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VOL.18, NO.1, WINTER 1987

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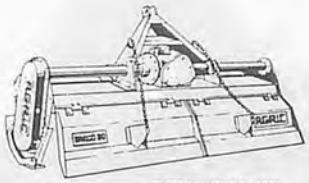
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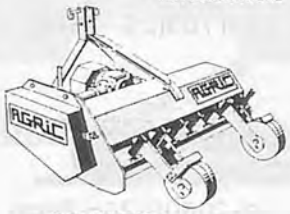
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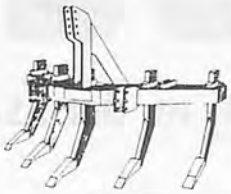
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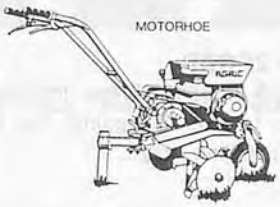
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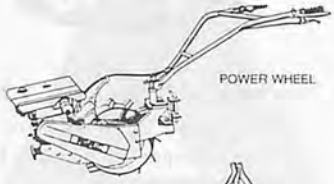
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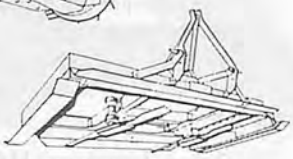
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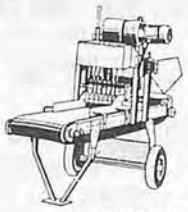
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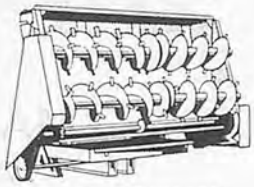
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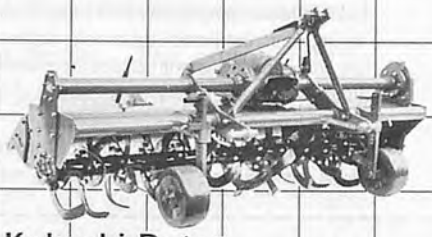

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EDITORIAL

A Tribute to Yoshikuni Kishida

When the late Yoshikuni Kishida passed into the Great Beyond last October, we received an outpouring of condolences from AMA readers, co-editors and friends from far and wide and which we acknowledged then as now. Those many words of kindness were truly a tribute to the man who was ahead of his time in terms of promoting agricultural mechanization long before many even toyed with the same idea. As a matter of fact, he founded our Company, the Shin-Norinsha Co, Ltd. of which AMA is a subsidiary. The condolences were meant to grieve the loss of Yoshikuni Kishida who championed the cause of agricultural mechanization not only in Japan but in many parts of the world as well.

Yoshikuni Kishida was born in Hokkaido, Japan, one of three sons of a farmer who pioneered in developing agriculture in Japan's so-called *last frontier.* He knew the problems of agriculture even at an early age. He was witness to the back-breaking toil of his fellow farmers. He left farming not because he wanted merely to escape the rigors of farm life but because he realized that he could better promote agricultural mechanization through the printed medium and consultation services which he did with consuming interest. He devoted his entire life, and much of his fortune, to the cause of farm mechanization as a means of hastening agricultural development and improving the lives of farmers and their families.

In the latter half of his life, he saw greater concern for the development of agriculture in the developing and underdeveloped countries of the world.

He will be missed by many, especially those who knew him in person. But he left behind a legacy for all of us in the agricultural mechanization field to uphold, particularly myself in my role as AMA's Chief Editor. Of course, even long before his death, I reassured him that I shared his views in life and his obsession about agricultural mechanization and that I am resigned to carry on the work he has started because I know that he had a noble cause and that AMA readers, co-editors and friends are behind me in "holding the torch" high.

At this time year, and particularly as AMA turns 16, it is a very happy occasion to wish you all a GREATER AND MORE PROSPEROUS NEW YEAR!

Yoshisuke Kishida
Chief Editor

Tokyo
January, 1987

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol. 18, No. 1, Winter, 1987

Yoshisuke Kishida	9	Editorial
Jun Sakai Surin Phongsupasamit Tadashi Kishimoto	11	Study on Basic Knowledge of Plowing Science for Asian Lowland (Paddy Field) Farming
Abdul Razzaq	19	Preparation of Medium-Textured Soil for Rice Production
Md. Wali Ullah S. Sonne Kofoed	22	Effect of Field Dimensions on Energy and Labour Consumption for Rotary Cultivating Small-Sized Plots
Harbans Lal	27	Flat and Broadbed-and-Furrow Systems of Cultivation
G.O.I. Ezeike	33	Energy Consumption in Rice Processing Operations in Nigeria: Selected Case Studies
A. Chakraverty D.S.K. Devadattam	41	Stabilization of Rice Bran by Conduction Heating in a Continuous Rice Bran Stabilizer
Md. Nurul Islam T.T. Pedrsen	45	Some Physical Properties of Wheat and Paddy and their Relationships
M.S.U. Choudhury	51	Relationship of Grain Shape and Mass to Tensile Strength of Rice
N.K. Bansal D.N. Sharma M.L. Jain	57	Development and Field Evaluation of a Stubble Collector-Cum-Planker
M.E. Herbst	60	Low-Cost Peat Production and Gasification
Hiroshi Shimizu Toshinori Kimura Rattanachai Pairintra	65	Integrated Regional System of Thermal Utilization of Biomass Resources
A.C. Srivastava R.D. Singh	72	Sugarcane Trash Management in India
Gyanendra Singh T.P. Ojha	75	Delivery System for Farm Machinery Technology in India
News	83	
New Products	85	

* * *

Co-operating Editors 86
Index to advertisers 87
Back Issues 88

Study on Basic Knowledge of Plowing Science for Asian Lowland (Paddy Field) Farming

—Plow Structures Related to Plowing Principles—

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Abstract

In order to understand the structural and operational principles of plow design, it is necessary to study not only the plow structures but also the farming conditions of the district where the plow will be used. The historical development of Asian animal-draft plow structures before the hand-tractorization age is studied. The functional mechanisms of the plows have developed to suit Asian lowland-paddy farming conditions different from European upland farming. This study comes in two reports. The first report is discussed in this paper regarding the size, structures and the flatness of the field, farming systems and their different plowing methods. The second one is forthcoming which will have further discussion about scientific reasons and developing target of plow structures to meet farming requirements.

Introduction

The farming may be broadly divided into *upland farming* and *lowland farming*. From Asian viewpoint, upland farming means agricultural practice in the areas of small amount of rainfall such as in Europe, America and so forth where wheat, maize, potatoes, pastures, and many other vegetables, fruits, etc. are grown. In contrast, lowland farming is practised in the rainy areas of Asian countries where paddy is cultivated as a major crop. The fields in lowland farming are flooded with irrigation water during the cropping season, while the soil moisture in upland farming is stored below the field surface. Asian countries also undertake upland farming in the dry season or upland zone.

Asian plows which have mainly developed under lowland farming conditions have had different structures and functions compared with European plows which have developed basically for upland farming conditions.

It may be necessary to discuss and compare important differences of farming structures and soil preparation between upland farming and lowland one in order to have better understanding of structural and functional principles of Asian plows.

The Japanese hand-tractor plows were developed within very short time at the beginning stage of hand-

(1) Part of this paper was presented at Annual Meeting of Agricultural Machinery Society, Japan in 1986.
(2) This paper is Part II of the research study on basic design theories of hand tractors and plows for Asian paddy fields.
(3) Mr. Surin Phongsupasamit is from the Mechanical Engineering Department, Faculty of Engineering, Chulalongkorn University, Bangkok 10500, Thailand.

Special Acknowledgements: When the authors were writing this paper in October 1986, it was announced that Mr. Yoshikuni Kishida, Chairman, Farm Machinery Industrial Research Corp. and Shin-Norinsha Co., Ltd., passed away.

He was very interested in plow science and encouraged us with his special letter. We remember his leadership and great contribution to the international development of agricultural mechanization especially in developing countries.

tractorization in the 1950s (as discussed in the previous paper).[1] However, this achievement was based on well-developed animal-draft plows for paddy cultivation done for the last several decades after 1900. Special adaptable characteristics of Japanese conventional plows to economical hand tractors, which have the possibility of avoiding social strain among small-scale family farms as the majority in a country, will be compared with those of European counterparts.

Basic Lowland-paddy Farming Conditions vs. Upland Farming for Plowing and Tractorization

It is commonly said that "The wider field is better to have more efficient mechanized farming, and also the deeper tillage is better for plant growth". However, the basic farming principles about this matter between upland farming and lowland-paddy farming are different and are discussed as follows.

Size, Structures and the Flatness of the Field

The upland cultivation is dominated by cereals: wheat, maize, fruits, vegetables, etc. and the water supply for these plants depends mainly on soil moisture from rain and groundwater. The size of a field lot of upland farming can be wide because it is not necessary for its field surface to be flat.[2]

In the case of lowland-paddy cultivation, however, the size of a field lot is traditionally small because field surface must be perfectly flat in order to be flooded with uniform depth of irrigation water. Furthermore, it is easier to make and maintain flat field surface in smaller field lots. For these reasons, paddy-growing countries in Asia historically divided their paddy fields into small field lots by levees. It is said that the common size of traditional paddy-field lots were more or less than 0.1 ha in Asia. In the case of very flat plain areas in continental countries, the size of plots is traditionally separated by also levees depending upon the possible area of one day's tillage by a family.

In 1989, the Meiji government in Japan promulgated the "arable land readjustment law" and began to establish the rural engineering project of reconstructing old irregular paddy-field lots. The main objectives of these projects at that time were to construct rational paddy fields of regular shape and size with better irrigation and drainage facilities for animal-powered farming. The projects were continuously established all over Japan for 60 years.[3] Ideal size of a paddy-field was 0.1 ha at that time.

When the new arable land readjustment project for constructing modern farms had been established at the beginning stage of hand-tractorization in the 1960s, Japan had to find the maximum but practical and reasonable size of paddy fields in order to achieve high efficiency in mechanization. The recommended shape and maximum size of a paddy-field lot in 1970s to 1980s was 0.3 ha of the rectangular shape as 30 m x 100 m. The width, less than 30 m, was determined by the machine performance of pesticide spraying from the levee. Moreover, the recommended tolerance of flatness in a paddy field was decided to be less than ±2.5 cm. Then, the water level in the field could be readily adjusted. Therefore, the uniformity of the paddy growth in such field lots can be maintained, and weed and insect control can be effective.

It is natural that the different conditions of field lots in size between upland and paddy field cultures because of flatness may become one of the causes of different development of tillage equipments and other farm machineries.

Farming Systems and Plowing Methods

Influence of Upland Farming on Plow Structures

The plowing methods done by the European one-way moldboard plow are generally divided into return and continuous plowings as shown in **Figs. 1** and **2**. The former can be further classified into two types of gathering and casting furrow slices at the middle of the fields, while the latter is also classified into two types of turning furrow slices toward and cutward from the middle of the field. All of these plowing methods are commonly described in European textbooks, and suggested that both methods are alternatively applied in every other cropping season in order to maintain the natural field surface.

Each size of upland fields could be relatively larger because their field surface are not necessarily flat. In such large plots, the return plowing method is not applicable because of wasted time at headlands as shown in **Fig. 1**. Therefore, continuous plowing method is commonly preferred for saving time in turning at headlands.

Farmers in European countries preferred to use hand tractors for small-sized upland fields in the 1950s and 1960s. In this case, the return and continuous plowing methods were inconvenient for them because of time losses at headlands and busy turning of machines at the middle portion of narrow fields. Owing to these reasons, the farmers preferred to cultivate their fields with the "continuous return plowing method" as shown in **Fig. 3**. Therefore, many reversible plows (having two sets of plow bottoms mounted on the

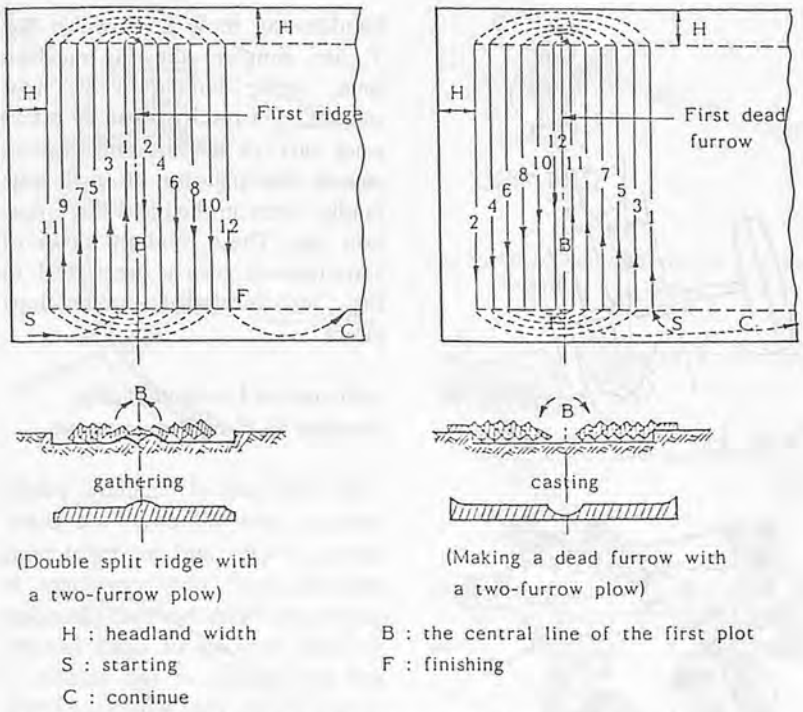

Fig. 1 The passing order of soil tillage for return plowing method.

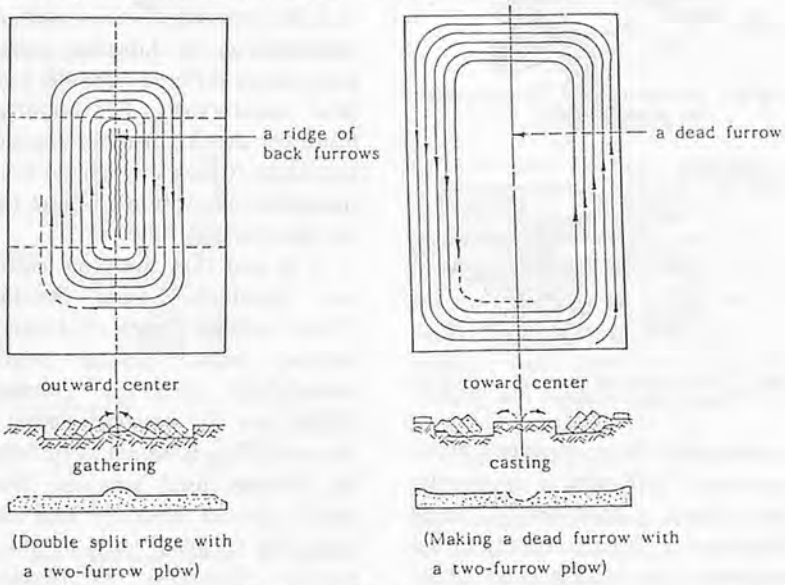

Fig. 2 Soil tillage patterns of continuous plowing method.

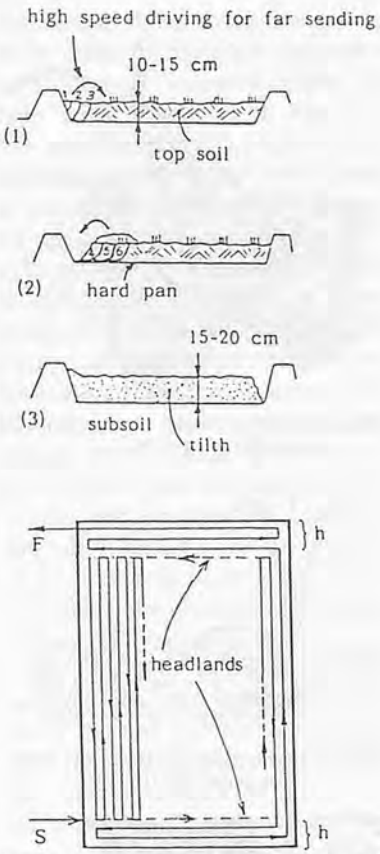

Fig. 3 The passing order of continuous return plowing method with a hand tractor turn-wrest plow. (1. h: headland width for about 10 plowing passes; 2. - - - - - - - - marking lines of headlands; 3. S: starting and 4. F: finishing).

main frame) for hand tractors were developed in Europe in the 1950s and 1960s. For example in 1965, the catalogues of 23 models among 24 hand tractor modles exhibited at a Paris Agricultural Show (according to Sakai's collections) were equipped with reversible plows as shown in **Fig. 4**.(4) There was only one land tractor exhibited with a European single plow having a simple beam structure.

The development target of Japanese and European plows for the hand tractors were similar, but they had different development in mechanisms because of different operating principles. The important technical reasons are explained as follows;

As a rule, the share of a European plow has an important principle of being used horizontally, as shown in **Fig. 5a**, and the plow pole has to be vertical all the time, as shown in **Fig. 5b**, while the hand tractor always has to incline, as shown in **Fig. 6a**.(2) It has a simple hitch to be connected directly to the plow beam through a pin (or pins) as shown in **Fig. 6b**. Thus, the plow pole has to incline with the hand tractor. The development of adjusting mechanisms of European hand-tractor plows at that time were mainly focused on three technical problems. These were the development of;

1. the mechanism for keeping the plow pole vertical
2. the mechanism for controlling the plowing depth
3. the mechanism for changing

Fig. 4. European hand tractor with a reversible plow (1965).

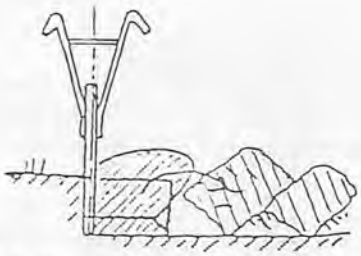

Fig. 5a. Basic plowing form of European animal-draft plow.

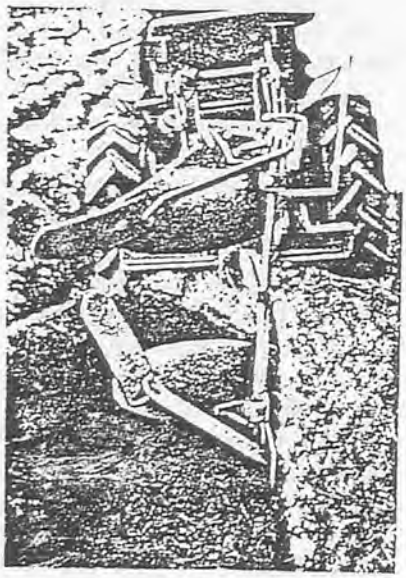

Fig. 5b. Basic plowing form of European riding tractor plow.

the inverting direction of furrow slices.

The first and second mechanisms were developed and the third one was realized by two plow bottoms but the mechanism of plowing width control was not installed. Furthermore, their plows were heavy in weight because of two plow bottoms

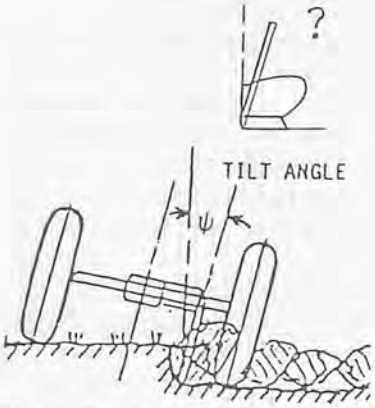

Fig. 6a. The basic inclination form of plowing with a hand tractor.

