significance. It can be concluded that all those polled were for providing the safety features irrespective of their category.

From **Table 1**, it shows that the opinions of individuals on the safety features were similar irrespective of their category. However, the percentage of response by individual category differs to the extent of 25%. This variation may be due to cost factor, lack of knowledge and awareness regarding recent developments in the tractor industry. The priority sequence of the safety features in the table differs by category. This also may be due to the reasons mentioned above. All the manufacturers contacted for the study expressed that turn signals and flashing ember lights, vital instruction plate and neutral start switch must be provided on the tractor whereas the opinion of other two

Table 1 Relationship between Ratio of Response of Individual Category and Safety Features

(Unit: %)

Safety feature	Response of Individual Categories		
	Educational institution	Manufacturer/ dealer	Tractor driver
Hand holds for mounting	72	60	69
Turn signals & flashing ember lights	92	100	97
Dipper	85	76	86
Rear view mirror	80	64	89
Hazard warning decals	74	52	60
Vital instruction plate	94	100	95
Emergency brake	78	76	77
Neutral start switch which prevents while in gear	92	100	89
Parking light	70	64	80
Brake	70 M*	62 H*	69 M*
Steering	65 H*	64 H*	52 H*
Accelerator	61 C*	76 C*	60 C*

*: M, mechanical brake; H, hydraulic brake and steering; C, combination of hand-and foot-operated accelerator.

categories was less than 100%. All three categories preferred the accelerator (combination of hand and foot operated) and steering (hydraulic).

Safety Features with Different Opinions

On safety features mentioned in **Table 2**, the calculated value of χ-square exceeded the table value at 1% level of significance. The result is significant at 1% level which means that the response differs by category.

This means that the opinion of the individual category differs by safety features. Almost all the individuals in the educational institution prefered protective frame on the tractor whereas the tractor driver and manufacturer/tractor dealer did not feel its need strongly but were in favour of having protective P.T.O. shaft cap. Almost all the individuals belonging to the manufacturer/tractor dealer were not in favour of providing a seat belt.

Table 2 Relationship between Ratio of Response of Individual Category and Safety Features

(Unit: %)

Safety feature	Response of Individual Categories		
	Educational institution	Manufacturer/ dealer	Tractor driver
Protective frame or protective enclosure	95	60	59*
Roll over protective structure	82	56*	54
Work light	83	84	52*
S.M.V. emblem	52	64	78
Seat belt	51	88*	98*
PTO shield	56	68*	80*
Protective PTO shaft cap	51*	95	98
Shield for fan & alternator	70	80	60*
Seat for the person other than driver	67*	60*	72
Red brake light	70	60	60*
Equipped with latches	80	72	55*

* Not preferable.

Conclusions

1. Of the 38 safety features identified the most essential in view of all the individuals are red tail light and red reflector, fenders, skid resistant platform, lights for field and highway, posture designed seat with position control and shock absorbing, provision for self start, gear marking (1, 2 & R) below the gear shifting lever same for low and high gear, PTO engaged and disengaged lever position marking, muffler provided, optimum visibility, instrument panel, ignition key, horn, panel light, and three-point hitch system, brakes, accelerator (C) steering (H).

2. All the individuals desired the provision of the following safety features even as responses differed by 25%: hand holds for mounting, turn signals, flashing ember lights, dipper, rear view mirror, hazard warning decals, vital instruction plate, emergency brake, neutral start switch with safety interlock to prevent starting while in gear and parking light.

3. The opinions of three categories of individuals varied widely on: protective frame or protective enclosure, roll over protective structure, work light, S.M.V. emblem, seat belt, PTO shield, protective PTO shaft, cap, shield for fan and alternative, seat for the person other than driver, red brake light, and latches on 3-point hitch system.

REFERENCES

1. Department of Transportation, Proceedings of the Public Meeting on Agricultural Tractor Safety, National Highway Safety Bureau, Washington, D.C.
2. Hanson, Merlin Engineering Consultant. The Evaluation of Tractor Design and Safety Features on Farm Tractors.

(Continued on page 78)

Status of Agricultural Manchinery Manufacturing in Sind, Pakistan

by
Muhammad Saleh Soomro
Associate Professor
Dept. of Agro-Polytechnic
Sind Agriculture University
Tandojam, Pakistan

Sheruddin B. Bukhari
Associate professor
Dept. of Farm Power and Machinery
Sind Agriculture University
Tandojam, Pakistan

Abstract

Survey of various districts of the Province of Sind, Pakistan was carried out to investigate the facilities, manufacturing capacities and capabilities of farm machinery manufacturing workshops and factories.

The major constraints in the promotion of local manufacture as observed, included the shortage of labour, specially skilled labour due to its drain to Middle Eastern countries, insufficient credit facilities for manufacturing processes, insignificant use of public media for creating awareness among the farmers for using various farm machines, consequently less demand of most useful farm machines for specific job requirements, and liberal import of foreign-made machines are the main affecting factors in this industry. Suggestions in this context are made to improve local manufacture of farm machines.

Introduction

Pakistan's economy is agro-based, where more than 70% of the population is supported directly or indirectly through agriculture and 80% of foreign exchange earnings are contributed through the export of primary and finished agricultural products. Of the 20 million ha of cultivated area, provinces of Punjab, Sind, N.W.F.P and Balochistan have 11.35, 5.48, 1.90 and 1.39 million ha respectively.

The present population growth rate of the country invites special attention for boosting agricultural production to feed the expected increase in population. Current irrigation resources do not permit to bring more land under cultivation, hence the probable solution to increase agricultural production lies in better crop husbandry and by increasing cropping intensities through timely farming operations. This could only be achieved through mechanized farming. A limited time span left between two crop seasons (*rabi* and *kharif*) has compelled the farmers to use agricultural machines so as to get two or more crops a year. Mechanization is progressively introduced into the country and the farmers are getting well acquainted with the benefits of mechanization. As a result most farmers are investing their capital in buying tractors and other farm machines to increase the cropping intensity of their lands.

Up to the early 1960s, tractors and other farm machines were imported, but later local manufacturers started manufacturing these machines. Today most of the farm machines are manufactured locally to meet the demand of the farmers although the farmers still prefer imported machines.

A great deal of the country's foreign exchange earnings could be saved through local manufacture of farm machines if the resources permit. Moreover, it also creates technical know how among the people and sufficient job opportunities for local skilled and unskilled labour. In addition, the locally manufactured machines could be modified according to agro-ecological needs of various regions of the country and maintenance costs of machines could be reduced and life enhanced if the spares and after-sale services are available locally.

According to FAO estimates, the minimum horsepower required per acre for a developing country to acquire self reliance in food is

0.2 hp. The current available power on farms is 0.142 hp per acre of which tractors contribute 0.056 and human and animals provide 0.016 and .07 hp per acre, respectively. It is estimated that assuming human and animal power remain the same, about 25000 tractors are to be imported annually for a six-year period to reach the minimum power requirement of 0.2 hp per acre (1). Presently about 16000 to 20000 tractors are imported every year; one can hopefully estimate to reach the required horsepower target in the late 1980s.

It was necessary to locate and interview the manufacturers in Sind in order to study the facilities available, particularly the basic production capacity and capability of these manufacturing plants so as to suggest measures to promote local manufacture of farm machines.

Materials and Method

A questionnaire was prepared for the survey. A survey team travelled to each district of the province, located the manufacturers and interviewed them. The data so collected was tabulated. Some manufacturers responded very well while others were reluctant to give information.

Results and Discussion

Eighty five manufacturers (all in the private sector) were interviewed: those manufacturing firms which are owned and financed by the owner himself; and those firms where the capital investment is shared by two or more partners.