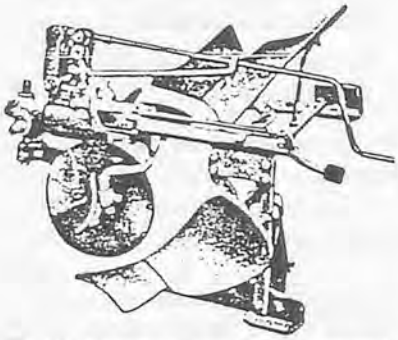

Fig. 6b. European hand tractor reversible plow (1965).

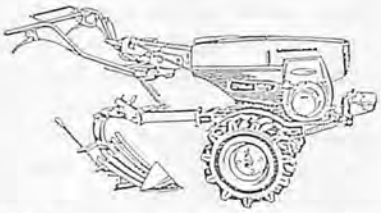

Fig. 7 Japanese hand tractor with a turnwrest plow (1965).

in one unit. Thus, plowmen might encounter difficulties to operate the plows. Consequently, those hand-tractor plows could not be extensively used among professional farmers in Europe.

According to these constraints, European plows may have good adaptability to working animals and riding tractors but not to hand tractors. Because the draft and hitch points of animals provide plows with freedom in all direction, and the three-point hitches of riding tractors can provide vertical holding of plow poles.

In comparison, the Japanese hand-tractor plow as shown in **Fig. 7**, had simpler adjusting mechanisms, and comparatively light weight. As a result, Japanese plows were easy to operate and popular among the majority of small-scale family farms in the hand-tractorization age. These modern plows of hand-tractors owe a great deal to the well-developed animal-draft plows.

Influence of Lowland-Paddy Farming on Plow Development

In the case of Japanese paddy fields in the old days, the continuous plowing and return plowing methods were not convenient in small-sized fields because the ridges of back furrows or dead furrows will be formed in the middle of narrow fields. That will make levelling of the field surface difficult in puddling operation. As a result, the development of Japanese animal-draft plows differed from the European counterparts. The important historical development of Japanese animal-draft plows which led to the successful innovation of hand tractor plows was as follows;

It is said that the plow culture was transferred from Northern China through Korea to Japan in ancient times.(5) The original animal-draft plow in Northern China was the long-sole plow as shown in **Fig. 8**. Korean and Japanese farmers used long-sole plows also in former times.(6) This long-sole plow is called "pushing plow", namely "Oshi-zuki" in Japanese. The long sole structure was effective for stable plowing and comfortable, too. The plow was useful in making or maintaining the plow pan under the top soil to support men and animals, and to reduce leakage of irrigation water and preserve plant nutrients. However, the plow was not effective in deep tillage because of the large bottom surface of the sole.

Between the 5th and 7th centu-

Fig. 8 Long-sole plow (by Mr. Hirobe, Tatsuzo).

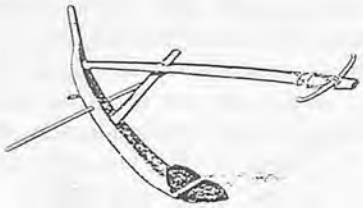

Fig. 9 Non-sole plow (by Mr. Hirobe, Tatsuzo).

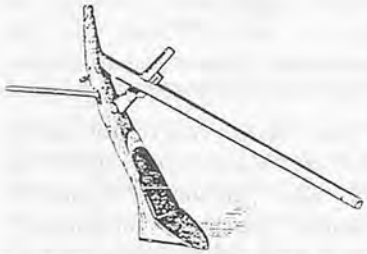

Fig. 10 Short-sole plow (by Mr. Hirobe, Tatsuzo).

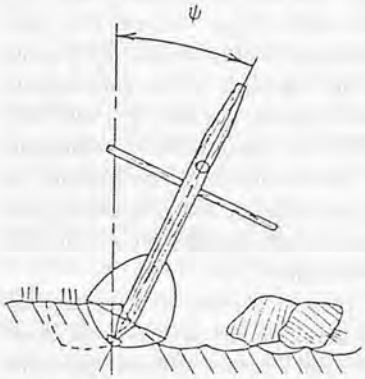

Fig. 11 Tilt angle ψ.

ries, the non-sole plow, as shown in **Fig. 9**, appeared first in the Southern Korea. Then, it was introdued into Japan and used initially in Kyushu district.(6) This plow is called "hanging plow", namely "Kakae-Mottate-ri" in Japanese. The special characteristics of the plow were the share of half-oval shape and the simple moldboard plate, sometimes a worn share is used, which was fixed along the lower front center of a wooden

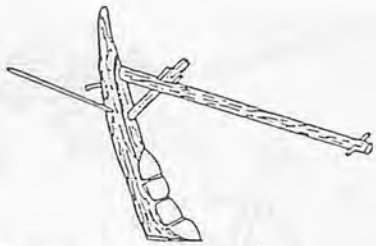

Fig. 12 Ohma-oshi-zuki (by Mr. Shigeo, Koga).

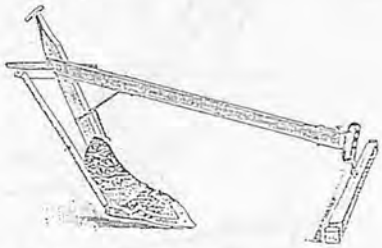

Fig. 13 Matsuyama turn-wrest plow.

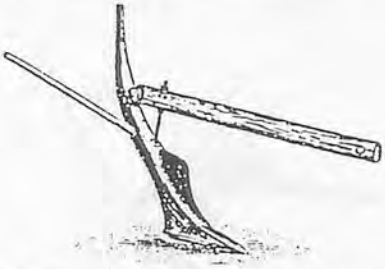

Fig. 14 Maruko suki (by Mr. Hirobe, Tatsuzo)

pole. The plow was effective to perform deep tillage but not convenient for the plowman to use. He was easily fatigued to handle this unstable plow. Therefore, only the leading and diligent farmers accepted non-sole plows.

Conventional plows began to be developed in Kyushu district as they found that the medium plow, between the non-sole and long-sole plows as shown in **Fig. 10**, had a possibility of having good working stability and with deep tilling performance. This plow was called "short-sole plow", and it was the original Japanese animal-draft plow.

There were two kinds of moldboard structures at that time. One had a inverting function for soil furrow slices to the left (or right) though the plow pole was kept vertical. The other had share and moldboard fixed along the lower front center of the plow pole with an additional sideward beam at right angle as shown in **Fig. 11**. The beam was used to control the inclination of the plow pole. There is no academic name of this inclined angle in plow science yet. The authors propose to name this angle ψ in **Fig. 11** "tilt angle" of Asian plows. Because of this feature, the plow could easily perform the continuous return plowing method as the plowman could alternatively change the throwing directions of the plow to the soil furrow slices to the left or right by changing and adjusting only the tilt angle ψ of the plow pole to the left or right. In general, the tilt angle ψ is adjusted from 25 to 30 degrees.

At that time in Japan, animal-powered plowing with short-sole plows became modern and enjoyable farm work, and plowing contest became a kind of fashion in every district. The winner was the hero in the district, and demanded the promotion of that plow performance to manufacturers. In 1899, Mr. Shichihei Isono, in Kyushu district, developed a simple short-sole plow called "Ohma-oshi-zuki" as shown in **Fig. 12**. The plow had three moldboard plates fixed along the lower front center of the wooden pole in order to lift forrow slices higher and turn them further away.

Mr. Genzo Matsuyama developed a turn-wrest plow, as shown in **Fig. 13**, in 1899 and got a patent for it in 1900.(7) This was a kind of reversible plow and had simpler mechanisms. The throwing directions of the plow to furrow slices can be easily changed to the same direction when the turn-wrest handle is shifted to the left or right at the headland where cattle turn. Therefore, the flat narrow paddy field is conveniently plowed from one side to the other by means of continuous return plowing. This plowing method is sometimes called

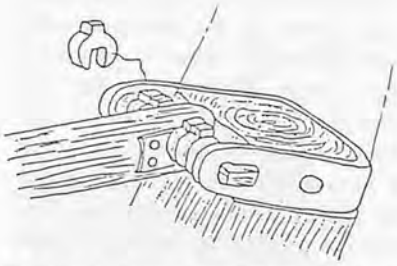

Fig. 15a. Adjusting mechanism of plowing width (by Sakai, Jun)

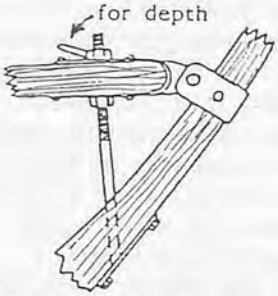

Fig. 15b. Adjusting mechanism of plowing depth

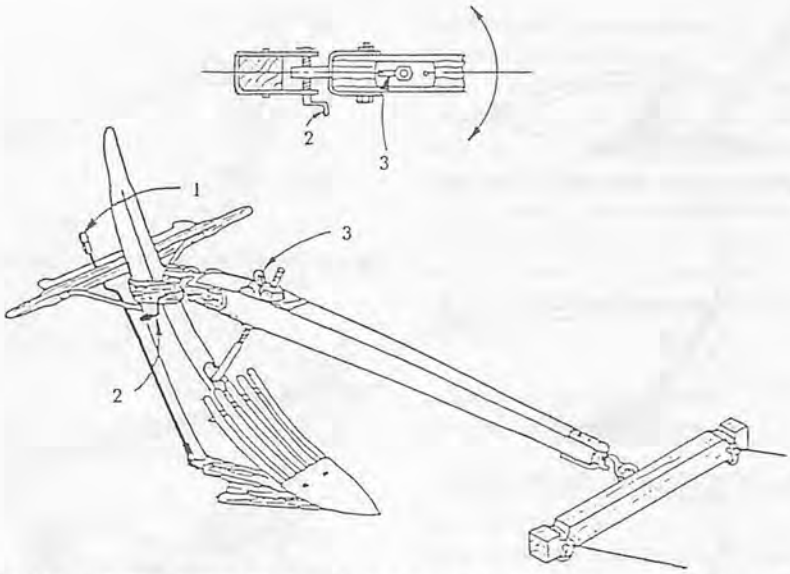

Fig. 15c. Japanese turn-wrest plow 1. turn-wrest handle, 2. width control handle and 3. depth control screw nut (by Sakai, Jun and Phongsupasamit, S.)

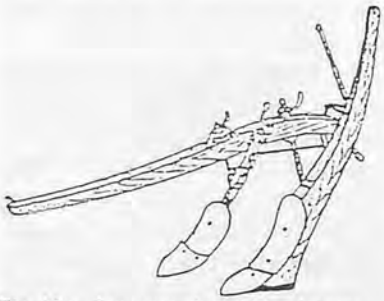

Fig. 16a. Japanese plow with a jointer

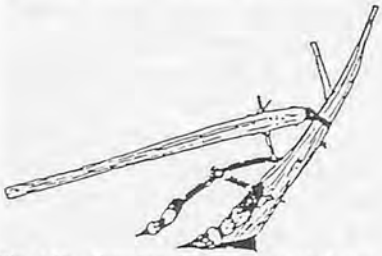

Fig. 16b. Developed structure of Japanese plow with a jointer

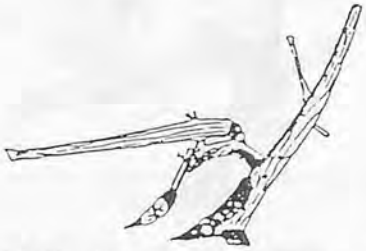

Fig. 16c. Modernized structure of Japanese plow with a jointer

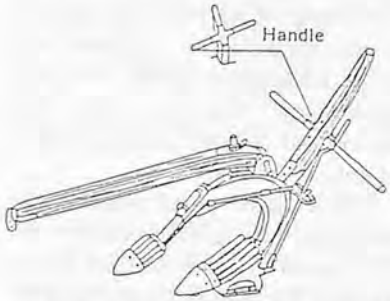

Fig. 16d. Japanese turn-wrest plow with a jointer

"plane tillage" in Japan.(8)

Still another plow model was developed by Mr. Suejiro Ohtsu in Higo (old name of Kumamoto Prefecture in Kyushu district) with control mechanisms for plowing width and depth called "Maruko-suki" by brand name (Fig. 14.).(5), (9) The plowing width can be adjusted by inserting collars at the side of the plow beam as shown in Fig. 15a, and the plowing depth is adjusted by the screw nut at the plow beam as shown in Fig. 15b.(10) This plow was also equipped with a cast-iron sole in order to reduce wearing and a modern moldboard plate. The control mechanisms and sole metal application of his plow were patented in 1900 also.

The Matsuyama's turn-wrest plow and "Maruko-suki" should be both called "the mother of modern Japanese short-sole animal-draft plows" from which modern Japanese turn-wrest plow as shown in Fig. 15c was developed. Thus, this turn-wrest plow became the standard and popular animal-draft plow in the last stage of the animal-powered farming age in the 1940s and 1950s in Japan. The development of these adjusting mechanisms in Japan might be one of great innovations in the world's plow structure and science.

It is no wonder that the successful development of turn-wrest plows for hand tractors in Japan mainly depended on these important technical sources of the modern animal-draft turn-wrest plows.

In 1930, Mr. Heijiro Fukami in Fukuoka, Kyushu district, developed a plow with a jointer which is called "two-stage plow" (Fig. 16a). The plow performed well in breaking stubbles of previous crops and better harrowing.(11) However, it had the problem of adjusting the relative location and angle of the jointer to the main plow when the setting of plowing depth was readjusted. This is because the jointer is

directly connected to the plow beam. Then, a two-stage plow as shown in **Fig. 16b** was developed in order to solve such a problem. The modernized two-stage plow as shown in **Fig. 16c** was modified from the previous ordinary two-stage plow. The "turn-wrest plow with a jointer" **(Fig. 16d)** was finally developed and became the most advanced model of Japanese animal-draft plows. It was also popular in the animal-powered farming age in the 1940s and 1950s in Japan.

There were many models of European animal-draft, turn-wrest plows. In this paper, two models are selected to discuss in comparison with their Japanese counterparts. One has a simple moldboard plate and a triangular share **(Fig. 17a.)**.[12] In order to change the throwing directions of the plow to furrow slices, the operating orders are as follows; At the headland the plow is lifted and the hook is detached from the moldboard. Then, the plow bottom is rotated downward to the other side, and the hook hangs the moldboard again. In the U.S.A., there were advanced models of this type to be operated by a pedal. The second has a curved moldboard and two shares mounted on the upper and lower edges of the moldboard as one unit **(Fig. 17b)**.[5] Its plow bottom is held to the plow beam by a pivot(A), and the end of the upper landside is locked to the beam. The plow bottom can be also rotated downward to the other side through the pivot(A) after lifting the plow at the headland and the lever(h) is pulled. It seems that the plowing with these plows is rather inconvenient. Other European animal-draft reversible and balance plows, as shown in **Fig. 18** and **19**, were also used in order to perform continuous return plowing.[5] The continuous plowing method and return plowing method are common in Western and Asian countries who studied only the Western farming culture, while the continuous return plowing method is popular in Japan, Korea and Taiwan.[13]

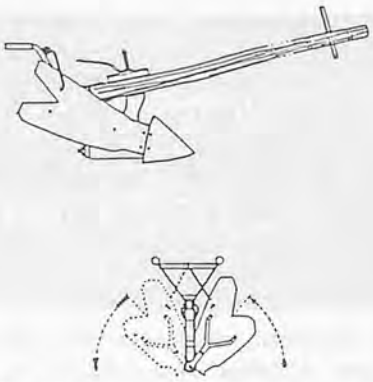

Fig. 17a. European turn-wrest plow (Florence, Italy).

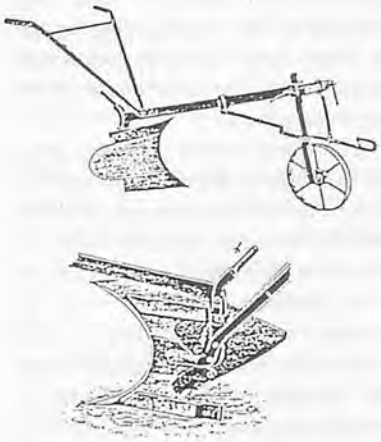

Fig. 17b. Euroepan turn-wrest plow (by Mr. Hirobe, Tatsuzo).

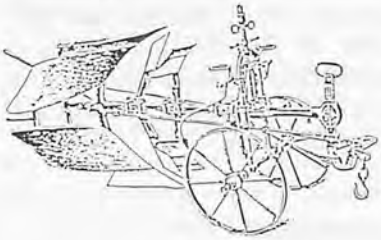

Fig. 18 European animal-draft reversible plow (by Mr. Hirobe, Tatsuzo).

In summary, the Japanese animal-draft plows are more convenient to control than the European ones because the plowman can easily control four important plowing functions, namely; inverting of furrow slices, plowing depth and width and changing direction of the plow to furrow slices.

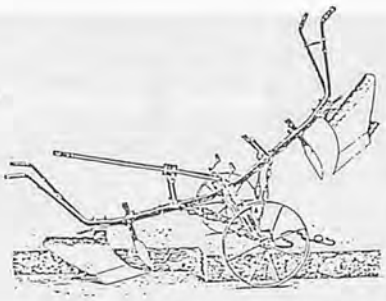

Fig. 19. European animal-draft balance plow (by Mr. Hirobe, Tatsuzo)

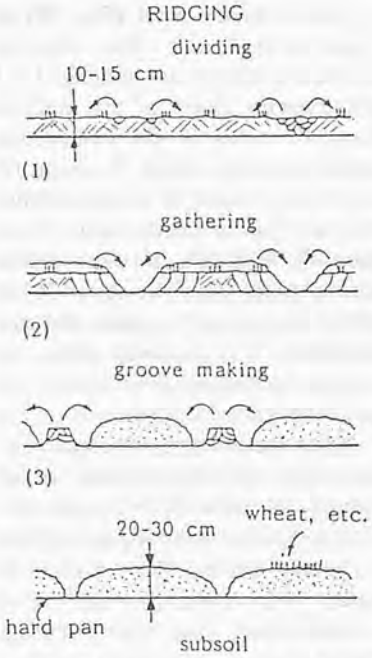

Fig. 20 Ridging operation with an ordinary plow

Double-cropping System of Lowland-paddy Fields and Plow Structures

In Japan and Korea wheat or barley is usually planted in paddy fields as second crop in dry winter. Such crops require soil of low moisture conent. Therefore, excess water in the fields should be drained in order to secure healthy root growth of those upland crops. It is commonly practised before harvesting paddy that water in the field is completely drained at about 30 to 35 days after heading period of the late varieties in warm regions.[14] The sub-surface drainage system is

recommended to be installed under the hard pan in the paddy field in Japan in order to prepare such field condition. Moreover, the bed planting for second crop in paddy fields is commonly practised in order to achieve lower moisture content of top soil where crops are planted and to have sufficient soil thickness of ridges of back furrows. Ridges are formed by gathering the turned-over furrow slices from both sides by the ordinary plow **(Fig. 20)** in Japan and Korea. This plowing method is known as "ridging".(15) The plowing depth of this method must be equal to the continuous return plowing which is about 10 to 15 cm in order to avoid breaking the hard pan of paddy fields. Then the soil thickness of those ridges after plowing becomes about 20 to 30 cm because of soil gathering and loosening. (At present, ridging is commonly practised by rotary tillers with attached ridgers.)