Labour Situation

Averagely each manufacturer employed 6 workers (except 11 in Sukkur) including both skilled and unskilled. Due to the seasonal demand of the farm machines, most manufacturers employ casual labour in peak season.

Basic Facilities

As regards the basic facilities the data in **Table 1** shows that only 2 manufacturers out of 85 have their own foundries and only 1 out of 85 has the forging facility. Seventy of them have their own lathe. Only one manufacturer has the milling machine and 77 manufacturers have drilling facility. Eight manufacturers have shapers and 55 have grinding facilities. As regards welding, almost all of them had arc welding facilities, however, only 20 of them have gas welding plants. Fifteen manufacturers have the heat treatment facility. Seventy of them have their own lathe. Only one manufacturer has the milling machine and 77 manufacturers have drilling facility. Eight manufacturers have shapers and 55 have grinding facilities. As regards welding, almost all of them had arc welding facilities, however, only 20 of them have gas welding plants. Fifteen manufacturers have the heat treatment facility. Seventy seven percent of the total manu-

Table 1 Number of Manufacturers in Districts by Ownership, Labour force, Basic Force, Basic facilities and Production Technology

Districts	Karachi	Thatta	Hyderabad	Badin	Tharparkar	Sanghar	Nawabshah	Khairpur	Sukkur	Shikarpur	Jacobabad	Larkana	Dadu
Ownership:													
Individual Firms	1	–	7	6	5	7	5	7	6	3	1	6	4
Partnership Firms	–	–	6	–	1	–	11	3	1	–	1	3	1
Labour:													
Skilled	3	–	39	34	–	4	50	28	54	12	6	–	5
Unskilled	2	–	35	2	48	27	46	29	23	9	6	64	29
Basic facilities:													
Foundry	–	–	1	–	–	–	–	–	1	–	–	–	–
Forging	–	–	–	–	–	–	1	–	–	–	–	–	–
Lathe	–	–	13	4	5	4	16	8	7	1	5	2	3
Milling	–	–	–	–	–	–	–	–	–	–	–	1	–
Drilling	1	–	13	4	5	6	16	10	7	3	3	4	5
Shaper	–	–	2	–	–	–	1	–	4	–	–	1	–
Grinding	1	–	12	3	4	6	6	3	7	1	3	4	5
Arc welder	1	–	13	6	6	7	16	10	6	3	2	9	5
Gas welder	1	–	1	2	–	–	–	3	6	–	–	2	5
Heat treatment	–	–	3	–	–	6	–	–	5	–	–	–	1
Assembly	1	–	12	6	6	7	–	10	5	2	2	9	5
Painting	1	–	12	5	6	7	16	1	7	3	2	9	5
Prod. Tech.:													
Design & drawing													
Laboratory	–	–	–	–	–	–	–	–	–	–	–	–	1
Testing facility	–	–	–	–	–	–	–	–	1	–	–	–	1
Quality control	1	–	13	6	–	7	16	10	6	1	–	–	–

Raw material procurement: Almost all manufacturers use local raw material including iron, steel, bearings, bushings, nuts, bolts, springs, tyres, paints, etc.. However on the request of the customer, they use imported tyres, springs and bearings. Discs for disc tools are all imported.

facturers assemble their products in their workshops and 74 manufacturers have the painting facility.

Raw Materials

Almost all the manufacturers use local raw materials. However some manufacturers use imported material on consumers demand. Only the discs of the disc plows and disc harrows are not manufactured locally.

The production technology includes the design and drawing laboratory, the implement testing facility and the quality control. It is observed that only one manufacturer has the design and drawing laboratory and two have the testing facility. As regards the quality control, 59 manufacturers have reported that their engineers and worker's workmanship is so reliable that they guarantee the quality of the product. However the quality control by the government is not yet institutionalized.

Machines Manufactured

Study of the master Table 2 reveals that majority of the manufacturers manufacture primary and secondry tillage implements. Mouldboard plow is manufactured by 11 firms. Cultivator, the most popular tillage tool in the province, is manufactured by 59 manufacturers. Trailers for transport are manufactured almost in every district by 67 manufacturers. Almost every tractor owner owns a trailor for nis personal use or for hire purposes.

Front or rear-mounted trailer blades are widely used for land levelling and reclamation work. The demand of the tractor blades is so high that 63 manufacturers are making blades. Disc harrows are manufactured by 47 manufacturers of the districts having light to loamy soils.

Five-bottom and seven-bottom modified mouldboard plow is also popular tillage tool and 20 manufacturers are making this implement.

Wheat threshers are manufactured by large manufacturing firms in the Punjab province. Due to its complex design and high skill needed in its manufacture, only 16 manufacturers make threshers. However, the farmers are mostly using threshers manufactured in Punjab.

It was observed that most of the manufacturers offered free after sales service upto a period ranging from 6 to 12 months and they also provide the facility for repair of the agricultural machines on the farms if they are called upon. However they charge the wages of the worker and mechanic and the spares. It is a common practice that the farmers bring their machines in nearby towns or cities for repair works as the charges on farm service are quite high as compared to the charges at the workshop.

About 85% of manufacturers have pointed out that the bank loans are provided at a very high interest rate and 84% manufacturers have complained that the total cost of the machines or finished products increases due to the taxes on the raw materials. Sales tax, municipality tax and professional tax also increase the cost of machines as pointed out by these manufacturers.

Table 2 Number of Manufacturers in Districts by Product

Districts	Karachi	Thatta	Hyderabad	Badin	Tharparkar	Sanghar	Nawabshah	Khairpur	Sukkur	Shikarpur	Jacobabad	Larkana	Dadu
Total	1	–	13	6	6	7	16	10	7	3	2	9	5
Moldboard plow	1	–	2	–	–	3	–	–	1	–	–	1	1
Panj hari & sat hari	–	–	–	–	–	–	3	6	4	1	–	6	–
Disc plow	–	–	5	–	–	5	2	–	4	–	–	–	2
Cultivator	1	–	10	1	–	7	10	9	6	2	–	8	5
Disc harrow	1	–	11	3	5	7	14	–	1	–	–	1	4
Rotary cultivator	–	–	1	–	–	–	–	–	–	–	–	–	–
Roller	–	–	–	–	–	–	–	–	–	–	–	–	1
Tractor blade	1	–	13	1	1	7	15	5	7	1	–	7	5
Leveller	1	–	2	1	–	–	–	1	5	–	–	3	1
Scraper	1	–	4	–	–	1	–	–	3	–	–	–	1
Ditcher	1	–	3	–	–	1	–	–	4	–	–	–	–
Dyke maker	–	–	3	–	–	–	–	–	–	–	–	–	1
Ridger	1	–	6	–	–	1	–	–	1	–	–	–	1
Seed drill	–	–	–	–	–	–	–	–	–	–	–	–	1
Fertilizer distributor	1	–	–	–	–	–	–	–	–	–	–	–	–
Thresher	1	–	2	–	1	6	4	–	–	–	–	1	1
Stalk cutter	–	–	1	–	–	–	–	–	–	–	–	–	–
Trailer	1	–	12	3	4	7	8	8	5	3	2	9	5

Remark: Most manufacturers manufacture these machines on demand. Their production capacity varied from time to time. It was observed that could easily increase their production if the demand from farmers increases for various farm machines. Many of them had plans to increase their production due to high demand of farm machines.

Suggestions

1. Foundry, forging and heat treatment facilities be provided by the government at least in major cities of the province, as the individual manufacturers cannot afford to have such facilities in a small scale manufacturing plant.
2. Agricultural Standard Institute be established and every farm machine before entering in production line be carefully tested, approved by the institute and should bear the seal of the institute to guarantee its standard. This will discourage the sale of substandard machines to poor farmers for the savings of just few rupees.
3. A government quality control cell should have strict watch and ward over the quality of the goods manufactured. Frequent visits of the authorized persons of the cell would greatly help to maintain the standard of the quality approved by the standards institute.
4. Some government agency be made responsible for the supply of raw materials and machine components throughout the calendar at controlled rates. These depots should be located in every district headquarter or at least divisional headquarters.
5. Public machine shows be organized at some convenient places in every province to display locally-manufactured machines to develop competition among manufacturers. Good quality manufacturers be awarded prizes or letters of appreciation by the government in these shows.
6. The import of those farm machines be completely banned which are locally manufactured in abundance.
7. More training institutes which impart technical training be established at convenient places of the province to meet the skilled labour requirements of this industry.

REFERENCES

1. Khokhar, A.H.; Ziaur-Rahman and Khan, A.S. 1982. Country Report of Pakistan "A report submitted in the Regional Workshop for Agricultural Machinery Manufacturers' Association" under RNAM.
2. Phatak, S. "Country Report of India 1982" A report submitted in the Regional Workshop for Agricultural Machinery Manufacturer's Association under RNAM".
3. Sakai, J. 1980. Research and development process of designing agricultural machinery: "Tractors" as example. A.M.A. Japan, 11(1): 19-25. ■■

(Continued from page 74.)

Results of an Opinion Poll on Safety Features of Tractors in India

3. "Indian Express" and "The Tribune" Indian Newspapers, 1983.
4. Kansas State Department of Health, Agricultural Accidents Death Report, Kansas, 1969, Kansas State Department of Health, Division of Registration and Health, Topeka, Kansas 66612.
5. Knapp, L.W., Piercy, L.R., An Epidemiological Study of Power Take Off Accidents, Institute of Agricultural Medicine, College of Medicine, The University of Iowa.
6. Leinbach, Samuel. Rural Safety as Seen by a Practicing Physician. Proceedings of the National Rural Safety Conference Held in Chicago, Illinois, April 5-6, 1963.
7. Farm Resident Accidents, 1965. 425 North Michigan Avenue, Chicago, U.S.A.
8. Phister, R.G. Fatal Farm Accidents, Michigan State University, File No. 18: 48, Information Series 228, East Lansing, Michigan.
9. Stuckey, W.E. An Analysis of Ohio Farm Tractor Fatal Accidents, 1956-69, Cooperative Extension Service, The Ohio State University, Columbus, Ohio 43210.
10. Schnieder, R.D. An Abstract of a Study Entitled Frequency and Type of Tractor Overturn on Nebraska Highways and Farm, 1966-68. National Institute of Farm Safety, June 17-20, 1969, West Lafayette, Indiana.
11. Wardle, N.J. Fatal Accidents of Iowa farm people 1947-19674, AE-1010, Cooperative Exten- Study of Tractor Overturning versity, Ames, Iowa.
12. Willsey, F.R., Liljedahl, J.B. A study of Tractor Overturning Accidents, Agricultural Engg. Department, Purdeu University, Lafayette, Indiana 47907. ■■

Need for Smallholding Mechanization in Pakistan

by
A.Q.A. Mughal
Faculty of Agricultural Engineering
Sind Agriculture University
Tandojam, Pakistan

Introduction

In recent years increasing attention has been given to improving small farms in most of the developing countries. This has stemmed from the realization that past development strategies have failed to benefit the smallholder. It has been already recognized at the international level that without improving the economic condition of the small farmer (depending on definition of small farmer) no country can make real progress in the agriculture sector (Ali, 1978; IFAD, 1979).

Pakistan is a land of small farms and a number of programs for developing these farm sectors were conceived and implemented in the past, but for one reason or the other these did not have much impact on improving smallholder productivity (Muhammad, 1978).

Thus, it is important and urgent to analyse the factors responsible for this relative ineffectiveness of the development programs. In the present paper, therefore, an attempt has been made to analyse the various mechanization programs implemented in Pakistan.

Distribution of Farms

The distribution of farm sizes in Pakistan is presented in **Table 1** which indicates that 68% of the farms are below the 5 ha size (average farm size of 2.35 ha) and 21% of farms are in the size group of 5-10 ha (average farm size of 6.66 ha). These are defined as subsistence holdings and small holdings, respectively*. Farms below 5 ha comprise 30% of the total and farms 5-10 ha in size occupy 27% farm area. On the other hand, 8% of the farms are between 10-20 ha and 3% above 20 ha comprising an area of 19 and 24%, respectively.

Table 1 Number and Area of Farms Classified according to Farm Size

Farm Size (ha)	Absolute Value		Percentage		Average farm size (ha)
	Farms (000)	Farm Area (000 ha)	Farms	Farm Area	
Up to 3	1 639.0	2 426	44	12	1.5
3 to 5	920.8	3 607	24	18	3.9
5 to 10	793.9	5 286	21	27	6.7
10 to 20	289.2	3 731	8	19	12.9
20 to 60	102.6	2 997	3	15	29.2
Above 60	16.2	1 815	< 0.5	9	112.0
Total	3 761.1	19 862	100	100	5.3

Source: Pakistan Census of Agriculture 1972.

Past experience illustrates that there has been a continuous decrease in farm numbers in Pakistan. The total number of farms in Pakistan was 4 895 983 in 1960 which declined to 3 761 688 in 1972, *i e*, about 22.6% decline. Another overriding feature is that the farms of smaller size (subsistence farms) up to 3 ha decreased while the farms having more than 3 ha experienced an increase in numbers. For example, farms less than 0.4 ha declined from 742 216 in 1960 to 156 462 in 1972, *i e*, about 79%. Small farms up to 2 ha constituted 49% of the total number of farms in 1960, while they constituted 28% in 1972. The proportion of farms in the range of 2 to 10 ha increased considerably in 1972** over the year 1960 (**Table 2**).

Ahmad (1979) observed that the changes in the size distribution of farms might be the result of the following factors:

(a) Uneconomical small farm size has forced the small farmers to move to other industries where the opportunity returns

* IFAD, 1979. Report and recommendations of the President to the Executive Directors and proposed loan to the Islamic Republic of Pakistan for the small farmer Credit Project. International Fund for Agricultural Development (IFAD) Publication No. EB79/6/R. 25 Rome, Italy. P.V. (134).

** The first agricultural census in Pakistan took place in 1960 and the second in 1972, the next agricultural Census will take place by the year 1983/84. Therefore, 1972 figures are the latest.

Table 2 Farm Numbers and Percentage Change in Number of Farms of Various Sizes in 1960 – 1972

Size Group	Farms in 1960		Farms in 1972		Recent increase (+) or decrease (–) in 1972 over 1960
	Number	Percent	Number	Percent	
Less than 0.4	742 216	15	156 462	4	–78.9
0.4 – 1.0	855 732	18	364 155	10	–57.4
1 – 2	805 984	16	538 421	14	–33.2
2 – 3	580 952	12	579 924	15	–0.2
3 – 5	758 703	16	920 848	24	+21.37
5 – 10	728 909	15	793 928	21	+8.9
10 – 20	285 882	6	289 146	8	+1.2
20 – 60	87 624	2	102 641	3	17.1
60 & Over	13 981	< 0.5	16 163	< 0.5	15.6
Total	4 859 983	100	3 761 688	100	–22.6

Source: Pakistan Agricultural Census 1960 and 1972.

to their labour were high.