After harvesting the second crop, the ridges are turned back to fill furrows in order to level again the field surface by using one-way plows or rotary tillers. This method is called "ridge-break plowing". It is recommended that the puddling direction after ridge-break plowing should be 45 degrees to the original ridge direction in order to level again the field surface for the next paddy rice crop.

The popular plowing methods in Japan are generally classified as follows;

- plowing
  - plane plowing: continuous return plowing
  - ridging
    - dividing
    - gathering
    - groove making
  - ridge-break plowing

In order to prepare such field requirements, the shape and curvature of the moldboard of a Japanese conventional plow had to have not only good functions of soil-turning performance for plain plowing in paddy production but also lifting property and sending-far performance to make optimum shape of ridges for the ridge plowing. In contrast to the moldboard of a Japanese plow, the important function of a European moldboard and the upper curvature of the share is to rotate the rectangular furrow or the crest without lifting it above the furrow-bottom surface. This was also one of the reasons why Japanese plows have different shapes and curvature of the moldboard from European plows.

According to the inverting principle of furrow slices of a European plow, the width of the plow share can be a little less than the width of th furrow slice. As for the Japanese plow, however, it should be equal or even wider than that of the furrow slice, so that the good lifting and turning with less resistance could be achieved.

The following papers may continue to discuss the local farming conditions in Asian lowland-paddy farming, which became also the cause of different structures and mechanisms of hand-tractor plows as well as animal-draft plows from European plows.

Conclusions

The different plowing principles of European upland farming from Asian lowland-paddy farming, and the development of European and Asian plows to suit their farming are studied and are concluded as follows:

1) In general, the sizes of an upland field can be large because the field surface need not be flat. In the case of lowland-paddy cultivation, however, the field lots tend to be smaller because field surface must be flat for uniform depth of irrigation water application. A smaller field is easier to make and maintain a flat surface.
2) The "return plowing method" and the "continuous plowing method" performed by the one-way moldboard plow or disk plow are common in wide upland fields. And the "continuous return plowing method" is useful and more convenient to Asian narrow paddy rice fields. However, the reversible plow of two bottoms is not so convenient, while the turn-wrest plow is convenient to use.
3) As a rule, European plows may have good adaptability to both animal power and riding tractors, but not to hand tractors, while Japanese plows have good adaptability to animal power and, especially, to hand tractors.
4) Ordinary plows in Japan and Korea are also used to make ridges for upland cultivation. Therefore, their moldboards should have additional lifting property and sending-far performance to make furrows better. The European moldboard rotates the rectangular furrow without lifting it above the furrow-bottom surface. A European plow has good performance in inverting soil furrow slices, but not in ridging.

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(Continued on page 21)

Preparation of Medium-Textured Soil for Rice Production

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Abstract

Notwithstanding the ability of tractors to be used with diversified implements, farmers normally own a cultivator and use it nearly for all kinds of tillage practices. The sole use of cultivator cannot prepare land to the standard as required for the optimum nourishment of rice plant.

The study was conducted at adaptive research farm and farmers' fields in district Sheikhupura which lies in the main rice growing tract of Pakistan. Comparative performance of cultivator and rotary cultivator used independently and in different combinations to prepare medium textured soil for rice production was evaluated. It was established that the use of cultivator thrice followed by rotary cultivator once in manipulating soil was the most promising combination as it recorded significant increase in paddy yield.

Introduction

Texturally, fine and moderately fine soils such as clayey and clay loam having clay as dominant component are ideal for rice cultivation. These soils have high water holding capacity, less water intake rate and can support power unit and implements while being operated for puddling in standing water. However, due to the cash value of the crop and the food necessity in fact, farmers do its cultivation also in the medium textured soil, i.e., loam. Such soil is normally prepared dry as it cannot be puddled easily because of its inability to withstand load of draft animals or tractor.

The land preparation in rice cultivation differs from other crops. For rice, the basic qualification of the prepared soil is that it should be as compact and impermeable below the rooting depth as possible in order to impede the downward movement of water to the maximum. However, the root zone soil must be well pulverised and cultured for the proper nourishment of plants.

The use of diversified tillage implements is not possible under bullock farming. But the mechanical cultivation can easily achieve the objectives provided farmers are shown the benefits of using appropriate implements. At the moment, farmers owning tractors normally hold and use conventional cultivator for preparing rice fields. The cultivator is the only soil opening tool. It has less pulverizing action and least sealing effect at any level. As a result, many repeats of cultivator followed by planking are required to transform the soil into the condition where rice nursely can be transplanted. The only combination of cultivator and plank tend to compact the surface of soil instead of transforming impermeability below root zone. Such practice entail poor land manipulation at the cost of energy, time and machinery life and low yield of rice.

Research regarding the inter-relationship of soil, implement and crop is quite a new field. This study was carried out to eavluate the effectiveness of different tillage implements, used independently and in combinations, for preparing medium textured soil in rice production.

Material and Methods

The study was conducted during the rice seasons of 1982 and 1983 at adaptive research farm and farmer's fields in Sheikhupura district. Trials were laid out at the same six different sites selected for medium

Table 1 Soil Analysis of Medium Textured Soil of Different Sites

Site No.	Sand (%)	Clay (%)	Silt (%)	TSS (%)		pH		OM (%)		Available phosphorus (PPM)	
				1982	1983	1982	1983	1982	1983	1982	1983
1.	27	28	45	0.11	0.10	8.0	7.9	0.96	0.97	2.66	2.56
2.	30	23	47	0.21	0.25	7.8	7.6	0.90	0.91	3.00	2.56
3.	25	26	49	0.15	0.14	7.7	7.6	0.80	0.79	1.89	2.10
4.	37	21	42	0.22	0.25	7.6	8.0	0.56	0.70	2.00	2.50
5.	30	22	48	0.20	0.25	8.3	8.1	0.40	0.45	3.30	3.40
6.	31	23	46	0.19	0.15	8.1	7.8	0.52	0.51	2.20	3.00

textured soils during both years. Soil analysis given in **Table 1** was done by Soil Testing Laboratory, Sheikhupura every year before the start of soil preparation. Crop rotation, wheat-rice-wheat-rice, was followed. Trials were laid out in completely randomised block design with three replications in an area of about 2 acres at each site.

The fields were irrigated and prepared on coming to proper moisture level 'Wattar' with the following six treatments: i) cultivator, thrice; ii) cultivator, five times; iii) rotary cultivator, twice; iv) cultivator, thrice + rotary cultivator, once; v) cultivator, twice + rotary cultivator, once; and vi) cultivator, once + rotary cultivator, once.

These implements were operated to their normal depths, i.e., 15-18 cm in the case of cultivator and 8-9 cm under rotary cultivator. Having finished all the treatments, planking was done twice uniformly to give a final touch. The fields were again irrigated and the Basmati 370 rice variety was transplanted during the second week of July each year in standing water.

The N, P_2O_5 and K fertilizers was applied at the rate of 27 kg/acre in Basmati 370. Zinc Sulphate was applied at the rate of 5 kg/acre. Insect pests attack was observed below injury level. All other agronomic practices were adopted as per departmental recommendations.

Growth was recorded fortnightly. Productive tillers were counted at maturity and yield samples taken at appropriate stage. The two-year data were averaged and the percentage change of yields over control was calculated. Statistical and economic analysis were carried out to test the significance level and establish economic value of the study.

Results and Discussion

The quantitative average effect of different treatments on tillering and yield of paddy is presented in **Table 2**. Economic analysis computed on the basis of expenditure incurred additional to the check and extra benefit gained is shown in **Table 3**.

Yield

The yield of Basmati 370 fine rice, its percentage increase over check, productive tillers are given in **Table 2**. Statistical analysis of the yield data resulted in significant difference between treatment means at 5% level.

Land prepared with the use of cultivator thrice followed by rotary cultivator once recorded significantly the highest yield of paddy, i.e., 898 kg/acre. The yield was increased by 32.84% over the control where land was prepared using cultivator thrice only. The highest

Table 2 Effect of Different Techniques of Medium Textured Soil Preparation on Basmati 370 Fine Rice Production (Average of Two Years)

Treatment	Productive tillers (No./m²)	Paddy yield	
		kg/acre	% increase over control
Cultivator (3) + Plank (2) – Control	153	676	–
Cultivator (5) + Plank (2)	170	777	14.94
Rotary cultivator (2) + Plank (2)	155	689	1.92
Cultivator (3) + Rotary cultivator (1) + Plank (2)	180	898	38.84
Cultivator (2) + Rotary cultivator (1) + Plank (2)	159	704	4.14
Cultivator (1) + Rotary cultivator (1) + Plank (2)	162	713	5.47
		L.S.D= 134.40	

Table 3 Economic Analysis of Different Techniques of Medium Textured Soil Preparation on Basmati 370 Fine Rice Production (Average of Two Years)

Treatment	Total expenditure (Rs./acre)	Additional expenditure (Rs./acre)	Yield (kg/acre)	Gross income (Rs./acre)	Additional income (Rs./acre)	Cost-benefit ratio
Cultivator (3) + Plank (2) – control	1261.50	–	676	1606	–	–
Cultivator (5) + Plank (2)	1351.00	89.50	777	1845	239	1: 2.67
Rotary cultivator (2) + Plank (2)	1354.50	93.00	689	1636	30	1: 0.32
Cultivator (3) + Rotary cultivator (1) + Plank (2)	1440.00	178.50	888	2133	527	1: 2.95
Cultivator (2) + Rotary cultivator (1) + Plank (2)	1329.00	67.50	704	1672	66	1: 0.98
Cultivator (1) + Rotary cultivator (1) + Plank (2)	1360.50	99.00	713	1693	87	1: 0.88

a. Rate of use of implements (Rs./acre): 1. Cultivator = 30 2. Rotary cultivator = 70 3. Plank = 15; b. Rate of paddy = Rs.95/40 kg.

With Compliment

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yield is due to better tillering which was observed under this combination of implements. The better performance of this treatment seems to be the result of more soil opening at greater depth with repeated use of cultivator followed by high degree of pulverisation and tendency of compacting soil at lower layers with rotary cultivator.

The next best yield, i.e., 777 kg/acre was obtained with the use of cultivator five times. Enhancing the repeats of cultivator increases soil pulverization which improved tillering and yield. The sole use of rotary cultivator twice gave 689 kg/acre yield which was slightly better than the control. There was small improvement in tillering comparatively. The poor performance of this treatment seems to be due to less manipulated soil depth.

Economic Analysis

Economic analysis of the effect of different land preparation techniques of medium textured soil on Basmati-370 fine rice production is given in **Table 3**. The analysis was carried out on the basis of expenditure incurred additional to the control and the ultimate benefit gained. The highest yield recording treatment, i.e., cultivator used thrice plus rotary cultivator once showed better cost-benefit ratio of 1:2.95. It is evident from the analysis that spending one rupee additional to the control generated extra Rs. 2.95. The next best cost-benefit ratio (1:2.67) was obtained with the use of cultivator five times. However, the yield is less than the former treatment.

Conclusion

Appropriate implements are essential for suitable land preparation in order to obtain high per acre yield in rice. The use of cultivator thrice followed by rotary cultivator once is the promising combination for enhancing rice yield in medium textured soil. This combination also returns high benefit per unit cost of production. ■■

Study on Basic Knowledge of Plowing Science for Asian Lowland (Paddy Field) Farming

(Continued from page 18)

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ERRATA

AMA, Vol. 17, No. 4, Autumn 1986, pp.11-19: "Studies on Evolutional Steps for Plowing and Tractorization in Japan"

Page	Col.	Line	Error	Revision
12	1	20	generally smaller than	nearly equal to that
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Effect of Field Dimensions on Energy and Labour Consumption for Rotary Cultivating Small-Sized Plots

by
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Abstract

Tests under different field conditions were conducted on sandy-loam soil with a rotary cultivator mounted on a 4-wheel tractor, at different tillage depths, forward speeds and tiller speeds. The data recorded were travel time, fuel consumption, tillage depth, tiller speed, width of cut and soil moisture content for a test distance of 50 m. From the recorded data, the energy and labour consumptions in different plots ranging from 0.25 ha to 4 ha for different geometrical configurations were calculated. The geometry of a plot has little or no influence on the fuel consumption. The size and shape of field influenced the energy and labour consumptions and thus small-sized plots required relatievely more energy and labour per unit area than bigger plots. The direction of ploughing is an important factor from the viewpoint of time lost in turning. Small-sized plots have a higher percentage of time lost in turning than bigger plots.

Introduction

The application of machines to agricultural production has been one of the outstanding developments in the developed countries because of the fact that there is a correlation between yields and effective power per ha (Giles, 1975). Among the tractor operating costs, that of fuel is the major item and direct expense on the part of a farmer. Although spot shortage of fuel have occurred, the escalating price and its effect upon the cost of agricultural production are more pertinent issues to the farmers than the question of availability. Because of this, the machinery system managers are becoming more aware of the need to minimize the use of energy from the points of view of both conservation and economics. Field operations can be achieved with various combinations of machines which result in different basic energy requirements. So, from the increasing range of sizes, types and capacities of tractors and implements the farmer needs to select appropriate tractor-implement systems and operate them in most energy-efficient manners.

In the recent past attempts have been made in different parts of the world to produce a cheap, effective mechanical power source for small farms in less developed countries (Lewis, 1978, Larson et al, 1976, Pollard and Morris, 1979). Hanna et al (1979) conducted tests in field conditions with a 4-wheel 48kW and 2-wheel 13 kW tractor for Egyptian conditions and concluded that the 4-wheel tractor is not suitable for plot sizes less than 0.42 ha. Lee (1972) suggested that the optimum size of power unit required for a country should be determined by the farming methods and the gross national product of the country.

The average size of a family farm in many Asian developing countries is in the range of 1 to 3 ha for 89.4% of total farms and less than 5 ha for 96% of total farms (Sakai, 1979). Data on the suitable ratio between plot size and size of tractor and implement are still inadequate but it is well known that the total length and maneuverability are more important as limiting factor for efficient operation in short and small-sized fields. Also, since most of the farm energy is spent in tillage, it has been of interest to investigate the effect of field dimensions on energy and labour consumptions for rotary cultivating small-sized plots with a 4-wheel tractor.

Apparatus

A rotary cultivator equipped

with standard rigid L-shaped blades mounted on a 35 hp wheel tractor was used during the tests. The rotary cultivator had 3 right-hand and 3 left-hand blades per flange except for the end flanges which carried only 3 blades each. A gasoline fuel meter to measure the fuel consumption during the test runs, was also mounted on the tractor. A DC electric transmission type cradled dynamometer was used in the laboratory to measure the power output at different levels of fuel consumptions.

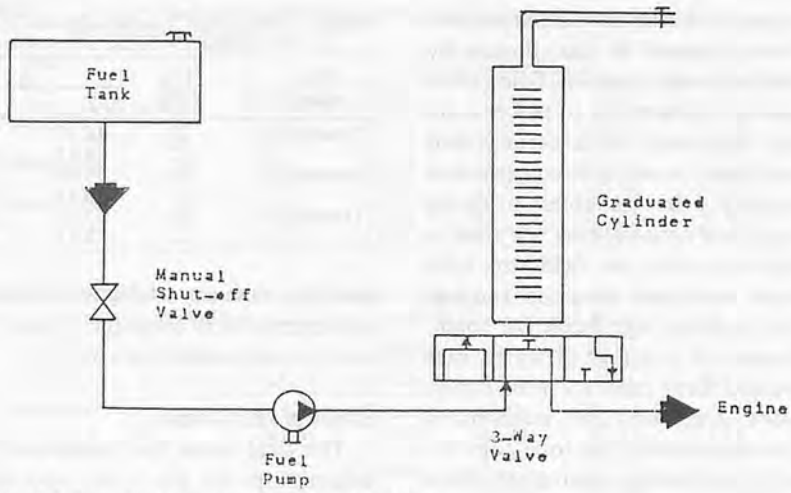

Fig. 1 Schematic diagram of gasoline fuel meter.

Fuelmeter Design Details

The gasoline fuelmeter which was used to measure the fuel consumption in the field is shown schematically in **Fig. 1**. The fuelmeter consists of a manually operated fuel pump, a 3-way valve and a graduated cylinder. The components were mounted on a plywood board which could be easily moved from tractor to tractor for field measurements. Mannually-operated 3-way valve routed the flow of gasoline in the desired path after the meter was connected in the fuel line between the shut-off valve and the carburetor. As can be visualized from **Fig. 1**, one position of the valve routed fuel from the tank to the carburetor; the second position of the valve pumped in fuel to the graduated cylinder and the carburetor while the third position routed the fuel from the graduated cylinder to the carburetor keeping the primary supply path to the cylinder or to the carburetor closed. These controls were within the reach of the operator's hand. The fuel level in the cylinder was maximum at 250 m*l* which could be read to the nearest 1 m*l*.

Experimental Procedure

The experiments were conducted in the vicinity of the Institute of Agricultural Engineering, Taastrup, Copenhagen. Since it was not possible to run the tractor in fields of different size and shape, field tests were accomplished in 50 m test length. The data for fuel consumption and time requirement were noted for each test run. The following test run was given at the adjoining strip and similar data were recorded. The average of the data was used to calculate the fuel and labour consumptions in different types of plots. From the fuel consumption data the power requirement was calculated using a calibration curve of fuel consumption rate (*l*/h) vs. power output (kW) at the PTO shaft. The field tests were done at different tillage depths, rotor speeds and forward speeds at two levels of engine revolutions, such as 1 400 and 1 700 r/min. Tests for turning time were conducted separately using the individual wheel brakes to take turn at the corner. **Fig. 2** shows the pattern and dimensions of different shapes of plots taken into consideration for calculating energy and labour consumptions in different sizes.

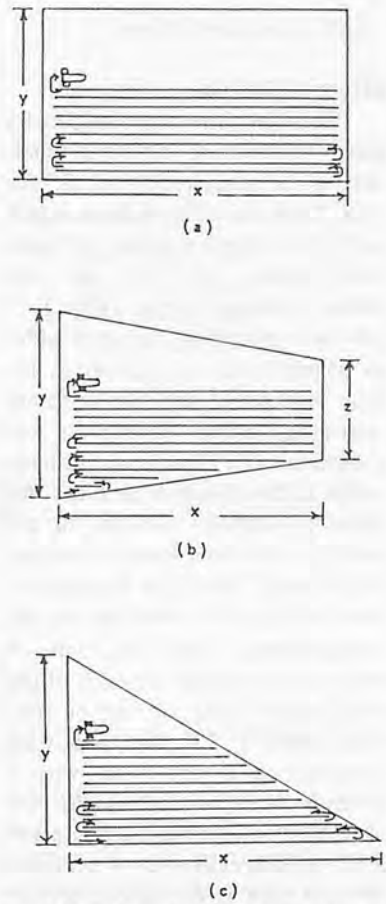

Fig. 2 Pattern and different dimensions of plots: (a) Rectangular, (b) Trapezoidal and (c) Triangular.