(b) Better housing, health and educational facilities in the urban areas could be another factor encouraging the farmers to migrate from rural to urban areas to give up farming.

(c) The ability of a few farmers to aquire extra land by using the inflow of money from their relatives in foreign countries.

He further commented that it was impossible to identify any particular component of these aggregate forces. However, using a Markov Chain Analysis, he forecasted the likely farm structure pattern for the year 1984 and 1996 which are presented in **Table 3**. He showed that the total number of small farms having less than 0.4 ha is expected to drop from 742 216 in 1960 to 29 262 in 1996, that is 83% decrease. These farms shared 15% of the total number of farms in 1960, while their share decreased to less than 1% in 1996. A similar trend was found in all the farm size groups less than 3 ha.

However, farm size group 3-5 and 5-10 ha are expected to experience a dramatic increase. The total number of farms in the former group increased from 758 703 to 1 156 328 and from 728 909 to 970 734 of the later group over the period of 1960 to 1996. In the end he concluded that the total number of farms, that is less than 3 ha would decrease, while all categories of farms having greater than 3 ha would increase in future. However, he added, there would be comparatively more concentration of farms in the size range of 3-5 ha and 5-10 ha in future.

Tractor Distribution on Different Farm Sizes

Despite the importance of the small farms, specially the size group of 5-10 ha, which is above the subsistence holding level, in the Pakistani agrarian structure they have not been included in mechanization programs so far. Figures for the tractors working on the different sizes of the farms in

Table 3 Projected Number of Farms by Size Group and Number of Farms for 1984 and 1996 Using 1960 – 1972 Basic Transition Probabilities

Size group (ha)	No. of farms in 1960		Projected no. of farms in 1984		Projected no. of farms in 1996		Percent increase (+) or decrease (–) in 1996 over 1960
	Number	Percent	Number	Percent	Number	Percent	
Less than 0.4	742 216	15	66 573	1.93	29 262	0.88	– 96.05
0.4 – 1.0	855 732	18	160 074	4.63	73 557	2.22	– 91.40
1 – 2	805 984	16	359 649	10.41	240 245	7.24	– 70.19
2 – 3	580 952	12	497 542	14.41	395 542	11.91	– 31.91
3 – 5	758 703	16	1 064 212	30.81	1 156 328	34.82	+ 52.41
5 – 10	728 909	15	875 396	25.35	970 734	29.23	+ 33.18
10 – 20	285 882	6	294 056	8.51	300 952	9.06	+ 5.27
20 – 60	87 624	2	117 503	3.40	132 279	3.98	+ 50.96
60 and over	13 981	<0.5	18 719	0.55	21 645	0.66	+ 54.82
Total	4 859 983	100	3 453 729	100	3 320 544	100	– 31.68

Source: Ahmed, 1979. Projecting the Size Distribution of Farms in Pakistan.

Table 4 Tractor Ownership by Farm Size in 1972 and 1975

Item			Below 5 ha	5 – 10 ha	10 – 20 ha	More than 20 ha	Total
(a)	Number of farms	(000)	2 560 (68.0)*	794 (21.1)	289 (7.7)	119 (3.2)	3 762 (100)
(b)	Total farm area	(000ha)	6 033 (30.4)	5 286 (26.6)	3 731 (18.8)	4 812 (24.2)	19 862 (100)
(c)	Number of tractors owned	1972	2 812 (9.1)	4 274 (14.0)	7 182 (23.5)	16 247 (53.3)	30 513 (100)
		1975	1 384 (4.2)	3 652 (11.0)	7 826 (23.7)	20 103 (60.1)	32 965 (100)
(d)	Farmers owning tractors	1972	2 790 (9.6)	4 249 (14.7)	7 098 (24.5)	14 776 (51.2)	28 913 (100)
		1975	1 366 (4.8)	3 627 (12.8)	7 736 (27.3)	15 591 (55.1)	28 320 (100)

* Figures in brackets represent percentage. Sources: 1) Pakistan Census of Agriculture 1972. 2) Pakistan Census of Agricultural Machinery 1975.

Pakistan for the years 1972 and 1975 are given in **Table 4** which show that 3% of the farms representing 24% of the area owned 54% of the tractors, whereas the small farms of 10 ha and less, representing 57% of the total area and 39% of the total farms, owned only 23%. The situation was exaggerated in 1975 when the small farms of 10% and less owned only 15% of the tractors.

Position of 5-10 Hectare Farms among the Small Farms

The view generally held is that a pair of bullocks is a norm for a 5-ha farm, but it is not mentioned at what cropping intensity it is a norm. A number of studies made in the past have shown that with the growing pressure on the present land a pair of bullocks is unable to satisfy the farm power requirements of the farms even below 5 ha size. Leaving aside for a moment the subsistence holdings (*i e* below 5 ha), the discussion will now concentrate on the holdings which are considered neither subsistence nor large, *i e*, a size group of 5-10ha.

The smallholder who possesses 5-10 ha of land is in a difficult position. He can neither rely on a pair of bullocks, nor can he keep two pair of bullocks. He is in a dilemma. Where should he go? If he keeps one pair of bullocks he cannot obtain the same cropping intensities as the farmer below 5 ha is getting with the same pair of bullocks. Furthermore, he cannot keep the two pair of bullocks, because of economic reasons, *i e*, less returns per hectare, as compared to the subsistence farmer.

In 1972, farms between 5 and 10 ha accounted for only 14% of the tractor population. In 1975 they received only 11% of tractor deliveries. This indicates that the gap was widening between the power available per hectare and the minimum power required per hectare. The overall shortfall on all farms of Pakistan is about 0.12 kW/ha, whereas on the farms 5-10 ha is about 0.21 kW/ha (Mughal, 1983). Therefore, it is essential to establish an institutional framework in which the smallholder of 5-10 ha has the same access to the various components of a high productivity agricultural system, such as an access to the credit for the purchase of tractor and other improved agricultural equipment, as the large farmers have. IFAD, (1979) believes that by the investment in tractors and tubewells the impact on the income of the small farmer would be as follows:

Size of farm	Current net annual income	With investment in a tractor and equipment	With investment in tubewell
5 ha	Rs. 8 240	Rs.23 630	Rs.13 440
10 ha	Rs.15 990	Rs.29 410	Rs.27 000

It is, therefore, in the intrest of the national economy, and the small farming community that necessary measures should be initiated by the government to eliminate the power gap on the small farms, particularly 5-10 ha size group, and to ensure that the maximum benefits are derived from the country's investment in irrigation projects. Mechanization will help the small farmers to carry out the farm operations which cannot be performed by animal power, or if they can, they are very difficult, involve drudgery, are inconvinient, uneconomical and time consuming.

REFERENCES

Ahmed, B. 1979. Projecting the Size Distribution of Farms in Pakistan – An Application of Markov Process. Quarterly Economic Journal of the National Bank of Pakistan Vol. 6, No. 1, pp. 50-53.

Ali, M. 1978. Welcome Address to CENTO. Seminar on Increasing the Productive Capacity of Small Farms. Lahore, Pakistan.

I.F.A.D. 1979. Report and Recommendations of the President to the Executive Directors on Proposed Loan to The Islamic Republic of Pakistan for the small farms Credit Project. International Fund for Agricultural Development Publication No. EB/79/6/R.25, Rome, Italy.

Mughal, A.Q.A. 1983. Smallholder Mechanization in Pakistan. Unpublished, Ph. D. Thesis submitted to the Cranfield Institute of Technology, U.K.

Muhammad, A. 1978. Inaugural Address to the CENTO. Seminar on increasing the productive capacity of small farms. Lahore, Pakistan. ■■

ABSTRACTS

Improved Nomographs for Estimating Field Efficiency and Field Capacity of Agricultural Field Operations: Lal, Harbans, Research Specialist-Consultant on Agric. Mechanization, IICA/EMBRAPA/CPATSA, Cx. Postal 23, Petrolina, PE, Brazil.

The nomographs presented in the paper are designed for estimating field efficiency and field capacity for agricultural field operations using animal power and tractor. The field efficiency is related to speed of operation, turning time, length of the field and time efficiency. The field capacity, in turn, is achieved by relating the estimated field efficiency to the working width and speed of operation.

Design Parameters of Plain and Serrated Blade Sickles in India: Pandey, M.M. and Devnani R.S., Scientist S-2, E.M.E. Div. and Project Coordinator, F.I.M. Scheme, respectively, Central Institute of Agric. Engineering, Bhopal, India.

The variation in sickle parameters was studied by analyzing the different design factors of 24 plain-edged and 35 serrated sickles used in India. The variation in size, blade type, weight of sickles and length of handle were determined. The variation in shear and frictional components of the cutting edge were analyzed and compared for the sickles. The different parameters studied indicated that while cutting with sickles, the shear force is dominant in plain edged sickles and frictional force in serrated sickles. The serrated sickles are lighter than the plain edged sickles. The number of teeth in serrated sickles are between 5 to 8/cm.

Status of Agromachinery Industry in India: Das, Pradip Kumar, Res. Scholar, Dept. of Industrial Engineering and Management, Indian Institute of Technology, Kharagpur, India.

The word agromachinery industry suggests the name of a class of industries the philosophy, concept, and usage of which grew up parallel to agricultural engineering in India. These industries now demand integrated action from planners, industrialists, research engineers, and farmers for overall development like their counterparts in order to be able to supply dependable and quality agromachinery inputs to agriculture for a still meaningful mechanization. This article further contains historical background, categories, structural features, all-round problems of production technology knowhow, management, finance, research and development, and marketing. This tries to paint a gloomy picture of the present status and thus attempts to draw up the attention of the concerned agencies for remedial action.

Comparative Performance of Tubular Type Plastic and Tin Solar Collectors: Roy, K.C. and Jindal, V.K., Senior Scientific Officer, Bangladesh Agric. Res. Institute, Joydebpur, Dacca, Bangladesh and Associate Prof., Division of Agric. and Food Engineering, Asian Institute of Technology, Bangkok, Thailand, respectively.

Two types of tubular type solar collectors – one made of thin black plastic sheet and the other made of blackened tin pipe, were tested to compare their performance characteristics. Both collectors were 12.2 meters long having diameter of 0.305 meter and tested under various solar intensities with different air-flow rates. It appears from the test that the thermal performance of both the collectors were similar as air heaters. Plastic pipe has some distinct advantages over tin pipe. It is cheaper, easy to construct, and easy to handle. So a plastic pipe collector can well be recommended as air heater.

A Pole-Drawn Toolbar for Animal Traction: Dogger, Jan Willem and Kersten, Marc, Department of Agric. Engineering, Wageningen Agric. University, Wageingen, the Netherlands.

For animal traction different kinds of toolbars exist (a main frame to which different implements like a plough, a ridger, a cultivator, etc. can be mounted). There are two versions, chain-drawn and pole-drawn. The pole-drawn type, as far as we know from literature, has only depth-control, no width-control.

In this paper we discuss a pole-drawn toolbar, fitted both with depth-control as well as width-control. Both controls are positioned within the reach of the man operating the toolbar; adjustments can be made without making a halt.

VADA-DENK-1 is the name the designers gave this new toolbar for animal traction. ■■

INQUIRY and REQUEST to AMA

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

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

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

7–2 Kanda Nishikicho Chiyoda–ku Tokyo–Japan 101

ADVERTISED PRODUCTS INQUIRY

Product	Advertiser	Vol., No., Page

EDITORIAL REQUEST TO AMA

Your Name :

Address :

Occupation :

SUBSCRIPTION/ORDER FORM

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

Issued Quarterly

Subscription Rate (includes surface mail postage)

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

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

★Spring, 1971	☐Vol.7 No.2, Spring, 1976	☐Vol.9 No.4, Autumn, 1978
☐Vol.2 Autumn, 1971	☐Vol.7 No.3, Summer, 1976	☐Vol.10 No.1, Winter, 1979
☐Vol.3 No.1, 1972	☐Vol.7 No.4, Autumn, 1976	☐Vol.10 No.2, Spring, 1979
☐Vol.3 No.2, Summer, 1972	☐Vol.8 No.1, Winter, 1977	☐Vol.10 No.3, Summer, 1979
☐Vol.4 No.1, Spring, 1973	☐Vol.8 No.2, Spring, 1977	☐Vol.10 No.4, Autumn, 1979
☐Vol.4 No.2, Autumn, 1973	☐Vol.8 No.3, Summer, 1977	★Vol.11 No.1, Winter, 1980
☐Vol.5 No.1, Summer, 1974	☐Vol.8 No.4, Autumn, 1977	☐Vol.11 No.2, Spring, 1980
☐Vol.6 No.1, Spring, 1975	☐Vol.9 No.1, Winter, 1978	☐Vol.11 No.3, Summer, 1980
☐Vol.6 No.2, Autumn, 1975	☐Vol.9 No.2, Spring, 1978	☐Vol.11 No.4, Autumn, 1980
☐Vol.7 No.1, Winter, 1976	★Vol.9 No.3, Summer, 1978	★: Indicates issues out of stock.

☐ **Abstract and Index, 1971-80 (Special Issue, 1983)**

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

Back Issues from 1981, ¥.1,700 per copy

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

SIMA 85
March 3-10, 1985, Paris/France

The 56th International Exhibition of Farm Machinery (SIMA) was held in Paris at the Place de la Porte de Versailles.

With 20 000 exhibits from 2 200 firms, this exhibition attracted 900 000 visitors.

The Gold Medal and Silver Medal Winning Machines selected by the Committee are introduced in the following "New Products" column.

International DLG Symposium
"Poultry Production in Hot Climate Zones"
June 16-19, 1985, Goslar, West Germany

The DLG (German Agricultural Society) is to again organise a symposium in Hannover, prior to Huhn and Schwein '85. Unlike the 1983 event, which attracted more than 200 poultry people from 40 countries, next year's symposium will cover The Far East as well as The Middle East and part of North Africa.

Once again, it will concentrate on the practical and economic aspects of poultry production in hot climates and is scheduled to run from 16 to 19 June, being followed by the Huhn and Schwein Trade Exhibition from 19 to 22 June.

Case studies, working groups, plenary and panel sessions will ensure a close contact between the lecturers and the participants, so that a maximum of information can be exchanged within a short time.

For details contact: Deutsche Landwirtschafts-Gesellschaft (DLG), Fortbildungswerk-Ausland, att. Dr. Riest, Zimmerweg 16, D-6000 Frankfurt 1, West Germany

International Symposium:
Farm Electronics and Computing
October 20-25, 1985
Stratford-upon-Avon, U.K.

The objectives of the Symposium are to draw together people concerned in the administration management, teaching and application of electronics in agriculture and to discuss and evaluate the contribution which is being made to agricultural development by advances in electronics and computing. Furthermore, it is the intention to share the expertise available in the United Kingdom and from other countries research development and advisory organisations to meet the needs of agricultural production, particularly in developed countries and to discuss possible developments in the future.