Results and Discussion

Time consumptions

The total time consumption to cultivate a field depends on many factors, such as theoretical capacity of the machine, machine maneuverability, field size, field shape, time

losses in turning and forward speed. Forward speed is also, limited by the nature of operation, field condition and the amount of power available. However, for a certain field condition, power unit and machine capacity, the variables affecting total time consumption for a particular operation are field size, field shape and time losses in turning. This is more significant for small, fragmented holdings in which case reduced field capacity with consequent high cost of mechanized operation result. The total time for rotary cultivating small-sized fields has been found to be influenced by the factors mentioned above each of which is discussed below.

Effect of field size

The total time consumption for rotary cultivating different small-sized plots, such as 0.25 ha, 0.5 ha, 1 ha, 2 ha and 4 ha has been calculated for a forward speed of 1 m/s and turning time 10 s per turn which is shown in the **Table 1**. It has been calculated for two width to length ratios (y/x), that is, the time required if the plot is rotary cultivated either lengthwise or widthwise. The total time has been taken as the effective time the machine is actually working in the field plus the time losses in turning at the ends. Time loss for support functions has been omitted with an understanding that this will be more or less similar for each of the plots under study. It can be seen from **Table 1** that the total time consumption is not linear with a linear increase or decrease in plot size. The total time consumption goes on decreasing non-lineary as the plot size is decreased, i.e. the cost of mechanized operation, with a four wheel tractor, for small holdings is higher than that for bigger plots. The cost of cultivation will still be higher if the plots are scattered because of the time losses for travelling between fields. Thus, it is observed that small-sized plots have the tendency of higher labour employment with consequent higher cost for mechanized operation.

Table 1 Total Field Time as Affected by Plot Size and Shape ($v = 1$ m/s, $t = 10$ s)

Plot shape	y/x ratio	Total time, min				
		0.25 ha	0.5 ha	1 ha	2 ha	4 ha
Triangular	½	46.77	89.05	171.43	333.70	654.22
	2	54.61	99.55	186.93	355.17	685.39
Rectangular	½	44.61	85.71	166.93	327.20	645.22
	2	50.11	93.55	177.43	342.70	667.22
Trapezoidal	½	43.44	84.38	164.93	324.37	641.22
	2	48.11	90.72	173.93	337.20	659.22

Effect of field shape

The field shape has a significant influence on the total time spent in small plots. The time required for three different shapes of plots have been compared in this study. It can be observed from **Table 1** (Ullah, 1983) that triangular shaped plots need more time than rectangular or trapezoidal shaped plots. Of the different shapes of plots, the trapezoidal shape needs the least time. Obviously, the reason is the length to width ratio of the field. The dimensions of field which determine the field shape is the most important factor controlling total time consumption. Hanna et al (1979) also concluded that the field dimension is a major factor influenced field efficiency.

Effect of turning time

The time lost in taking turns largely depend on the direction of ploughing. If the ploughing operation is done in the longer direction of the plot less number of turns is required and time lost in turning is less. It is worth noting that as the plot size increases the total turning time per unit area decreases. This is evidenced by the **Fig. 3** which shows the effect of different shapes and sizes of plots on the ratio of total turning time to total field time. It can be observed from the figure that smaller plots have more time

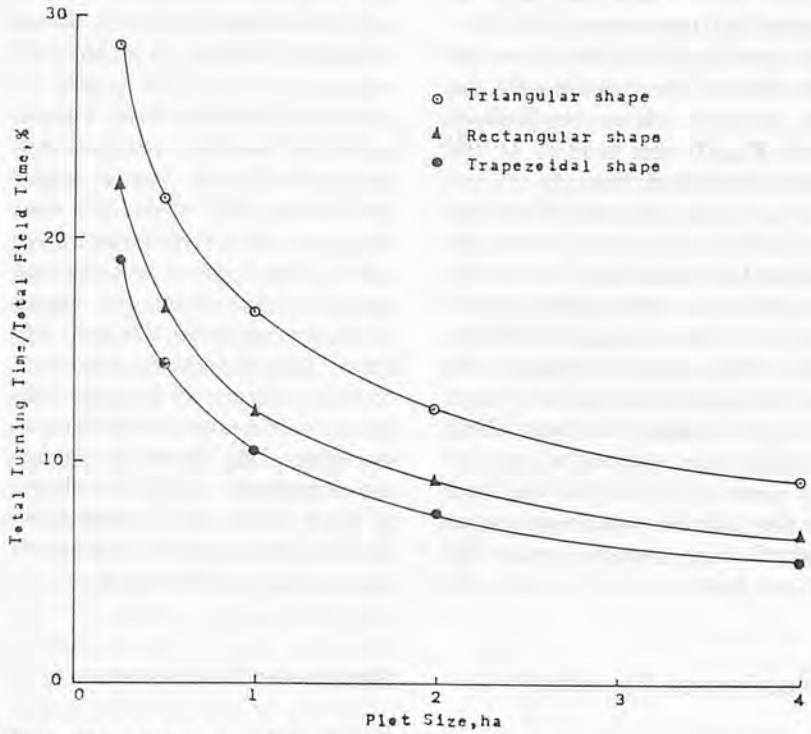

Fig. 3 Effect of plot size and shape on the total turning time.

lost due to turns. Hence, it can be inferred that the smaller the plot size the higher the percentage of time lost due to turns which is a great loss of labour and constraint to mechanized operation.

Energy consumptions in small plots

The energy consumption to rotary cultivate a certain plot depends on factors like soil strength, soil type, tilling depth, forward speed, quality of tillage, etc. Since energy is measured as the product of time and power; and the time-requirement has been found to depend on plot size, shape and turning time, the energy requirement is also, to some extent, dependent on these factors, especially for small holdings. However, the effect of these factors are discussed individually.

Effect of field size

The energy consumptions for different plots have been calculated to rotary cultivate at a depth of 85 mm with forward speed of 1 m/s. The fuel consumption rate at this speed and depth has been found to be 7.8 *l*/h. **Table 2** shows the total fuel consumption to rotary cultivate different plots. It can be observed from the table that there is not much variation in the fuel consumption whether the plot is rotary cultivate in the longer direction or in the shorter direction. The geometry of the plots is also found to have little or no influence on the fuel consumption. The fuel consumption varies linearly with the plot size.

The energy required to rotary cultivate the plots in one pass is shown in **Table 3** which shows that there is a linear relation between plot size and the energy required to work a soil. However, a precise judgement can be made from **Fig. 4** which has been drawn as the average energy required per hectare (calculated from **Table 3***) vs. the different size of plots. The figure shows that the smaller plots, on the average, consume more energy than bigger plots. Hence it can be concluded that smaller holdings consume relatively more energy per unit area than bigger holdings.

*Brake measurements have shown that 7.8 *l*/h equals 15.6 kW or 1 *l* equals 2.0 kWh

Table 2 Fuel Consumption as Affected by Plot Size and Shape at a Speed of 1 m/s and Working Depth of 8.5 cm

Plot shape	y/x ratio	Fuel consumption, *l*				
		0.25 ha	0.5 ha	1 ha	2 ha	4 ha
Triangular	½	5.17	10.27	20.45	40.79	81.40
	2	5.27	10.41	20.65	41.07	81.81
Rectangular	½	5.14	10.23	20.40	40.70	81.29
	2	5.21	10.33	20.53	40.90	81.57
Trapezoidal	½	5.12	10.21	20.37	40.67	81.23
	2	5.18	10.29	20.49	40.83	81.47

Table 3 Energy Requirements as Affected by Plot Size and Shape at a Speed of 1 m/s, Working Depth of 8.5 cm and Fuel Consumption Rate of 7.8 *l*/h

Plot shape	y/x ratio	Energy requirements, kWh				
		0.25 ha	0.5 ha	1 ha	2 ha	4 ha
Triangular	½	10.33	20.54	40.91	81.58	162.80
	2	10.53	20.82	41.31	82.15	163.61
Rectangular	½	10.27	20.45	40.79	81.41	162.57
	2	10.41	20.66	41.06	81.81	163.14
Trapezoidal	½	10.24	20.42	40.74	81.34	162.47
	2	10.36	20.58	40.98	81.67	162.94

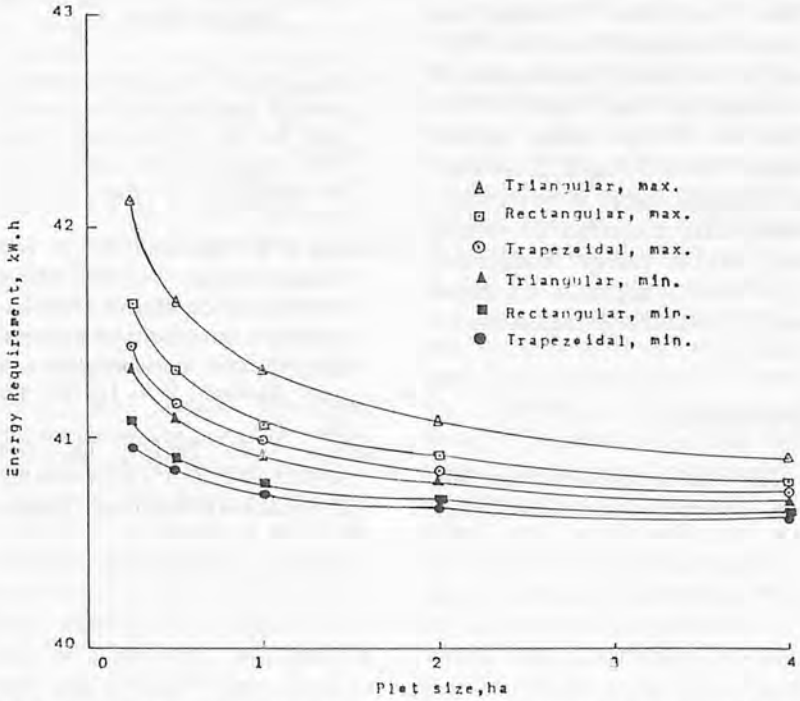

Fig. 4 Average energy requirement per ha for different plot size and shapes (v = 1m/s, fuel consumption rate = 7.8*l*/h, tillage depth = 8.5 cm)

Effect of field shape

The geometry of a plot has a very little effect on energy requirement. From **Table 3**, if the energy required for 0.25 ha triangular and rectangular plots is compared, the variation can be observed to be about 1.1% while the variation for triangular and trapezoidal plots is about 1.6%. For bigger plots the difference is even less than 1%. The effect of geometry of field can also be seen from **Fig. 4** which shows that the average energy consump-

tion per hectare for triangular plot is higher than rectangular or trapezoidal plots. But the difference is very little. Further, the difference decreases as the plot size increases. Hence it may be said that field shape has little influence on the energy requirement and the magnitude of variation decreases with the increase of plot size.

Effect of turning time

The energy expended in turning has been calculated by multiplying the total turning time with the no-load power requirement. This is a very small quantity, especially, when expressed in kWh. From **Table 3** the effect of turning time can be determined from the difference of the energy requirements of a certain size and shape of plot (each plot has two energy requirements). The difference, in all cases, is very small. Hence it may be concluded that the effect of turning time on the energy requirement of a plot is negligible compared with the total energy requirement.

Conclusions

The results obtained from field tests reveal that small-sized plots consume relatively more labour per unit area and the ratio of turning time to effective operating time is higher. Field shape affects the turning time and thereby brings about a change in the magnitude of time lost. Of the three shapes compared, the triangular plot is found to consume relatively more time.

The size of field has a linear relationship with the amount of fuel consumption. Small-sized plots consume more energy per unit area than bigger plots. Energy consumption is influenced negligibly by plot shape or turning time.

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Flat and Broadbed-and-Furrow Systems of Cultivation

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Abstract

The paper reports on the results of an experiment conducted for 3 years (1981–83) to evaluate the performance of flat and broadbed-and-furrow systems of cultivation. The study initially aimed at quantifying the time required for land preparation and other operations and to determine the crop response on the two systems when prepared with different implements. The other objective was to quantify the effect of different levels of weeding which was added in the third year of the experimentation. The land preparation operations in all the treatments was done using respective sets of implement allocated for each of them, the planting (cowpea in 1981 and 1982 and sorghum in 1983) was done uniformly using hand planter in 1981 and 1982 on one single day and using a locally adapted two-row planter, in 1983, in two stages. In 1983 weeding was done using wheeled tool carrier incorporating different weeding treatments while during earlier years weeding on traditional implement treatment was carried out using traditional 5-time cultivator.

The broadbed-and-furrow system of cultivation did not present the expected advantage of higher in-situ rainwater harvesting and soil moisture retention due to the high slopes of the furrows (approx. 1%).

The improved animal-drawn implements, namely, wheeled tool carrier, presented higher time-saving advantage over traditional implements when used for broadbed-and-furrow system as compared to the flat cultivation system. The tractorized implements required much less time for different operation but consume much higher HP-hour as compared to animal-drawn implements for both systems.

The soil resistance to penetration was much higher in the furrows as compared to the cropped row for both systems. The severe draught during the period of experimentation resulted in total failure of the crop in 1981 and 1982 and very low yield of sorghum in 1983. However, the principal treatments did show any effect on the initial crop development during 1981 and 1982 but the two planting dates and different levels of weedings showed definite effects on sorghum yield in 1983.

Introduction

The broadbed-and-furrow system of cultivation (Lal, 1981) is being experimented by CPATSA-EMBRAPA (Agricultural Research Centre for Semi-Arid Tropics/ Brazilian Enterprise for Agricultural Research) Petrolina (PE), at its research farm and on farmers' fields at various locations in northeast Brazil as an alternative to traditional flat cultivation system for agriculture totally dependent on rainfall and for agriculture supported by supplemental irrigation. These efforts, for the last seven years, are basically aimed at increasing and stabilizing agricultural production of basic crops in semi-arid climate of northeast Brazil. The broadbeds are laid out on contour for agriculture totally dependent on rainfall and on certain slope upto 0.4% when the furrows are to be used for supplemental irrigation. Up until 1979 land preparation and planting were done by tractorized implements (plow, harrow and ridger) and hand tools were used for other operations such as planting, weeding and harvesting. With the development of wheeled tool-carrier type machinery package (Lal and Nunes 1981), it became possible to carry out land preparation operations for broadbed-and-furrow system of cultivation using animal power.

Theoretically, the introduction of wheeled tool-carrier for land preparation reduced considerably the amount of energy input for the system. The three operations: plowing, harrowing and ridging done with tractor require approximately 7.5 tractor-hours, leading to approximately 450 hp hours; if a 60 hp tractor is used and is assumed to

be operating at full capacity for all the operations. On the other hand, the wheeled tool-carrier with a pair of bullocks can prepare the land in approximately 10 h thus requiring only 10 hp hours assuming a pair of bullock producing 1 hp during each operation. However, the response of the crop planted under the two methods of preparation (tractorized implement and animal-drawn implements) could be different due to different level of tilth (seedbed) achieved.

With these points in view, an experiment to evaluate the broadbed-and-furrow system in comparison to the flat system of cultivation using tractorized and animal-drawn implements was initiated in 1981 at the Cattingha Experiment Station of CPATSA-EMBRAPA. The phisycal characteristics of the soils of the experiment site are presented in **Table 1**.

Table 1 Physical Characteristics of Soils at Experiment Site

Soil depth cm	Granumetric analysis, %			Natural clay	Density g/cc	
	Sand	Silt	Clay	%	Real	Apparent
0 – 10	85	8	7	4	2.65	1.64
10 – 20	83	9	8	5	2.63	1.65
20 – 30	77	10	13	8	2.82	1.64
30 – 45	74	11	15	8	2.62	1.67
45 – 60	69	13	18	11	2.65	1.56

The main objectives of the experiment were: i) to quantify the time required for soil preparation and other operations using different types of implement sets for the two systems of cultivation; and ii) to quantify the crop response from flat and broadbeds when prepared with different implement sets.

Another objective was added in 1983 aimed at quantifying the effects of different levels of weeding (no weeding, mechanical weeding and mechanical weeding plus inter-row hand weeding) on crop production under different soil preparation/implement treatments.

The experiment was conducted for three cropping seasons (1981–83) with cowpea as test crop for the first two years and sorghum during the third year. The experiment encountered problems as follows:

i) a severe draught during 1981–83 prevented any harvest during 1981 and 82 and very low sorghum yield in 1983;
ii) large area under experimentation (approximately 3 ha) and wide variation in soil fertility on experiment site resulted in non-uniformity in crop establishment and its stand.
iii) field operations (plowing, harrowing, ridging and planting) along the length of each parcel to increase field capacity resulted in the slope of approximately 1% for broad bed-and-furrow system, thus increasing the surface runoff and eliminating the expected advantage of in-situ rainwater harvesting of the system;
iv) the equal size of each plot (approx. 0.3 ha) for three level of mechanization (animal-drawn traditional and improved implements and tractorized implements) resulted in great variation in time requirement for similar operations for the two systems;
v) existence of an irrigation channel at one end of the experimental field caused turning problem for tractor thus decreasing field capacity; and
vi) some of the implements, particularly the wheeled tool-carrier, were under development stage during the initial period of the experiment thus causing delays in the critical operations.

However, even with these problems, the experiment yielded some interesting information.

Methodology

The experiment was initially planned with nine treatments with no replications: (1) flat with traditional implements; (2) flat with Multicultor CPATSA (a locally developed wheeled tool-carrier); (3) flat with Tropicultor (an imported wheeled tool carrier); (4) flat with alcohol tractor; (5) flat with diesel tractor; (6) broadbed-and-furrow with Multicultor CPATSA; (7) broadbed-and-furrow with Tropicultor; (8) broadbed-and-furrow with alcohol tractor; and (9) broadbed-and-furrow with diesel tractor.

Based on the experience in the first year of experimentation it was decided to merge the treatments of two types of wheeled tool-carrier and that of two types of tractors both for flat and broadbed-and-furrow system of cultivation (0.3 ha each parcel) thus considering them as a replicate rather than a separate treatment resulting in five treatments instead as follows:

(i) flat with traditional implements (one replication);
(ii) flat with wheeled tool carrier (two replications);
(iii) flat with tractor (two replications);
(iv) broadbed-and-furrow with wheeled tool carrier (two replications); and
(v) broadbed-and-furrow with tractor (two replications).

This modification was principally done to simplify the experiment and to increase the reliability of data from treatments with low time demanding field operations.

The land preparation operations in all the treatment, was done using the respective set of implement allocated for each of them. Planting (cowpea) during 1981 and 82 and sorghum in 1983 was done uniformly using hand planter (Tico-

Tico) in 1981 and 1982 and a locally adapted animal-drawn two-row planter in 1983.

During 1981 and 1982 the entire area was planted on a single day. However, in 1983 due to uncertainty of climatic conditions the planting was carried out in two stages, selecting one replicate in treatments 2, 3, 4, 5 and half area of treatment 1 for planting with first shower on December 27, 1982 and rest of the area on Jan. 20, 1983. At weeding stage of crop development in 1983, the three levels of weeding treatments were made. In order increase the probability of getting some reliable information under a wide variation of crop stage at the time of introduction of weeding treatments, each plot (replicate or half parcel of treatment 1) were divided into three sub-replicates and in each sub-replicate the three levels of weeding treatments were introduced on random basis thus achieving four crops rows for each weeding treatments in each sub-plots in treatments 2, 3, 4 and 5 and two rows in treatment 1 thus practically leading to 30 replications for different levels of weeding treatments.