The first two days will incorporate a number of papers given in two parallel sessions. The programme has been so arranged as to allow ample time for discussion in order that the topics can be covered in depth.

Two visits are included in the programme – the first to the Farm Electronics '85 Exhibition at the National Agricultural Centre, providing an opportunity to examine current commercial applications of electronics and computing to farming in the United Kingdom and to make contact with the organisations and companies involved.

The second visit will be to the National Institute of Agricultural Engineering to examine exhibits illustrating the current research work relevant to the Symposium topics.

For details contact: George H Jackson, Agricultural Director, Royal Agricultural Society of England, National Agricultural Centre, Stoneleigh, Kenilworth, Warwickshire, CV8 2LZ, U.K.

International DLG Exhibition
AGRITECHNICA '85
November 25-29, 1985
Frankfurt am Main, West Germany

"AGRITECHNICA '85" – International DLG Exhibition for Agricultural Technology, Accessories and Spare Part Management will take place, for the first time, from 25 to 29 November 1985 on the fair grounds of Frankfurt am Main. Organizer of this event will be the German Agricultural Society (DLG). It has conducted exhibitions since 100 years and has acquired an international reputation in this respect.

This marks the start for the first German exhibition for agro-technology which will, in the future, offer an opportunity to the agricultural machinery industry, every other year, to present its offers. This market will, of course, also attract the international offer. As visitors, primarily German and foreign trade partners of the agro-technological industry are to be expected, as well as decision-makers of supra-national institutions, from state trade countries and from threshold and developing countries. Besides professional consultants, the exhibition is to address primarily specialists from the repair profession, from maintenance and services, and, above all, from the users of agricultural technology, *i e* the farmers, contractors and representatives of the machine pools.

The exhibition program of the "AGRITECHNICA" comprises the

entire agro-technological offer and that of the supplying industry. A new feature of this exhibition is that the sector of accessories and spare part management will find enormous consideration. The exhibition will be classified into the following sections:

Tractors and transportation vehicles

Machines and equipment for

- Soil cultivation
- Seeds and plant care
- Fertilizing
- Overhead irrigation, irrigation and drainage
- Harvesting
- Crop processing and preservation
- Feedstuff preparation
- Forest technology
- Landscaping
- Orchards, horticulture, viticulture and special crops

Conveyor installations and equipment

Barn technology and milk production

Energy and environment technology

Accessories and spare part management

Organization, consulting, management and electronic data processing.

For further information contact: Deutsche Landwirtschafts Gesellschaft, Zimmerweg 16, D-6000 Frankfurt am Main 1 West Germany

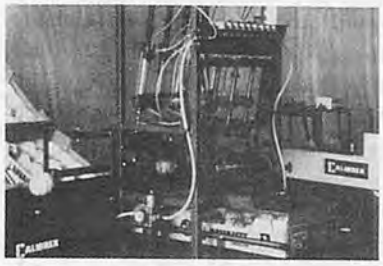
Africa's Newest Agricultural University was Established in Morogoro, Tanzania

Tanzania established East Africa's first Agricultural University in Morogoro (200 km west of Dar-es-Salaam, the capital). The former faculty of Agriculture, Forestry & Veterinary Science of the University of Dar-es-Salaam has developed into the Sokoine University of Agriculture (named after the late Prime Minister of Tanzania Edward M. Sokoine) with effect from 1st July 1984 and was officially inaugurated by the President of the republic H.E.Julius K. Nyerere.

The president had emphasized "the University is intended to be directly useful to our farmers and our nation, now, as well as in the future." It has to be practically oriented – that is a place of practical learning and research. He had also been concerned with the status of mechanisation in Tanzania and wished it to be appropriate to different circumstances of use and the different levels of technical knowledge prevailing in different agricultural sectors. The interests of the majority, that is peasant farmers, must not only be kept in mind but protected at all costs.

He had also stressed several key issues like making (i) University administration efficient, (ii) University library a national library of agriculture (iii) Staff and student housing cheap and simple in design (iv) University farm profitable and productive, (v) admission of mature students a possibility, (vi) extension services useful, (vii) research oriented towards solving problems of farmers, improved production and standard of living, (viii) changes in curriculum for self- reliance, practical applications and inter-disciplinary approaches, and (ix) service to rural people and agriculture an attitude. ■■

SIMA No. 1 GOLD METAL
Automatic Melon Packer/Grader

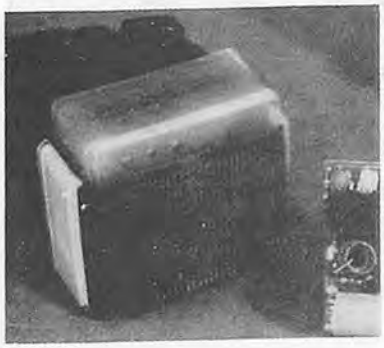


This diameter grader calls upon a line of fully automated manipulators which simultaneously packages the melons onto pocketed trays.

A conveyor belt moves the melons individually in front of a light barrier emitted by diode, where each level corresponds to the minimum diameter of the size chosen by the manipulator which is linked up with it. The melons are therefore selected in decreasing order of diameter into five sizes, oversized melons being discharged before the manipulators, and undersized melons discharged at the end of the belt.

Tray packaging is by means of three pairs of pneumatic rams per station. The rams are fitted with a low density rubber suction cup for gentle depositing of the melons. Output can attain 13,000 melons per hour.

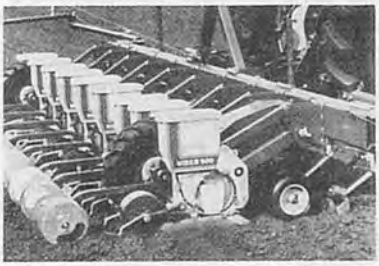
SIMA No. 2 GOLD MEDAL
Hoof Gauge Heat Detector for Cows



This electronic sensor is a new facility, particularly in dairy farming, for detecting when the cow is on heat. This hoof guage is in the form of a box worn on the hoof of the cow and which records the cow's activity and its particularly sensitive variations when the cow is on heat. The datum activity is recorded automatically 5 days before calving.

Indicator lamps visualize increase in activity according to three successive thresholds. This instrument does not require any special maintenance and should make it possible to substantially reduce problems of fertility connected with poor heat detection which increases calving intervals.

SIMA No. 3 SILVER MEDAL
Electronic Precision Seed Drill



On this electronic seed drill, an electric motor replaces the pinion gearbox which regulates distribution. A central unit records the desired density of seeds. The travelling speed is furnished by an optical indicator mounted on one of the implement carrying wheels. According to this information, the unit controls the electric motor so that it makes the desired number of rotations and guarantees the desired quantity of seeds.

With electronic equipment, any spacing whatsoever can thus be obtained between seeds. Distribution can be modified during running. Various information can in addition be given: area sown, distance travelled, quantity of seeds distributed, duration of running.

This electronic drill, presented on NIBEX 500, can be mounted on earlier models of the same make.

SIMA No. 4 SILVER MEDAL
Centrifugal Muck Spreader with Distribution Proportional to Advance and Variable Spreading Width

This muck spreader has two centrifugal trays spaced 190 cm apart. Each tray is equipped with two blades of different lengths, one of which with fore notched edge. Fertilizer is therefore spread according to three different modes on each tray, bringing about multiple overlaps.

The fertilizer is extracted from the hopper by two belts whose feed speed is proportional to the rotation of strake wheel following in the wheel tracks of the tractor. The metered amounts are regulated by the height of the trap doors. Checks are carried out when the implement is stationary.