The weeding operation during 1983 was carried out uniformly over all main treatments with different levels of weeding treatments while in earlier years it was done using a traditional 5-tine cultivator.

The treatment of "cultivation of broadbed-and-furrow system with traditional implements" was not included in the experiment because of the non-suitability of traditional animal-drawn implements for managing broadbed-and-furrow system.

Table 2 Time Required for Different Operations for Cultivation on Flat and Broadbed-and-Furrow System Using Different Implements

Operations (period)	Unit**	Treatments* 1	2	3	4	5
	1981					
Land preparation (Cultivation and ridging)	BPH/ha	4.4	3.3	4.7		
(Feb. 1981)	TH/ha				0.9	2.5
Planting (Mar. 81)	MH/ha	1.4	2.2	1.8	2.8	2.3
Weeding (Apr. 81)	BPH/ha	5.8	6.3	2.6	5.0	4.8
Total	HPHr/ha	10.4	9.8	7.5	57.3	155.0
	1982					
Land preparation (Cultivation and ridging)	BPH/ha	4.0	3.0	4.2		
(Dec. 1981)	TH/ha				0.8	2.3
Planting (Dec. 81)	MH/ha	2.3	2.0	1.6	2.5	2.1
Weeding (Jan. 82)	BPH/ha	5.3	5.7	2.3	2.6	4.4
Total	HPHr/ha	9.5	8.9	6.7	50.9	142.6
	1983					
Land preparation (Cultivation and ridging)	BPH/ha	19.2	19.9	11.4		
(Jun.–Dec. 1982)	TH/ha				3.3	5.6
Planting (Dec. 81/Jan. 83)	MH/ha	3.3	3.5	2.9	3.4	2.8
Weeding (Feb. 83)	BPH/ha	–	–	–	–	–
Total	HPHr/ha	22.4	23.4	14.3	201.4	338.8
Overall total (81, 82 & 83)	HPHr/ha	42.3	42.1	30.7	309.6	636.4

*Treatments: (1) Flat with traditional implements. (2) Flat with wheeled tool carrier. (3) Boradbeds-and-furrow with wheeled tool carrier. (4) Flat with tractor. (5) Boradbed-and-furrow with tractor.

**BPH/ha–Bullock pair hours per ha; TH/ha–Tractor hours per ha; MH/ha–Man hours per ha; HPHr/ha–Horse power hour per ha calculated with the assumptions: 1 BPH = 1 HP Hr, 1 MH = 0.1 HP Hr, 1 TH = 60 HP Hr.

Results and Discussion

Cultivation Requirements

The time required for various operations for different treatments over three cropping seasons has been grouped into three categories: i) time for land preparation; ii) time for planting; iii) time for post-emergence operations.

Table 2 shows the time spent for various groups of activities in terms of bullock pair hours, man-hours and tractor-hours for three cropping seasons and indicates that improved animal-drawn implements, namely; wheeled tool-carrier, present higher time-saving advantages over traditional implements when earlier used for broadbed-and-furrow system as compared to flat cultivation system. The tractorized implements required much less time for different operations but consumed much higher HP hours as compared to animal-drawn implements (traditional or improved) for both the systems. The management of broadbed-and-furrow system with tractorized implements consumed much more time compared to flat cultivation when managed by similar implements.

Soil Moisture Variation

The soil moisture content was measured using gravimetric method in the planting rows (mean of 5 observations) during the 1982 and 1983 cropping seasons. **Table 3** shows the soil moisture content over three periods (Jan. 16 to Jan. 27, 1982; Feb. 27 to March 8, 1982 and Dec. 27, 1982 to Jan. 12, 1983) observed under different treatments at non-regular interval. Though the soil moisture was measured throughout the cropping seasons the periods shown in **Table 3** were selected because they were considered critical in judging the ability of different treatments to store and retain soil moisture. These periods started immediately after heavy showers (49.4 mm on Jan. 15, 1982, 21.6 mm on Feb. 27, 1982 and 38.9 mm on Dec. 26, 1982) followed by dry spell.

The values in the **Table 3** can only be considered as indicative because of low number (10 only) of soil moisture reading over a waste area of 0.30 ha but they do bring

Table 3 Soil Moisture Content (percentage dry weight basis) under Flat and Broadbed-and-Furrow Systems of Cultivation Using Different Implements

Date	Soil depth									
	0 – 15 cm					15 – 30 cm				
	Treatments*									
	1	2	3	4	5	1	2	3	4	5
16.01.82	9.72	8.67	9.37	9.48	7.33	8.98	8.31	7.54	8.60	6.21
18.01.82	7.31	6.73	5.93	6.06	6.48	6.70	7.10	8.03	6.53	5.58
25.01.82	3.83	3.63	3.24	2.65	2.53	5.55	5.80	4.86	4.14	3.63
27.01.82	2.71	2.48	2.83	3.56	2.53	4.58	3.99	4.54	6.58	3.37
27.02.82	7.96	9.42	8.94	9.71	9.12	5.84	4.78	5.48	5.61	4.88
02.03.82	8.04	7.92	7.18	7.53	6.12	7.33	8.57	6.62	7.06	5.56
05.03.82	4.01	4.62	3.36	3.67	3.49	4.79	4.66	5.66	5.77	5.09
08.03.82	2.70	3.09	2.46	2.97	2.57	3.32	4.70	3.84	3.98	3.52
27.12.82	10.97	11.08	9.05	9.70	9.36	7.53	8.90	6.09	8.13	7.29
29.12.82	6.84	6.95	6.51	5.59	6.61	7.13	6.59	4.33	4.58	4.61
31.12.82	6.53	5.59	5.17	4.87	5.13	6.57	6.44	4.44	5.58	4.86
03.01.83	4.80	4.70	4.80	4.87	4.07	5.79	5.09	3.87	5.33	4.52
12.01.83	2.44	2.99	2.26	2.79	2.45	5.58	5.19	3.74	5.13	3.28

*Treatments: 1–Flat with traditional implements; 2–Flat with wheeled tool carrier; 3–Broadbed-and-furrow with wheeled tool carrier; 4–Flat with tractor; 5–Broadbed-and-furrow with tractor.

Note: Underlined observations show inconsistancy in data. Planting on Dec. 30, 1981 and Dec. 27, 1982.

Table 4 Soil Resistance to Penetration[a] (kg/cm^2) under Flat and Broadbed-and-furrow Systems of Cultivation Using Different Implements.

Date	Location	Treatments[b]				
		1	2	3	4	5
29.12.83	Surface:					
	Crop row	2.63	1.92	2.17	1.70	1.91
	Furrow bottom	–	–	2.75	–	3.63
	15 cm depth:					
	Crop row	18.43	17.23	7.55	14.90	11.73
	Furrow bottom	–	–	7.94	–	23.52
12.01.83	Surface:					
	Crop row	3.06	1.54	1.74	1.09	3.13
	Furrow bottom	–	–	4.58	–	5.43
	15 cm depth:					
	Crop row	9.05	16.34	13.46	16.29	17.69
	Furrow bottom	–	–	19.94	–	20.51

a–Measure by Cone Penetrometer of "SOLO TESTE-S210", Rua Cons. Carrão, 275 (Bela Vista), São Paulo (SP), Brazil.

b–Treatments: (1) Flat with traditional implements; (2) Flat with wheeled tool carrier; (3) broadbed-and-furrow with wheeled tool carrier; (4) Flat with tractor; (5) Broadbed-and-furrow with tractor.

out a comparative evaluation of the different treatments. As expected and explained earlier, the broadbed-and-furrow system performed poorly in terms of soil moisture conservation as compared to traditional flat cultivation due to high slope of furrow both with tractorized and animal-drawn implements. The other factor which might have contributed to a high rate of moisture loss from broadbed-and-furrow system could be the high exposed area in this system. According to Lippitz (1982) if sowing is followed by a lengthy dry period there is a risk that soil will dry out rapidly in ridged system as compared to flat.

Soil Resistance to Penetration

The soil resistance to penetration was measured during 1983 cropping season on two dates to estimate the soil compaction on the surface at 15 cm depth. The instrument used for the purpose was the cone penetrometer (SOLO TESTE S210). **Table 4** shows the values of soil resistance to penetration observed on the cropped row for the two systems along with its values in furrows for broadbed-and-furrow system of cultivation. The soil resistance to penetration on the cropped row did not vary much for different treatments. However, the furrow bottom of broadbed-and-furrow system was found highly compacted both for tractorized and animal-drawn implements. As expected the tractorized implements caused higher compaction in the furrow-bottom as compared to animal-drawn implements, thus reducing the infiltration and increasing the surface runoff resulting in low moisture contents in these treatments.

Crops Establishment and Stand

The observations on crop establishment and development were recorded during the 1982 and 1983 cropping seasons. Though planting during the seasons was done uniformly using hand planter "Matraka" in 1982 and an animal-drawn planter in 1983 on all the treatments, observations on plant stand showed some variations right at the initial stages during both seasons. **Table 5** shows initial plant stand and height recorded during various stages of crop development for cowpea in 1982. The low stand under flat cultivation treatments was due mainly to wide row spacing and distance between the hills within the rows caused by human error in planting. The possibility of such error on the broadbed-and-furrow system is considerably reduced due to the presence of equi-distance furrows. The plant height was almost uniform at the initial stages. A slightly lower plant height has been registered for the broadbed-and-furrow system which could be attributed to low moisture availability.

On the other hand, the stand of sorghum crop (**Table 6**) though varied slightly among various treatments did not show any definite effect on different soil cultivation as planting was done by pre-calibrated animal-drawn planter thus

reducing the possibility of human error. The crop stand for the second planting was generally higher than the first planting.

Effect of Weeding

In order to evaluate the effect of different levels of weedings, the effect of variation of stand and crop development within different principal treatments was reduced by sub-dividing each plot and introducing various weeding treatments. The three yield samples (sorghum-grain and fodder) of 10 m length each sub-plot thus covering an area of 7.5 m^2 were collected in each weeding treatments of different sub-plots. The sample area where plants did not bear cobbs (grain) were considered zero for grain as well as fodder production. Appendix A shows the mean values of three samples of grain and fodder (in grams) harvested from different treatment systems.

The effects of various treatments were estimated and shown in **Table 7** for sorghum crop yield (grain and fodder). Though the overall yield of 159.4 kg/ha for grains and 1 424.7 kg/ha for fodder is very low compared with potential yield of the crop under normal situation, under the climatic conditions of the experimentation year with use of fertilizer, no better yield could have been expected. Even with these low yield values, the weeding treatments and date of planting contributed to the yield.

The mechanical weeding, supplemented by hand weeding, increased the grain yield approximately by 10 times as compared to no weeding and only mechanical weeding treatments. The fodder yield increased approximately 4 and 15 times in the mechanical weeding and mechanical plus hand weeding treatments when compared with the no weeding treatment.

The plots planted during the first rain produced approximately 2.4 times the grains in the plots planted after second rain, with no significant difference in the fodder yield. This indicates that the vegetative growth of the crop planted after the second rain was equal to that of the crop planted after first rain, but the crop planted later suffered moisture stress in grain setting and thus resulted in low grain yield.

The main treatments of flat and broadbed-and-furrow systems of cultivations with different implement system did not effect the grain and fodder yields as distinctly as the weeding and planting dates treatments did. However, higher grain and fodder yield have been

Table 5 Plant Stand and Development of Cowpea under Flat and Broadbed-and-Furrow System of Cultivation Using Different Implements.

Date	Treatments				
	1	2	3	4	5
	Stand (plants/ha)				
06.01.82	37,968	37,070	51,067	37,832	52,698
	Plant hight (cm)				
06.01.82	11.00	11.10	11.95	10.40	11.10
22.01.82	19.40	18.00	18.90	18.40	17.90
12.02.82	31.00	32.55	28.30	32.85	30.15
04.03.82	34.10	38.15	37.55	41.75	37.00

Treatments: (1) Flat with traditional implements; (2) Flat with wheeled tool-carrier; (3) Broadbed-and-furrow with wheeled tool-carrier; (4) Flat with tractor; (5) Broadbed-and-furrow with tractor.

Table 6 Sorghum Stand under Flat and Broadbed-and-Furrow Systems of Cultivation Using Different Implements.

Date	Treatments*					Mean
	1	2	3	4	5	
	Stand (plants/ha)					
04.01.83**	188 266	139 600	191 200	155 066	144 834	163 793
31.01.83***	184 800	234 800	268 400	284 134	256 866	247 600

*Treatments: (1) Flat with traditional implements; (2) Flat with wheeled tool-carrier; (3) Broadbed-and-furrow with wheeled tool-carrier; (4) Flat with tractor; (5) Broadbed-and-furrow with tractor.

**Planted on December 27, 1982; ***Planted on January 20, 1982.

Table 7 Effect of Various Treatments on Sorghum Grain and Fodder Yields

Treatment	Yield (kg/ha)	
	Grain	Fodder
Weeding:		
No weeding	33.2	220.4
Mechanical weeding	38.9	885.7
Mechanical weeding + Hand weeding	405.5	3166.7
Mean	159.2	1424.7
Planting Date:		
27.12.82	224.7	1354.7
20.01.83	94.0	1494.7
Mean	159.4	1424.7
Main Treatments:		
Flat with traditional implements	135.8	816.9
Flat with wheeled tool carrier	193.0	1903.1
Broadbed-and-furrow with wheeled tool carrier	145.4	1637.9
Flat with tractor	218.5	1930.0
Broadbed-and-furrow with tractor	101.6	835.3
Mean	158.9	1424.7

obtained under flat cultivation system as compared to broadbed-and-furrow system for both types of implement systems (which may be attributed to low moisture availability.

Conclusions

The improved animal-drawn implements, namely, wheeled tool-carrier, present higher time-saving advantage over traditional animal-drawn implement when used for braodbed-and-furrow system as compared to flat cultivation systems.

The tractorized implements, though requiring much less time for different operations, result in consuming much higher HP-hours as compared with animal-drawn implements (traditional and improved) for both systems.

The broadbed-and-furrow system performed poorly in terms of in-situ rainwater harvesting and soil moisture conservation as compared to flat cultivation due to high slope of furrows both for the tractorized and animal-drawn implements.

The soil resistance to penetration was much higher in the furrow as compared to cropped row for both the system.

Even as the severe draught during the period of experimentation resulted in total crop failure during 1981 and 82 and very low yield in 1983, the different treatments did show appreciable effect on crop establishment and initial crop development during the three cropping seasons.

The mechanical weeding supplemented by hand weeding increased the sorghum grain yield approximately 10 times as compared to other weeding treatments.

The plots planted during the first rain produced approximately 2.4 times the grain in the plots planted after the second rain with no significant difference in the fodder yield.

Appendix A Sorghum (Grain and Fodder) Yield from Different Treatments

Planting date	Main treatment plot	Sub plot	Grain (fodder) harvested, g/7.5m² *		
			Weeding treatments		
			No weeding	Mechanical weeding	Mechanical hand weeding
27.12.82	Flat with traditional implements	A	0	0	400.0 (2117)
		B	100.0 (180)	0	310.3 (2497)
		C	291.6 (1565)	66.6 (827)	498.3 (2193)
	Flat with wheeled tool carrier	A	0	150.0 (3767)	773.0 (4755)
		B	0	375.0 (5246)	456.0 (2627)
		C	0	0	344.0 (2170)
	Broadbed-and-furrow with wheeled tool-carrier	A	0	66.6 (1133)	391.6 (2013)
		B	0	66.6 (1060)	341.6 (2083)
		C	0	0	466.6 (2585)
	Flat with tractor	A	0	0	425.0 (2170)
		B	0	0	661.6 (4360)
		C	155.5 (233)	0	331.0 (1333)
	Broadbed-and-furrow with tractor	A	0	0	383.3 (863)
		B	0	0	333.3 (1046)
		C	0	0	161.6 (897)
20.01.83	Flat with traditional implements	A	0	25.0 (233)	200.0 (1056)
		B	0	0	41.7 (360)
		C	0	0	0
	Flat with wheeled tool carrier	A	0	0	232.3 (2780)
		B	0	0	116.6 (2497)
		C	0	0	158.3 (1850)
	Broadbed-and-furrow with wheeled tool-carrier	A	0	41.7 (4333)	316.6 (5106)
		B	0	0	206.6 (2375)
		C	0	0	65.0 (1423)
	Flat with tractor	A	0	66.6 (2637)	391.6 (6356)
		B	91.6 (144)	0	660.0 (4373)
		C	0	0	166.0 (5153)
	Broadbed-and-furrow with tractor	A	0	0	16.6 (1200)
		B	0	0	33.3 (1350)
		C	108.0 (1540)	16.6 (693)	320.0 (3688)

*Average of three samples

Recommendations

In the arid and semi-arid climate of northeast Brazil and in other similar regions, the introduction of soil management system should be done with proper orientation. The broadbed-and-furrow system, if laid out on higher slope would not only reduce its expected advantage of in-situ rainwater harvesting and soil moisture conservation but also could reduce crop yield under low and limited rainfall.

Under uncertain rainfall situations like in northeast Brazil, one could gain by planting the crop during the first rains and carrying out required weeding operations at appropriate timing.

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Energy Consumption in Rice Processing Operations in Nigeria: Selected Case Studies

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Abstract

The bulk of energy consumed in agriculture arise from components connected with primary production, processing and transportation, and food preparation and preservation. Energy consumption associated with processing can often be substantial.

This paper deals with a study conducted to determine the energy consumption in post-harvest rice processing operations as carried out in two rice mills in Nigeria, one of which is a modern integrated plant. The experimental design allowed the energy consumed in each unit operation to be measured. Areas of waste were identified and remedial measures recommended.

The results indicated that about 1286 kWh/t and 1250 kWh/t of milled rice was needed in the semi-mechanized and integrated mills, respectively. The food energy ratio (FER) was greater than 2.8 in both industries while the energy ratio, considering the by-products, was 4.0. These indices indicate favourable energetics in rice production in the two mills.

Introduction and Literature Review

The purpose of agriculture is to capture solar energy in plants to produce food, fibre and other products. The goal is to achieve a high yield of high quality products at a low cost. The high cost of conventional energy sources puts a great pressure on the production and post-harvest handling phases of farm products. Consequently, new technologies have continued to evolve over the years. Several options are available to farmers, namely; i) reduce energy use; ii) substitute enterprises that require less energy; iii) substitute abundant for scare forms of energy; iv) modify farm enterprises to increase efficiency; and cease farming.

Non-renewable energy sources are used to increase agricultural productivity, enhance productive capabilities and reduce human labour. Human capability to perform physical work is limited and the cost is relatively high. It has been well demonstrated that the substitution of energy-intensive agriculture in place of labour-intensive agriculture greatly increases productivity. To produce today's crops at desired levels with yesterday's technology will be an uneconomical proposition. In order to sustain humanity, enough food must be produced and although energy is not one of the major items we are attempting to harvest, agriculture, like other enterprises, must be energy efficient.

Rice contributes about 21.2% of man's calorie intake (U.S.D.A., 1970) and is a staple food in most developing countries in Africa and Asia. In Nigeria, about 550×10^3 ha of agricultural land was devoted to rice production in 1980 and the annual output the same year was 725,000t (FAO, 1981). This represents a considerable input of resources and it is necessary to determine the magnitude of energy consumption in the phases of farm operations. This paper deals specifically with energy consumption of post harvest processing operations of rice production.

To undertake the study, the energy consumption in pre-milling, milling and post-milling operations was determined and analysed in two rice mills. The mills are located in the rice growing area of Uzo-Uwani in Anambra State of Nigeria. One of the factories, Adarice Production Company, is a semi-mechanised establishment. Parboiling in this mill is done by the traditional drum method and labour is required to move paddy from one activity area to another. This mill began operation in 1976 and the production data is shown in **Table 1**. The factory operates its own farms and has two growing seasons, namely; January to April during which early maturing varieties are grown,

Table 1 Paddy Production Data for Adarice and WBRP

Year	Paddy Output, t	
	Adarice	WBRP
1976	57.44	315
1977	412.4	340
1978	984.33	1155
1979	1023.35	1686.75
1980	1493.92	3108
1981	649.9(Jan.-March)	3570
1982	NA	4500
1983	NA	5378

Source: Mill records

and the second season starts from June and ends in November or December.

The other factory is the World Bank Rice Project (W.B.R.P.) which has a fairly modern integrated mill employing conveyors, steam boiler and mechanical dryers. It also commenced production in 1976, and operates the same paddy production schedule as Adarice. The production data is shown in **Table 1** and the plant layout of the mill is shown in **Fig. 1**.

Studies have been done (Srivastava, 1982; Sarker and Farouk, 1982; Hassi et al, 1981; Sembery, 1981 and Meiering, 1977) to determine the energy content of field operations and crop drying.

Table 2 Energy Use in the US Food System for 1970

Component	Energy Consumed $\times 10^{14}$ kJ
The Farm	
Fuel	9.71
Electricity	2.68
Fertilizer	3.95
Tractor and machinery manufacture	4.17
Irrigation	1.47
Foof Processing Industry	
Food processing and equipment	13.19
Packaging and containers	8.69
Transport	13.44
Food Preparation and Preservation	
Commercial refrigeration and cooking	11.10
Home refrigeration and cooking	20.16
Storage machinery	2.56
Total	91.12

Source: Araullo et al (1976)

A recent review on rice production technology (Igbeka, 1984) considers the machinery involved in the production phase. The introduction of tractors around 1910 gave impetus to greater energy-intensive agriculture as this enhanced the use of sophisticated farm machinery. These devices and subsequent operations consume energy in the form of fossil fuels such as coal and natural gas, bio mass, electricity and solar energy. As the scale of farm operation increases, energy must be conserved in the various production phases as is the case in advanced countries of the world (CAST, 1973). The amount of energy consumed in the USA food system is shown in **Table 2** and such data is lacking in most developing countries.

It would appear that there has not been any study done to determine the energy consumption in post-harvest rice processing operations. Such information is vital so as to compliment the component

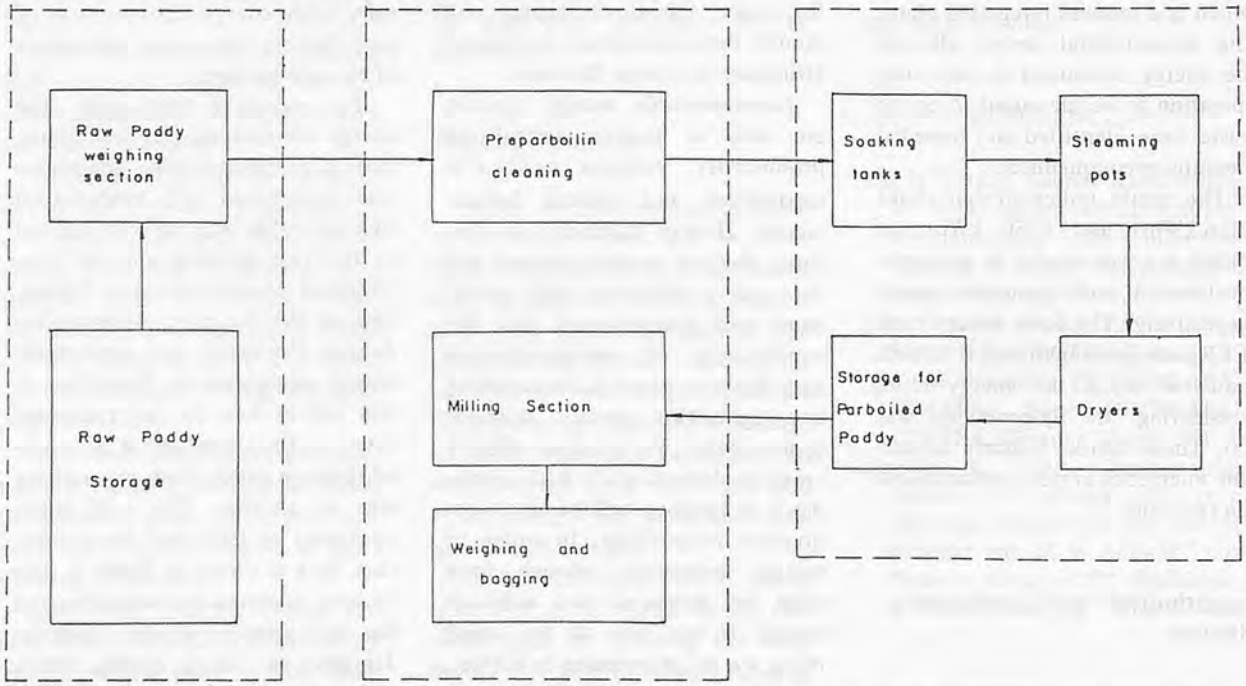

Fig. 1 Plant layout of the World Bank Rice Project factory.

arising from field operations that has been performed (Srivastava, 1982). Besides, it will enable the management of rice processing mills to develop strategies for better control of their production operations. It will also enable them to modify areas of waste and to properly appraise their energy consumption in planning their production and marketing activities. This work is, therefore, an attempt to fill the gaps in the area of energy consumption in rice post-harvest operations.

Post-Harvest Technology of Rice and Methods of Energy Evaluation

Harvested paddy undergoes some sequential processing operations which convert it to the final primary product known as milled rice. The technology of rice processing has evolved over the years by the introduction of new processes to ensure a high quality of the final product. The current sequence of operations are outlined in **Fig. 2**. At each stage of the unit operations, some level of energy input is required in the form of electrical energy, thermal energy and human energy. The type and magnitude of the energy input is a function of the technology employed and the quantity of paddy being processed. To access these energy demands, quantitative data on operating conditions will be required for each unit operation. Based on the production technology under study (**Table 3**), the type and magnitudes of the parameters required for the energy evaluation of each unit operation are detailed in **Tables 4** and **5** for the Adarice and WBRP mills respectively. A brief description and method of energy evaluation, of each operation now follows. For consistency, the energy components are calculated on the basis of 1t of paddy.

Table 3 Processing Techniques at Adarice and WBRP

S/No.	Operation	Equipment and Principle Adopted	
		Adarice	WBRP
1	Pre-Parboiling cleaning	Wet cleaning by floatation	Pneumatic separation
2	Parboiling		
	soaking	metal drums	concrete soak tanks
	steaming	metal drums, live steam	pressure vessel, live steam
	drying	mechanical/solar	mechanical
3	Destoning	electrical-mechanical destoner	electrical-mechanical destoner
4	Milling	IC-powered	Electricity-powered
5	Weighing and bagging	manual	automatic
6	Stitching	mechanical	mechanical
7	Conveying	manual/tractor	mechanical conveyors

Table 4. Measured Parameters of Energy Input Data at Adarice

Operation	Parameters measured	Magnitude
1 Parboiling	Volume of water in drum	596 *l*
	temperature rise of soaking water	36°C
	Quantity of paddy handled	450 kg
	Quantity of wood used for soaking	22 kg
	Quantity of wood used for steaming	54 kg
	Power required for drying	2.4 kW
	Quantity dried	1 t
	Times taken	3 h
2 Destonishing	Quantity of paddy destoned	75 kg
	Time taken	90 s
	Power consumed	2.52 kW
3 Milling	Quantity of paddy milled	75 kg
	Time taken	10.5 min
	Diesel fuel used	3.6 *l*
4 Stitching of bags	Number of bags	1
	Power consumed	62.2W
	Time taken per bag (50 kg)	16 s
5 Conveying	Fuel consumed per hour	2.16 *l*

Table 5 Measured Parameters of Energy Input Data at WBRP

Operation	Parameters measured	Magnitude
1 Pre-Parboiling cleaning	Power consumed	6.14 kW
	Time taken	2.3 h
2 Parboiling	Quantity of paddy	5.5 t
	Fuel used for soaking	131.3 l
	Fuel used for steaming	52.5 l
	Fuel used for drying	196.87 l
	Steam generating rate	340 kg/h
	Volume of water in soak tank	8628 l
	Time taken for soaking	2.5 h
	Total electrical power (5 motors)	30 kW
3 Milling	Quantity of Paddy milled per hour	2.1 t
	Power consumed	7.3 kW
4 Destoning	Power consumed	5.5 kW
	Quantity of rice destoned	75 kg
	Time taken	110 s
5 Stitching of bags	Power consumed	62.2 W
	Time taken per bag (50 kg)	16 s
6 Conveying	Electrical power used	7 kW

Pre-parboiling Cleaning

This is an operation carried out on paddy from the field to separate the seeds from foreign materials such as premature seeds, straw, leaves and sometimes stones. Two main methods are employed, namely; floatation method and aspiration separation. In the floatation method used by Adarice, the paddy is poured into floatation tanks containing water and the mature grains are allowed to settle at the bottom while the foreign matter are buoyed up on the water surface and can be easily removed

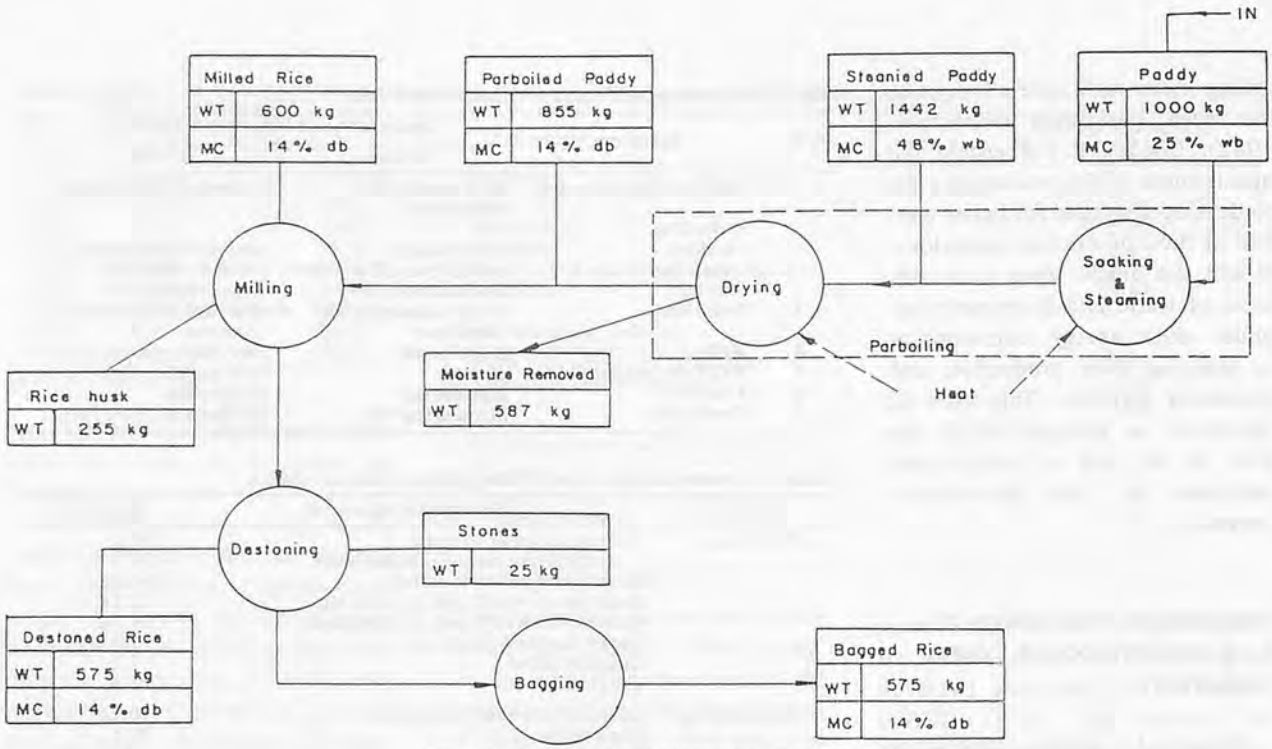

Fig. 2 Flow chart of rice processing operations.

by skimming. In the aspiration method employed by WBRP the paddy is separated from undesirable fractions by proper adjustment of air velocity in an aerodynamic chamber. This chamber also contains a primary destoner which removes stones and metal pieces from the paddy.

The electrical energy required for pre-parboiling cleaning was obtained from the expression;

$$E_c = \frac{I\,Vt\,(Pf)}{Qp} \quad \ldots\ldots\ldots (1)$$

where

E_c = energy used per t paddy, kJ/t

I = actual current drawn, ampere

V = voltage across motor, volts

t = time taken for the operation

Pf = power factor of the motor

Q_p = quantity of paddy handled, t

Parboiling

Parboiling is a hydrothermal treatment given to paddy to improve its qualities and involves the three basic processes of (a) steeping (soaking), (b) steaming and (c) drying (Fig. 3).

The benefits derived from parboiling include an increase in the total head rice yield of paddy, prevention of loss of nutrients during milling, salvaging of damaged paddy, achievement of desirable flavour and cooking characteristics and reduced incidence of breakage during milling.

Soaking is a result of the combined phenomena of molecular absorption, capillary absorption and hydration (Ali and Ojha, 1975). Water molecules first adhere to the surface of the hull, and then penetrate through the micropores into the caryopsis and are retained in the voids or intergranular spaces due to capillary absorption. Paddy, being a hygros copic material then undergoes a process of simultaneous water absorption and swelling of the starch granules. A temperature of 60–70°C over a period of 18–24 h is usually suitable for most rice varieties.

Steaming of soaked paddy with live steam, follows the soaking process. This treatment allows the starch granules to gelatinize and fuse changing from crystalline to amorphous form. The duration of steaming depends on the quantity of paddy and for quantities above 6 t, a steaming time of 20–30 min is used (Bal et al, 1974). In systems using non-pressurized steam (at

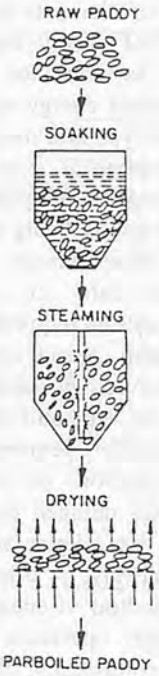

Fig. 3 Three steps required for parboiling.

100°C), as in traditional methods, colour changes, and amount of swelling of the milled parboiled rice is relatively minimal. This method is used at Adarice. In pressure systems, saturated steam generated in steam boilers at pressures of 4–5 kg/cm^2 is used as is done in WBRP. During steaming the moisture content of paddy increases from the harvest moisture content of about 25% to 40–50% wet basis (wb), and steaming is deemed to be completed once splitting of the husk occurs.

Drying is the last of the three phases of paddy parboiling. This is done at a controlled rate to minimize cracks due to thermal stresses, on the caryopsis, which could lead to up to 20% breakage (Bhattacharya and Indudharaswanry, 1967). The paddy is usually dried down to about 14% dry basis, suitable for milling and storage.

The energy required for parboiling was calculated from the expression;

$$E_p = [(Wso + Wst + Wdr)\,Cf + Pdr\,t]/Qp \quad \ldots\ldots\ldots (2)$$

where,

- Wso= quantity of fuel used for soaking, kg or litres for wood and diesel fuel respectively.
- Wst= quantity of fuel used for steaming, kg or litres for wood and diesel fuel, respectively.
- Wdr= quantity of fuel used for drying, *l*
- Pdr= electrical power consumed in drying, kW
- t = drying time, s
- Cf = calorific value of fuel used (16514 kJ/kg for wood (Ezeike, 1983), and 39020 kJ/*l* for diesel fuel).
- Q_p = quantity of paddy parboiled, t.

A batch operation at Adarice uses 30 to 50 drums of 225 kg capacity each giving total parboiled paddy of 6.75 to 11.25 t. The boiler efficiency ϵ_b was obtained from;

$$\epsilon_b = \frac{Ws\,(Cpw\,\Delta T + L) \times 100}{Wf\,Ct} \quad \ldots\ldots\ldots (3)$$

where

- Ws= steam generation rate, kg/h
- Cpw= specific heat of water
- ΔT = increase in water temperature °C
- L = latent heat of vaporization of water, kJ/kg
- Wf = fuel consumption rate, *l*/h.

Destoning

This operation is carried out to eliminate stones and pebbles that are still mixed with the paddy after parboiling. The equipment is usually motorized and capable of handling 3 t of paddy per h. The energy consumed per t of paddy is obtained from the expression;

$$E_d = \frac{Pd\,.\,t}{Qd} \quad \ldots\ldots\ldots\ldots (4)$$

- Ed= energy used per tonne of paddy, kJ/t.
- Pd = power demand by destoner, kW.
- t = duration of operation, s
- Qd = quantity of destoned paddy, t.

Milling of Paddy

The major effects achieved during the milling process are: dehusking of the rice kernel; separation of husks, immature seeds and undehusked grains; polishing – removal of the rice bran; and grading – separation into whole grain, 3/4 size, and fragmented seeds. These fractions are collected from different chutes.

A common equipment used for milling is the Blackstone machine which is capable of handling up to 3 t/h.

The energy consumed per tonne of paddy is obtained from;

$$E_{ml} = \frac{W_{ml}\,Cf}{Q_{ml}}$$,when I.C. engine is used . . . . . (5)

or

$$E_{ml} = \frac{P_{ml}t}{Q_{ml}}$$, when electricity is used . . . . . (6)

where

- Eml= energy used per t of paddy, kJ/t
- W_{ml}= quantity of diesel fuel used, *l*.
- P_{ml}= power consumed, kW
- Q_{ml}= quantity of milled paddy, t.

Weighing and Bagging

A continuous flow process is often complemented by a mechanised bagging device in order to eliminate any bottle-necks. Such devices are often motorized and consume energy for the period they are in operation. This energy component can be quantified by use of the expression;

$$E_{st} = \frac{Pst\,.\,t}{Qst} \quad \ldots\ldots\ldots\ldots (7)$$

where

- Pst = power consumed for stitching, kW.
- t = time taken, s
- Qst = quantity of milled rice handled per unit time, t.

Conveying Operations

Another major source of energy consumption is the conveyance of paddy or milled rice from one operation to the other. When the tractor is used for conveyance as in Adarice, fuel energy is consumed and when mechanical conveyor systems are employed, electrical energy is consumed. Thus the energy consumption for conveying operations can be expressed as;

$$E_{cv} = \frac{Wf\,.\,Cf}{Q_c} \quad \ldots\ldots\ldots\ldots (8)$$

or

$$E_{cv} = \sum_{n=1}^{n=n} P_{cv}(n)\,t_n/Q_{cv}(n) \quad \ldots\ldots\ldots\ldots (9)$$

- E_{cv} = energy used per tonne paddy, kJ/t. ıe.
- P_{cv} = power consumed per con-

Table 6 Manual Energy Input Data

Parameter	Soaking & steaming	Destoning				Conveying		
		Drying	Pre-Milling	Post-Milling	Milling	From Storage	In-plant	Bagging
				ADARICE				
Number of persons	1	3	6	–	2	1	–	3
Man - hour	7.5	3	0.15	–	2	1	–	0.02
Quantity (t)	0.45	1	0.075	–	0.43	0.43	–	0.05
				WBRP				
Number of persons	3	2	3	1	4	6	2	3
Man - hour	7.5	10	7	0.03	4	1.5	7.5	0.02
Quantity (t)	5.5	5.5	6.3	0.075	2.1	6.3	5.5	0.05

veyance, kW

t_n = time taken for the nth conveyance, s

$Q_{cv(n)}$= quantity of material handled, t.

n = number of conveyances.