Adjustment of the spreading width (up to 24 meters) is by moveing the spout which pours fertilizer onto the trays.

SIMA No. 5 SILVER MEDAL
Mounted Maize Harvester/Chopper with Rotary Headers

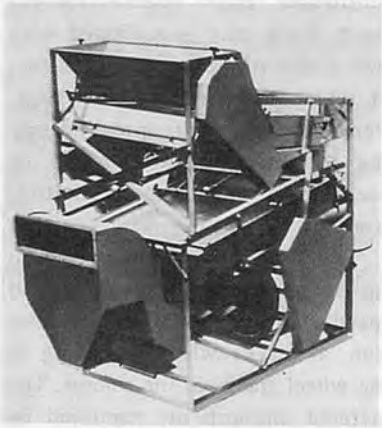
Two horizontal knives turning at high speed cut the maize stalks. The

bottom drums which overtop them, turn less quickly and convey the stalks, whose feet are held by special claws, towards the feed cylinders.

Harvesting can be carried out independently from the direction of the rows or the row spacings.

All mechanical units are simplified. Wear and maintenance should be substantially reduced.

New 4-screen, All-steel Seed Cleaner



Pearson Company has recently introduced it's all-new, revolutionary Seed King Model 104, 4-screen seed and grain cleaner. The new Model 104 is constructed of all steel for long-life, carries a 100% warranty and can clean more than 100 different commodities varying from seeds to grains to pellets. The capacity range of the new cleaner varies from 200 to 2 500 bushels per hour varying with the type of product and the function being performed.

Features of the new Seed King Model 104 include 4 screen cleaning with hundreds of screens to select from, an automatic roll feed inlet hopper with a rack and pinion flow control gate, top (scalping screen) knockers that beat the screen via a polyurethane knocking system for thorough non-clog cleaning, a lower ball rack on the fine materials screens that virtually eliminates all clogging, variable speed drive off the drive motor pulley, adjustable pitch (angle) controls on the screens to accommodate any product, a positive industrial blower and aspiration system that is totally adjustable, a dust-collection chamber and easy-change screens that easily slide in and out. The unit is priced at less than 1/2 of anything even remotely comparable.

Options include slurry treaters, augers, seed legs, dust collector extensions, baggers, sewing machines, etc.

For further information contact:
Pearson Company
Hwy. 34 East P.O. Box Z, Galva, Illinois 61434, U.S.A.

Papillon "Model 210" Sequential Ammonia Monitor

Papillon Agricultural Products, Inc. of Easton, Maryland has introduced an atmospheric ammonia monitor for poultry houses.

The "Model 210" Sequential Ammonia Monitor has the built-in capacity to control four independent circuits, allowing the user to automatically control ventilation fans and curtains to maintain a preselected ammonia level in the house. Fans can be operated either independently, or sequentially. Alarms, lights, and other electrical devices can also be activated at any ammonia level selected.

The "Model 210" provides highly accurate ammonia detection from 0 to 100 ppm and comes with a direct-read meter mounted on the control panel. The sensor head is equipped with 156 feet of pretested shielded wire. Additional sensor head line extensions are available in 50, 100, and 150 foot lengths.

Dependability, accuracy, and flexibility of use were the primary concerns during the last year of development and field testing. Confidence gained during this period has allowed the manufacturer to offer a one year full guarantee on all parts and labor, plus a 30 day unconditional satisfaction guarantee.

For further information contact:
Papillon Agricultural Products Inc.
P.O.Box 1161, Easton, MD 21601, U.S.A. ■■

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.

Co-operating Editors

J G Van Lancker | G B Hanna | A·Kandiah | D B Ampratwura | M S Choudhury | J C Igbeka | E U Odigboh | N G Kuyambeh | A H Abdoun | M A Bedri

A B Saeed | W T Weerakoon | I de A Nääs | A E Ghaly | A L Phillips | A A Valenzuela | A H Mirdha | W J Chancellor | M L Esmay | 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.

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

Md. Shahansha-ud-Din Choudhury
Faculty of Agriculture, University of Sokoto, P.M.B. 2346, Sokoto, Sokoto State,
Nigeria

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

E.U. Odigboh
Professor & Head of Agricultural Engineering Department, University of Nigeria, Nsukka, Nigeria

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

Abdelkader Elmetwally Ghaly
Associate Professor, Agric. Engineering Dept., Faculty of Engineering, Technical University of Nova Scotia, Halifax, Nova Scotia, Canada

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

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.

Megh Raj Goyal
Associate Agric. Engineer, Fortuna Agric. Research and Development Center, SR-No.2 - Buzón No.101, Juana Díaz, P.R. 00665, USA

Krishna Prakash Srivastava
CFTC Expert, Agrkc. Engineer (Soil and Water). Caribbean Agric. Research and Development Institute, Friars Hill, P.O. Box 766, St. John's, Antigua (W.I.)

— ASIA and OCEANIA —

Shah M. Farouk
Professor, Dept. of Farm Power & Machinery, 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

KP Srivastava | S M Farouk | K C Roy | M Gurung | Wang Wanjun | S Chandra | A M Michael | S R Varma | S Soepardjo | J Sakai

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

Harry D. Henderson
Professor and Chairman, Dept. of Soils, Irrigation and Mechanization, American University of Beirut, Beirut, Lebanon

Muhamad Zohadie Bardaie
Associate Professor, 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

Mohammad Afzal
Senior Engineer (Mechanization Engineer), Farm Machinery Institute, National Agric. Research Centre P.O. NIH, Islamabad, Pakistan

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)

Muhammad Siddique Chaudhry
General Manager (HGAM Ltd.), Aziz Manzil, 185-B, Nazimabad Colony, Faisalabad, Pakistan

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

A.A. Mughal
Associate Professor, Faulty of Agricultural Engineering, Sind Agriculture University, Tandojam, Sind, Pakistan

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

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

Richardo P. Venturina
Assistant Scientist for Agricultural Research, National Science Development Board, P.O.Box 3596, Rizal, Manila, Philippines

M.H. Abdel Aziz
Professor of Irrigation Engineering and Head, Agricultural Engineering Dept., Riyadh Univ., Saudi Arabia

S. Illangantileke
Head, 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

Yunus Pinar
Assistant at Agricultural Engineering Department, Atatürk University, Erzurum, Turkey

— 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. ■■

INDEX TO ADVERTISERS

EIMA 92
Iseki & Co., Ltd. 2
Kaneko Agricultural Machinery Co., Ltd. 4
Kubota, Ltd. 6
Mametora Agric. Machinery Co., Ltd. 95
Matsuyama Plow Mfg. Co., Ltd. 93
Ochiai Cutlery Mfg. Co., Ltd. 93
Sukigara Agricultural Machinery Co., Ltd. 92
Toyosha Co., Ltd. 94

BACK ISSUES

(Vol. 15 No. 1, Winter 1984)

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

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

◇ ◇ ◇

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

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

◇ ◇ ◇

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

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

◇ ◇ ◇

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

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

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

◇ ◇ ◇

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

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)

BOLOGNA
13-17 NOVEMBRE 1985

Admission by invitation:
13-14-15 November

Admission to public:
16-17 November

international exhibition of agricultural machinery manufacturers

exhibition of gardening machinery

Organized by **UNACOMA**
with the collaboration of the ENTE AUTONOMO FIERE DI BOLOGNA

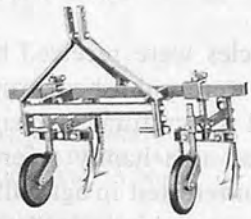
for further details :

eima 00161 ROMA-VIA L. SPALLANZANI 22/A
TEL. (06)8449441 TELEX 614126 -TELEGRAMMI (UNACOMA-ROMA)