Manual Energy Expenditure

The energy components treated thus far represent only energy supplied by fuel or electricity. Human energy expenditure involved in the processing operations can be computed by quantifying suitable data. The information required for determining human energy input include number of persons engaged in an operation, man-hour requirement and quantity of material handled at each stage. **Table 6** gives experimental data on the manual energy input data at both mills.

The total manual energy input per tonne of milled rice produced was calculated from the expression;

$$E_{ma} = \frac{268.56}{Cr} \left[\sum_{n=1}^{K} Mh(n)/Q_{ma}(n) + Cr \sum_{m=1}^{1} Mh(m)/Q_{ma}(m) \right] \quad \ldots\ldots (10)$$

where,

E_{ma}= energy used, kJ/t rice.

Mh = man-hour involved in each operation

Qma= quantity of material handled, t.

Cr = Paddy to rice conversion rate, decimal

n = index for operations involving paddy

m = index for operations involving milled rice.

Equation 10 was developed on the assumption that one normal human labour supplies 0.0746 kW.

Total Energy Expenditure

The total energy expenditure in producing one tonne of milled rice is the sum of the energy components involved in each process. Thus the total energy E_T becomes;

$$E_T = (E_c + E_p + E_d + E_{ml} + E_{st} + E_{cv}) / Cr + E_{ma} \quad \ldots\ldots (11)$$

With this equation it is possible to determine the total energy consumed in the mill producing milled rice at a given production rate.

Energy Ratio and Food Energy Ratio

The sum of the energy requirements for various operations embodied in a productive process is referred to as the gross energy requirement. The food material produced is often associated with an energy content. Thus the Food Energy ratio (FER) is defined as;

$$FER = \frac{\text{energy content of milled rice}}{\text{gross energy input for production}} \quad \ldots\ldots (12)$$

Another index that can be used in determining the energetics of rice production is the Energy Ratio (ER) which is defined as;

$$ER = \frac{\text{energy, content of raw material}}{\text{gross energy input for production}} \quad \ldots\ldots (13)$$

These indices are influenced by the production method, nature and use of the products and management of energy resources.

It is noted that ER considers not only the energy content of the food produced but also the energy content of by-products which can be used as fuel, in this case rice husk. The calorific value of milled rice and rice husk has been found to be 4117.2 kWh/t and 3789.7 kWh/t respectively.

Results and Discussion

The average conversion rate of paddy to milled rice for the two mills studied are shown in **Table 7**. The rice recovery rate at Adarice is relatively higher than that at WBRP probably due to the secondary destoning operation carried out at WBRP after the rice has been milled.

The energy consumed per tonne of milled rice for both mills and for each operation is shown in **Fig. 4**. The total manual energy expenditure is also superimposed on this graph. From the results the total energy consumed per tonne of milled rice produced is 1286 wh/t at Adarice and 1250 wh/t at WBRP. From **Fig. 4** it is observed that the energy expenditure for parboiling

Table 7 Paddy to Milled Rice Conversion Rate

Year	Conversion Rate, %	
	Adarice[a]	WBRP[b]
1981	–	64.37
1982	–	63.44
1983	70.1	65.06

a – average of 5 tests on different days, b – mill records

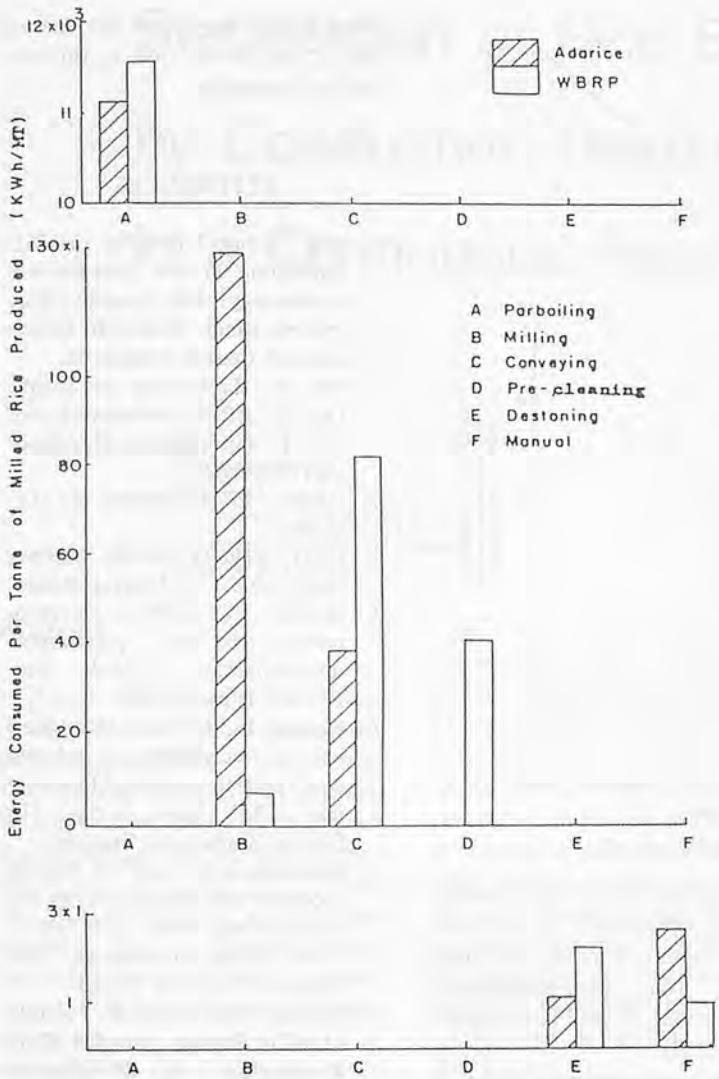

Fig. 4 Energy consumed in each operation per ton of milled rice.

in the two mills is almost the same while the specific energy consumption for milling is much higher in Adarice than at WBRP. This difference is due to the face that the power source for milling at Adarice is an internal combustion engine which probably due to age consumes a lot of diesel fuel (3.6 l/h). On the other hand, the power source for milling at WBRP is electricity at normal rate of consumption irrespective of the equipment employed. It can also be observed that considerable difference exists between the energy used for conveying in the two mills. The relatively lower input energy at Adarice is due to the fact that conveyance is mostly by tractor and large quantities can be handled per trip. Conveyance at WBRP is by an integrated system of chain conveyors, augers and bucket elevators with synchronized handling capacities. The ratio of energy for conveyance in Adarice to that in WBRP is approximately 0.47. Furthermore, as observed from **Fig. 4**, the manual energy input in the two mills has a ratio of 2.62. This inverse relationship is due to minimal manual handling in the highly mechanised mill at WBRP.

Using the production data for the two mills, **(Table 1)**, the total energy consumed per tonne of milled rice was determined and shown in **Fig. 5**. The result shows a consumption level of 51.78 MWh and 252 MWh in 1976 for Adarice and WBRP, respectively. Values for 1980 were 1.35×10^3 and 2.50×10^3 MWh respectively. Although the energy consumption in the WBRP appears to be consistently higher than that in Adarice, this relationship appears to be consistent with the level of paddy production per year in the two mills. The ratio of annual production of milled rice is shown in **Fig. 5** for proper interpretation of the energy relationships.

At a steam production rate of 340 kg/h, the total generated heat for parboiling at the WBRP was obtained as 869.3 MJ/h while the fuel energy consumed was 1024.3 MJ/k which gave a boiler efficiency of about 85%. The efficiency of utilization of generated heat in raising the temperature of the soaking tank at the WBRP was calculated to be 51.5% while that for Adarice was 24.7%. This means that the potential for reducing heat losses in both mills is great by adding optimum insulation at WBRP and better design of the furnace space in the traditional method adopted at Adarice.

In order to determine the gross energy input for milled rice production, it would be necessary to obtain the energy content of field operations leading to paddy rice. Such information is not currently available under Nigerian specific cultural practices. However, in a production schedule similar in level of technological input to prevailing practices in Nigeria, Srivastava (1982) obtained that the total energy required to produce rice up to threshing is 102 kWh/t of paddy. This result is appropriate in Nigeria in view of the low level of mechanization of production in the farms operated by the two factories under study. This will be equivalent to

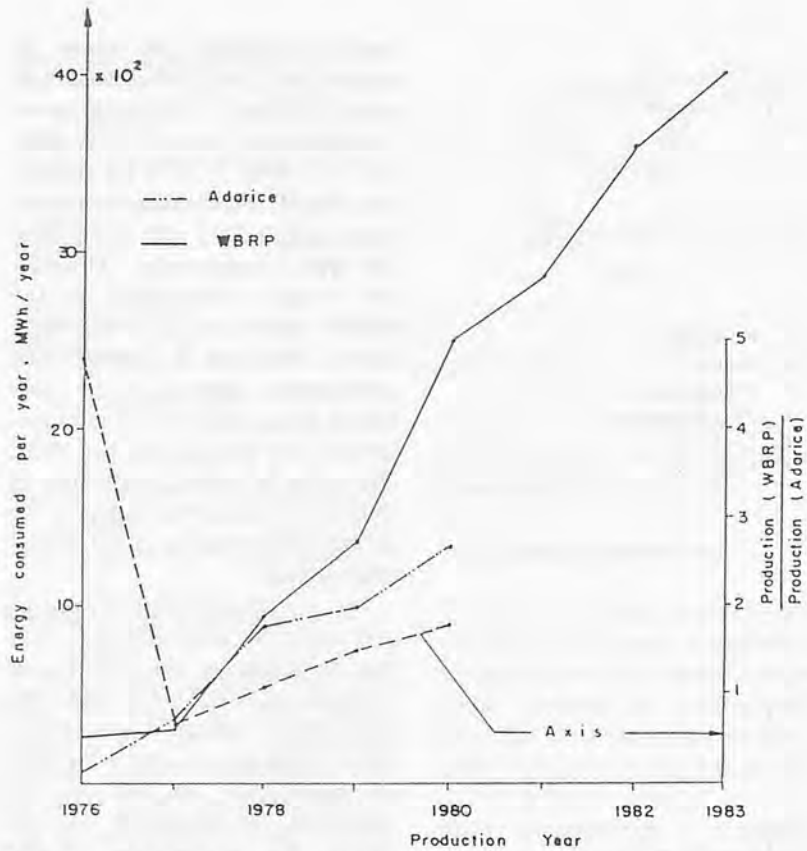

Fig. 5 Energy consumed per year and production ratio of the two mills.

145.4 kWh/t of milled rice in Adarice and 158.5 kWh/t of milled rice in WBRP. This means that the gross energy expenditures per tonne of milled rice in the two mills are 1431.4 kWh/t and 1408.5 kWh/t respectively.

For Adarice, 1 t of milled rice will yield an energy value of 4117.2 kWh and produce 0.426 t of rice husk which is equivalent to 1614.4 kWh. These results yield an FER of 2.88 and ER of 4.0. By a similar analysis, the FER and ER for WBRP are 2.92 and 4.41, respectively. These energy indices indicate that although there is room for improvement of energy efficiency in the two rice factories, the energetics of rice production appears to be favourable.

Conclusion

A study was conducted to determine the energy consumed per tonne of milled rice, in post harvest processing operations of two rice mills in Nigeria. One of the mills (Adarice) was semi-mechanised while the other (WBRP is a modern integrated mill.

The study was designed in such a way that each unit operation was studied closely and the energy input determined experimentally. Methods of computing energy consumption using measured input data are presented.

The results showed that Adarice produced one tonne of milled rice with 1286 kWh of energy while WBRP produced the same quantity with 1250 kWh. The differences in the component input are explained in terms of production technique, equipment and management. The annual energy usage was also determined based on the production level. The energy ratio (ER) for Adarice was 4.0 and 4.41 for WBRP while the food energy ratio (FER) were 2.88 and 2.92, respectively. These results show that the energetics of rice production in the two mills is favourable.

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Stabilization of Rice Bran by Conduction Heating in a Continuous Rice Bran Stabilizer

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Abstract

A continuous rice bran stabilizer of 30 kg/h capacity has been developed and tested at Post Harvest Technology Centre (PHTC), India. Rice bran was dried by conduction heating at each of the bran temperatures of 100°, 110°, 115°C for 10, 20 and 30 min. in the above stabilizer. The dry conduction heat treatment at a rice bran temperature of 110°C for 20 min was taken as optimum to keep the free fatty acids (FFA) of the treated bran below 10% for 60 days stored in sealed polyethylene bags at the storage temperature of 18-35°C and relative humidity of 62-98%. The regression equations, developed for each of the above treatment temperatures, relating FFA content to heat treatment period, storage period and type of packaging materials are in fairly good agreement with the experimental data.

Introduction

Among several methods of stabilization, wet heat and dry heat treatments are the commercially feasible methods under the existing conditions (Chakraverty and De, 1981). The main advantage of the dry heating method is that it does not require any boiler and the cost of stabilization is also less. Therefore, dry heating method of stabilization should be adopted where raw rice is produced and the boiler is not available. Conduction heating is an efficient method of heat transfer to the heating media. Therefore, a project was undertaken to develop and test a continuous rice bran stabilizer which had been designed on the basis of conduction heating and drying.

Materials and Methods

The continuous rice bran stabilizer of 30 kg/h capacity, consists of a vibratory feeder, a feed hopper, a screw conveyor and a steam jacketed cylindrical dryer. The rice bran in the dryer came in direct contact with the drying surface at a controlled temperature and it is thoroughly agitated for uniform heating and drying while passing from the inlet to the outlet of the dryer. The conduction drying of rice bran was carried out at each of the drying surface temperatures of 105°, 110°, 115° and 120°C and the corresponding rice bran temperatures were 100°, 105°, 110° and 115°C after 10, 20 and 30 min of conduction heating. The above heat treated bran samples were sealed in fabric and polyethylene bags, cooled in a desiccator and then stored at a temperature of 18-35°C and relative humidity of 62-98% for periodical analysis of moisture, oil and FFA contents by using standard AACC methods (AACC, 1962).

Results and Discussion

Figs.2 through 5 show that after 60 days of storage of the heat treated bran samples in sealed polyethylene bags under ambient conditions, the FFA contents of the rice bran samples increased from about 3.3% to 12.75, 10.80, 9.65% for the bran treatment temperature of 100°C; to 11.77, 10.05, 8.78% for 105°C; to 10.10, 9.20, 7.55% for 110°C and to 9.65, 8.25, 6.85% for 115°C corresponding to the heating periods of 10, 20 and 30 min. The FFA of the control sample increased from 3.0 to 72.0% after the same 60 days of storage. Therefore, the formation of FFA in rice bran during storage decreased with the increase of either heating

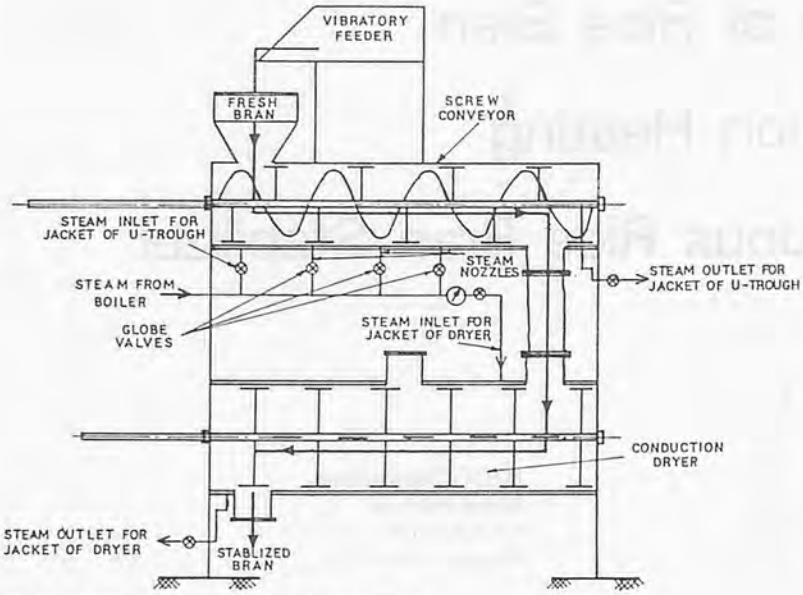

Fig. 1 Schematic diagram of rice bran stabilizer.

temperature or heating time or both. The heat treated samples when stored in fabric bags exceeded 10% FFA within 5 days of storage as evident from curves 3, 4, 5 of **Figs. 2** through **5**. The rapid rise in moisture content of the rice bran stored in fabric bags is mainly responsible for the rapid formation of FFA. The dry conduction heating of rice bran at a temperature of 110°C for 20 min followed by storage of the treated bran in sealed polyethylene bags under ambient conditions 18-35°C and 62-98% relative humidity which keeps the FFA level within 10% for 60 days, is considered suitable for stabilization of rice bran.

It is also clear from **Figs. 2** through **5** that irrespective of temperature and time of heat treatment, the rate of formation of FFA was rapid for all heat treated and untreated bran samples stored in fabric bags and this rate of FFA formation was very rapid in the first quarter of storage compared to that in the subsequent periods of storage.

It may be seen from **Table 1** that the moisture contents of the heat treated rice bran samples stored in fabric bags went up from 3.52-5.31% to 9.25-11.20% in 15 days and 10.80-15.25% in 60 days of storage. The moisture contents of raw rice bran prior to the heat treatments were 10.51 and 13.81%. Therefore, the conduction heat treated bran samples stored in fabric bags attained almost their pre-dried moisture content within 15 days of storage. **Table 1** also indicates that there are small changes in moisture contents of rice bran stored in sealed polyethylene bags which were due to absorption

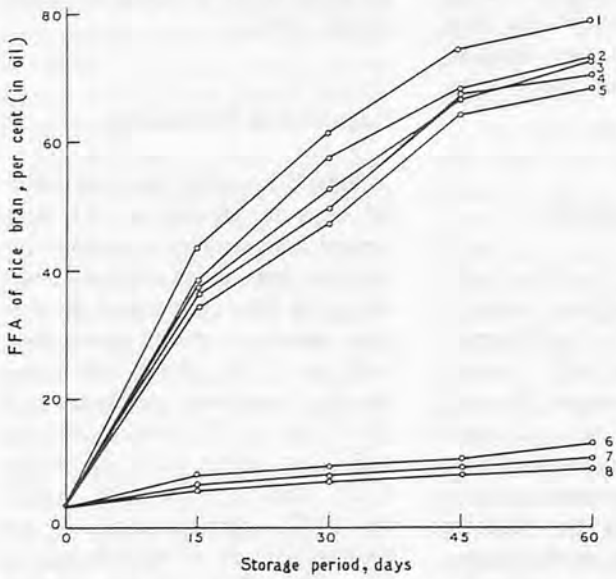

Fig. 2 Effect of conduction drying of rice bran at 100°C for different periods on the formation of FFA during storage in different packaging materials.
Sealed polyethylene bag stored samples:
(2) Control, (6) 10 min, (7) 20 min, (8) 30 min.
Fabric bag stored samples:
(1) Control, (3) 10 min, (4) 20 min, (5) 30 min. (Ambient temp.: 18.5°-34.7°C; Relative humidity: 62-98%).