UNACOMA

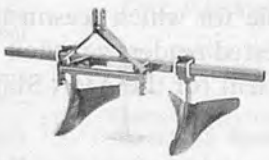
SUKIGARA
CULTIVATOR & RIDGER

IMPLEMENTS & ATTACHMENTS
FOR TRACTORS



Double-Row Cultivator TBC
(Tool Bar & Cultivator)

Triple-Row Ridger TCRM



Double-Row Ridger TBR-H2
(Tool Bar & Ridger)

SUKIGARA AGRICULTURAL MACHINERY CO., LTD.
YAHAGI-CHO, OKAZAKI-CITY, AICHI PREF., 444 JAPAN
TEL OKAZAKI (0564)31-2107
FAX (0564)32-1990(G2)
CABLE ADDRESS; "SUKIGARA" OKAZAKI, JAPAN

CONTRIBUTORS WANTED

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

FARM MACHINERY INDUSTRIAL RESEARCH CORP.
7-2 Kanda Nishikicho, Chiyoda-ku, Tokyo, Japan (Tel. 03/291 – 5717 – 8, 3671 – 4)

Niplo AGRICULTURAL MACHINERY

(1) **Rotary Tiller : SX-1700**
The spiral bevel gear on the drive shaft is lighter and stronger than older types and much more silent in operation.
We have reduced weight but maintained top cutting efficiency in these new ribbed blades.

Model SX-1700(25～45ps)

(2) **Drive Harrow : HA-2000B**
This makes it possible to bring back into the paddy field the soil that tends to pile up against the border levee, in the final puddling stage.

Model HA-2000B(20～24ps)

(3) **Reversible Plow : MR-44N**
A high performance standard plow for 4-6PS power tillers.
The plow can be adjusted to perform well in all types of soil by adjusting the differential fingers.

Model MR-44N(4～6ps)

MATSUYAMA PLOW MFG. CO.,LTD.

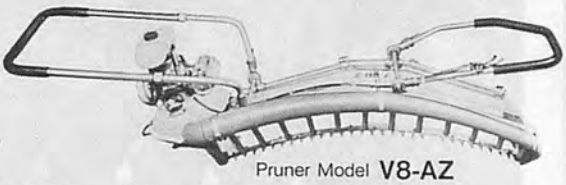
2949, Shiokawa, Maruko-machi, Nagano-ken, 386-04 Japan

OCHIAI LEADS THE TEA MACHINE INDUSTRY IN JAPAN

Engine-driven Pruner
Model **E-6B**

GUIDE TO OCHIAI

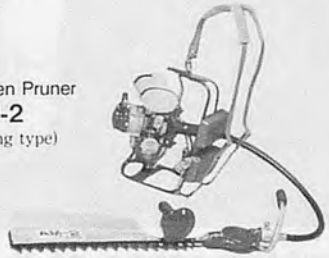
- Succeeded in devising Japan's first automatic tea-leaf picker in 1959.
- Received the Director of the Board of Scientific Technology Award in 1967.
- During the intervening period (1959-1967) obtained a number of patents as well as receiving a variety of awards and prizes in the domain of science and technology.



Pruner Model **V8-AZ**

- 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-driven Pruner
Model **AM-2**
(Reciprocating type)



Engine-driven Pruner
Model **E-6B**
(With attachment)

Self-propelled Tea Picking Machine
Model **T-100**
(One-man operation)

Self-propelled Cultivator
Model **JR-8A**

OCHIAI CUTLERY MANUFACTURING 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

HINOMOTO® CREATES A SENSATION IN THE TRACTOR INDUSTRY AND FORMS A NEW ERA IN THE HISTORY OF PLOWING METHODS

POWER DISC

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

	APPLICABLE TRACTOR
F-400 (4Blades)	20~30ps
F-500 (5Blades)	25~35ps
F-700 (7Blades)	30~60ps
F-800 (8Blades)	50~80ps

since 1863

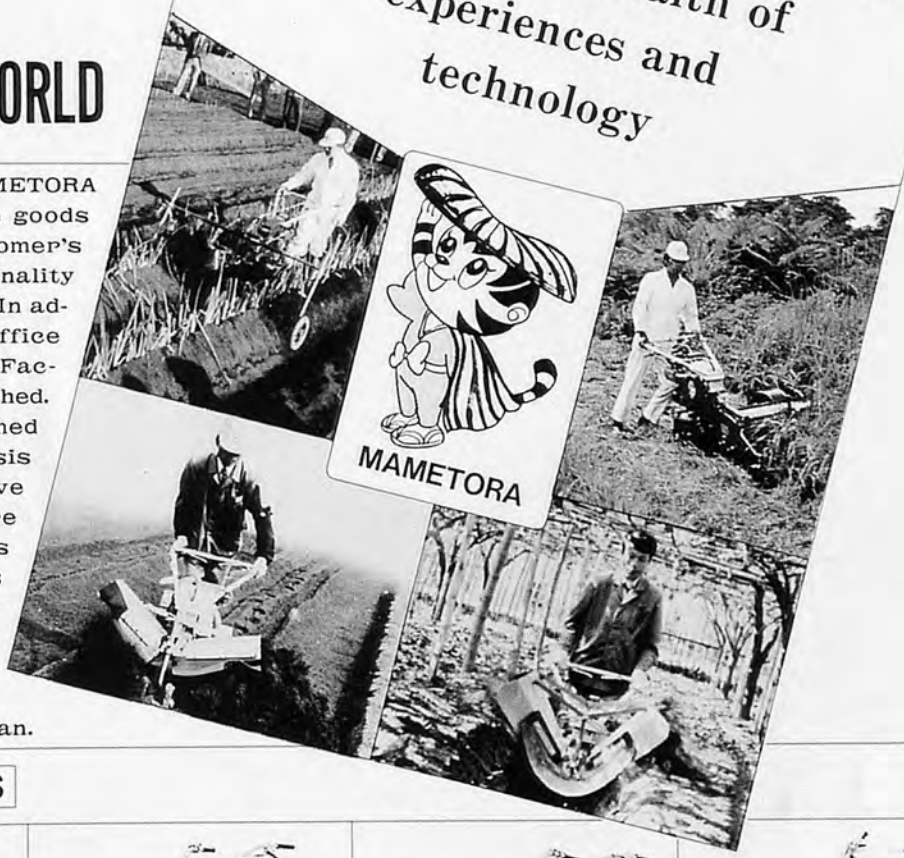
TOYOSHA CO.,LTD.

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

HINOMOTO®

MAMETORA DEDICATES TO AGRICULTURE ALL OVER THE WORLD

Researches and Development
Unequaled Wealth of
experiences and
technology



It is the motto of MAMETORA that we manufacture goods in order to meet customer's benefits with originality trusty and hearty. In addition to the head office in Okegawa Kisakata Factory has been established. Now that we have formed the much steadier basis as a comprehensive manufacturer. We are always making efforts to manufacture goods of high quality and are pleased to devote ourselves to the food industry in the world as well as that in Japan.

EXPORT SERIES

MC-80R Multing Rotor Set

MC-100

MC-130E

MC-181SB

MC-200

MC-210 スキ付

LV-1

LV-2

MAMETORA AGRIC. MACHINERY CO., LTD.

HEAD OFFICE ADD : 9-37, NISHI-2 CHOME, OKEGAWA-SHI, SAITAMA-KEN, JAPAN.
TELEPHONE : 0487-71-1181 TELEX : 2922561 MAMETO-J