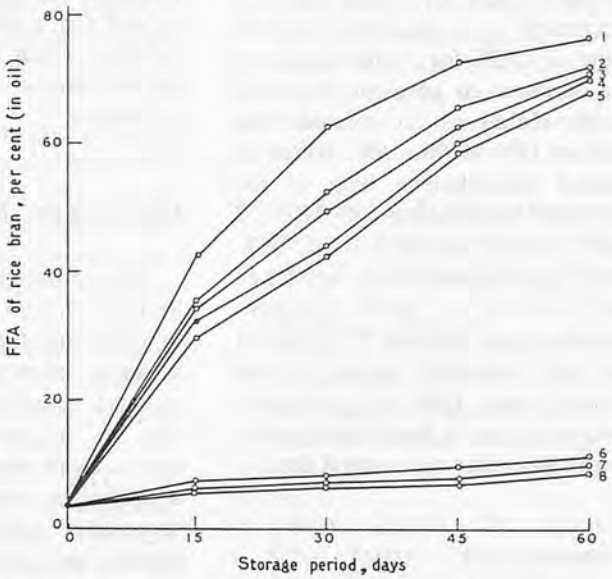

Fig. 3 Effect of conduction drying of rice bran at 105°C for different periods on the formation of FFA during storage in different packaging materials.
Sealed polyethylene bag stored samples:
(2) Control, (6) 10 min, (7) 20 min, (8) 30 min.
Fabric bag stored samples:
(1) Control, (3) 10 min, (4) 20 min, (5) 30 min.
(Ambient temp.: 18.5°-34.7°C, R.H.: 62-98%).

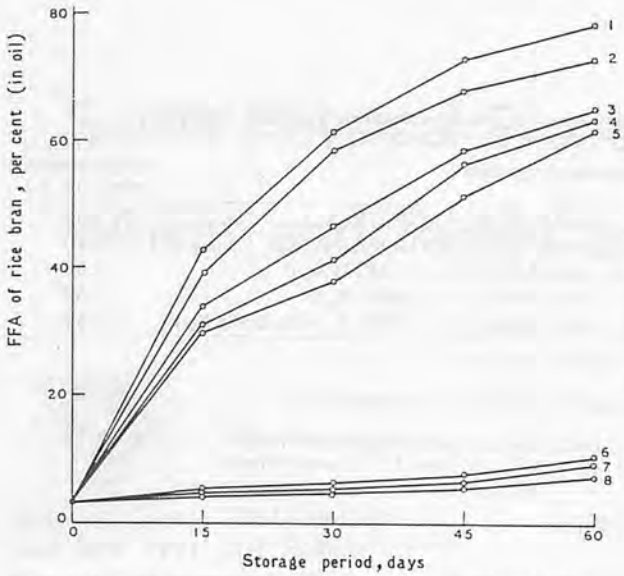

Fig. 4 Effect of conduction drying of rice bran at 110°C for different periods on the formation of FFA during storage in different packaging materials.
Sealed polyethylene bag stored samples:
(2) Control, (6) 10 min, (7) 20 min, (8) 30 min.
Fabric bag stored samples:
(1) Control, (3) 10 min, (4) 20 min, (5) 30 min.
(Ambient temp.: 18.5°-34.7°C; R.H.; 62-98%)

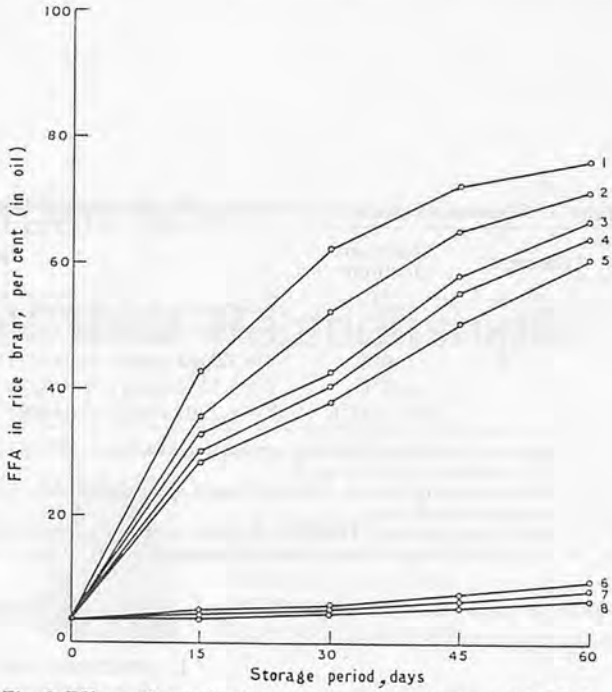

Fig. 5 Effect of conduction drying of rice bran at 115°C for different periods on the formation of FFA during storage in different packaging materials.
Sealed polyethylene bag stored samples:
(2) Control, (6) 10 min, (7) 20 min, (8) 30 min.
Fabric bag stored samples:
(1) Control, (3) 10 min, (4) 20 min, (5) 30 min.
(Ambient temp.: 18.5°-34.7°C; R.H.: 62-98%)

Table 1 Moisture Contents of Rice Bran Samples, Heat Treated at Different Temperatures and Stored for Different Periods.

Treatment temp. °C	Treatment period (min)	Packaging material	Storage period, days				
			0	15	30	45	60
			Moisture contents, % (d.b.)				
100	Control	Poly	10.51	10.70	10.85	10.92	10.96
		Fab	10.51	14.27	14.59	16.45	16.30
	10	Poly	5.31	5.47	5.71	5.88	5.87
		Fab	5.31	10.20	14.10	15.43	15.25
	20	Poly	4.46	4.50	4.55	4.70	4.82
		Fab	4.46	9.71	13.95	14.65	14.60
	30	Poly	4.03	4.16	4.30	4.38	4.45
		Fab	4.03	9.50	13.60	14.37	14.35
105	Control	Poly	13.81	13.85	13.95	14.05	14.10
		Fab	13.81	14.95	13.62	15.69	14.88
	10	Poly	4.72	4.85	4.90	4.98	5.05
		Fab	4.72	11.20	12.60	12.54	12.62
	20	Poly	4.35	4.40	4.52	4.65	4.75
		Fab	4.35	10.28	10.92	11.10	11.34
	30	Poly	4.10	4.27	4.35	4.52	4.60
		Fab	4.10	10.10	10.72	9.92	11.25
110	Control	Poly	10.51	10.70	10.85	10.92	10.96
		Fab	10.51	14.27	14.59	16.45	16.30
	10	Poly	4.28	4.42	4.55	4.75	4.87
		Fab	4.28	10.50	11.00	11.20	11.10
	20	Poly	4.02	4.15	4.35	4.46	4.66
		Fab	4.02	10.05	10.74	11.15	11.18
	30	Poly	3.85	4.00	4.10	4.15	4.28
		Fab	3.85	9.25	10.44	10.85	10.80
115	Control	Poly	13.81	13.85	13.95	14.05	14.10
		Fab	13.81	14.95	13.62	15.69	14.88
	10	Poly	4.18	4.35	4.65	4.80	4.88
		Fab	4.18	10.85	12.68	12.55	12.58
	20	Poly	3.96	4.28	4.42	4.67	4.80
		Fab	3.96	10.64	12.51	12.40	12.54
	30	Poly	3.52	4.08	4.30	4.52	4.65
		Fab	3.52	10.65	12.65	12.42	12.60

Ambient temperature during storage: 18.5°–34.7°C
Relative humidity during storage: 62–98 %

of moisture during exposure to the atmosphere at the time of removal of samples for analysis. Previous studies clearly indicate that moisture content plays a major role in hydrolysis of rice bran oil and in the growth of lipase-producing insects, moulds and microflora in the bran (Chattopadhyay and Srimani, 1972; Loeb et al, 1949; Loeb and Mayne, 1952; Viraktamath et al, 1972). This reveals that the storage of rice bran in sealed bags made of impervious material is essential in protecting stabilized bran against deterioration by the action of moisture, moulds, insects and microflora. It was observed that the insects could make holes and enter into the 150-200 gauge polyethylene bags. It is, therefore, suggested that the stabilized rice bran should be stored in 300 gauge polyethylene lined gunny bags to preserve its quality.

Regression equations for predicting FFA contents of heat treated bran for different heat treatment temperatures and times, storage period and packaging materials are given in **Table 2**. The fairly high values of coefficient of multiple determination indicate that the

Table 2 Regression Equations for Predicting FFA Contents of the Dry Heat-Treated Rice Bran for Various Conditions

Treatment	Treatment condition	Regression equation	Coefficient of multiple determination, R2
Dry heat treatment*	100°C	$Y = 5.228 \exp [(-0.02694) X_1 + (0.035375) X_2 + (1.08776) X_3]$	0.66
	105°C	$Y = 7.007 \exp [(-0.027589) X_1 + (0.025177) X_2 + (1.11473) X_3]$	0.60
	110°C	$Y = 3.0768 \exp [(-0.032291) X_1 + (0.033895) X_2 + (1.1827) X_3]$	0.66
	115°C	$Y = 5.1152 \exp [(-0.03352) X_1 + (0.03299) X_2 + (1.2424) X_3]$	0.68
	100°–115°C	$Y = 6.2207 \exp [(-0.03008) X_1 + (0.03186) X_2 + (1.1569) X_3 + (0.0598) X_4]$	0.62

* Dry heat treatment involves conduction heating at 100–115°C for 10–30 min.
Y = FFA content of rice bran, %
X_1 = Heat treatment period, minutes. Levels are assigned as 0, 1, 2 and 3 to control, 10, 20 and 30 min.
X_2 = Storage period, days
X_3 = Packaging materials. Levels are assigned as 0 and 1 for sealed polyethylene and fabric bags respectively.
X_4 = Treatment temperature. Levels are assigned as 0, 1, 2 and 3 to 100°, 105°, 110° and 115°C, respectively.

observed data are fairly good fit to the regression equations.

Conclusion

The dry conduction heat treatment at a rice bran temperature of 110°C for 20 min in the PHTC continuous rice bran stabilizer is considered to be optimum to keep the FFA content of the treated rice bran below 10% for 60 days at the storage temperatures of 18-35°C and the relative humidities of 62-98%.

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Some Physical Properties of Wheat and Paddy and their Relationships

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Abstract

Selected physical properties of wheat and paddy such as kernel volume and dimensions, specific gravity, solid density and spherical radii were determined within the range of moisture content of wheat between 8 and 12% (w.b.) and that of paddy between 12 and 27% (w.b.) and the relationship of those properties with the moisture content were shown. The kernel volume increased while the specific gravity decreased with increasing grain moisture content. Equation determining single kernel volume and the relations between grain dimensions were developed. Spherical radii of the crest of wheat were measured from cross-section of the kernel and their relationships were developed, but the correlation between the spherical radii were not significant.

Introduction

Determination of physical properties like shape, size, volume, specific gravity, density, length, width, spherical radii, etc of agricultural grains are very important for describing their theological characteristics in many respects. The shape and size of grains affect the processes involved in many applications.

A number of works have been reported to describe physical characteristics of agricultural grains. But no single method or standard procedure has yet been developed for describing the physical characteristics of agricultural grains due mainly to the irregular shape and uneven size of the grains. In an attempt, Griffiths and Smith (1964) related the volume of a set of specimens of pebbles to their axial dimensions using the following relationships.

$$V=(a_1)^{b_1}.(a_2)^{b_2}.(a_3)^{b_3} \ldots\ldots\ldots (a_n)^{b_n} \qquad (1)$$

where, V=volume of specimens

$a_1\ a_2\ a_3 \ldots a_n$ = diameters within the body considered

$b_1\ b_2\ b_3 \ldots b_n$ = exponents

Mohsenin (1978) has also reported similar relationship of the volume of kernel with their dimensions. He suggested that the volume of wheat kernel may be calculated by using the equation of oblate spheroid as follows:

$$V = \frac{4\pi}{3 \times 8} (l^2 . w) \qquad (2)$$

where, l = length of kernel

w = width of kernel

Determination of volume equation, the relation between dimensions of kernel and the relation between physical properties of agricultural grain has great importance in designing post-harvest machines. Obtaining pure mathematical relations of physical properties of agricultural grains is very difficult because of their non-describable and irregular shape and size. Therefore, it is necessary to develop empirical relations of physical properties that should be helpful for the researchers in designing post-harvest machines and equipment.

Objectives

i) To determine a general equation describing a single kernel volume of both paddy and wheat from linear dimensions.

ii) To determine relations between kernel dimensions such as length, width, breadth and the radii of crests.

iii) To determine the relation between physical properties such as single kernel volume and specific gravity and grain moisture content.

Materials and Methods

The spring wheat of "sappo" variety and transplanted "amon"

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paddy BR-10 were used in the experiment. Both wheat and paddy grains were conditioned at 16.5, 18.7, 22.0, and 27.5% (w.b.) moisture levels. High moisture grains were obtained by remoistering the kernel at predetermined rate. The grains were periodically stirred in air tight plastic bags during remoistening. The samples were preserved in air tight plastic bags and stored in a refrigerator at 5°C.

An accurate electric balance (Mettler H10 T/HID Tw, least measure 0.1 mg) was used for determining single kernel average volume and solid density of paddy and wheat.

One hundred fully matured whole kernels were sorted by hand and thoroughly examined by eye sight to check physical damage. The kernels were accurately measured in air and then they were put into a perforated steel beaker and covered by lid. The weight of the grain along with steel beaker (sink) was taken in liquid ethyl alcohol of 0.8 sp. gr. by an accurate balance. The weight of the empty sink was also taken.

The following equations were used to calculate the volume and solid density of kernels:

$$\text{Sp.gr.of grain} = \frac{W_{ag}(SG)_L}{W_{ag}+W_{ws}-W_{wgs}} \quad (3)$$

$$\text{Solid density of grain} = W_d \times \text{sp.gr. of grain} \quad (4)$$

$$\text{Weight per kernel} = W_{ag}/\text{Number of kernel} \quad (5)$$

$$\text{Vol. per kernel} = \frac{\text{Weight per kernel}}{\text{Solid density of grain}} \quad (6)$$

Where,

W_{ag} = wt. of grain in air, gm
W_{ws} = wt. of sink in water, gm
W_{gs} = weight of grain and sink together in water, gm.
W_d = density of water, kg/m^3
(SG)L= specific gravity of liquid

Table 1 Grain Dimensions, Computed and Corrected Volume

Nos of kernel	Length mm l	Width mm a	Thickness mm h	Computed volume v_c mm^3	Corrected volume v mm^3
1	5.53	3.40	2.67	26.28	29.77
2	5.70	3.98	3.24	38.48	41.97
3	5.95	3.50	2.91	31.73	35.21
4	5.01	3.02	2.65	20.99	24.48
5	5.00	2.97	2.38	18.50	21.99
6	5.68	3.53	3.06	32.12	35.61
7	5.72	3.35	2.97	29.79	33.28
8	5.23	3.22	2.61	23.01	26.50
9	5.71	3.47	3.09	32.05	35.54
10	6.23	3.85	3.27	41.06	44.55
11	5.78	3.73	2.88	32.46	35.95
12	5.65	3.50	2.75	28.47	31.96
13	5.95	3.62	3.05	34.39	37.88
14	6.03	3.83	3.34	40.38	43.87
15	6.02	3.62	3.06	34.91	38.40
16	5.88	3.01	2.50	23.16	26.65
17	5.35	3.37	3.01	28.41	31.90
18	5.86	3.69	3.31	37.47	40.96
19	5.83	3.40	2.86	29.68	33.17
20	5.96	3.37	2.78	29.23	32.72
21	5.76	3.42	3.18	32.80	36.28
22	5.87	3.65	3.28	36.79	40.28
23	5.41	3.40	3.00	28.89	32.38
24	6.09	3.81	2.97	36.08	39.56
25	5.90	3.90	3.50	42.16	45.65
26	5.21	3.01	2.64	21.63	25.12
27	5.71	3.82	3.10	35.40	38.89
28	5.81	3.77	3.20	36.69	40.18
29	5.19	2.97	2.50	20.17	23.66
30	5.35	3.20	2.82	25.27	28.76
31	5.56	3.48	2.81	28.46	31.95
32	5.25	3.22	2.82	24.96	28.44
33	5.92	3.47	3.14	33.77	37.26
34	5.51	3.20	3.10	28.62	32.10
35	5.45	3.25	2.67	24.76	28.24
36	5.15	3.08	2.63	21.84	25.33
37	5.31	3.30	2.90	26.60	30.09
38	5.29	3.24	3.14	28.17	31.66
39	5.75	3.96	3.13	37.31	40.80
40	5.86	3.67	3.14	35.35	38.83
41	5.78	3.64	3.15	34.70	38.18
42	5.97	3.15	3.12	30.72	34.20
43	5.72	3.65	3.03	33.12	36.61
44	5.68	3.12	2.65	24.58	28.07
45	5.48	3.26	2.81	26.28	29.77
46	6.14	3.93	3.33	42.07	45.56
47	5.25	3.25	2.99	26.71	30.19
48	5.67	3.41	2.82	28.54	32.03
49	5.72	3.60	3.18	34.28	37.77
50	5.56	3.43	3.14	31.35	34.84
Mean	5.65	3.45	2.96	30.62	34.10
Std. dev.	0.30	0.28	0.25	5.93	5.92
Cov. %	5.35	8.12	8.47	19.36	17.37

Spring wheat, Sappo variety, 1980; Grain moisture content = 16.5% (w.b.); Experimentally determined mean volume = 34.105 mm^3; Sp. gr. = 1.1315; Solid density = 1131 kg m^{-3}; Volume correction factor = 3.3872.

The physical parameters of winter wheat were determined within 8 to 21% (w.b.) grain moisture contents. Following the same procedure, similar physical properties of spring wheat were determined within the range of 16.5 to 27.5% (w.b.) grain moisture content. **(Table 1).**

Single Kernel Volume

The volume equation of sphere was used by modifying it as an ellipsoid and substituting the major axes by the three perpendicular dimensions of wheat kernel.

The volume of sphere is given by

$$V = \frac{4\pi r^3}{3} \quad (7)$$

where, r = radius of sphere.

In equation (7) r was replaced

by three perpendicular dimensions such as length, width and thickness of wheat kernel.

$$\text{Therefore, } V = \frac{4\pi}{3} \cdot \frac{l}{2} \cdot \frac{w}{2} \cdot \frac{h}{2} \qquad (8)$$

$$\text{or, } V = \frac{\pi}{6} \cdot l \cdot w \cdot h \qquad (9)$$

The length, width and thickness (three mutually perpendicular axes) of 50 wheat kernels at 16% (w.b.) grain moisture content were measured by micrometer dial gauge.

Spherical Radii of Wheat Kernel

The wheat kernel was fixed vertically on soft rubber, and a small piece of transparent plastic tube was placed on it to hold the wheat kernel at the centre (**Fig. 1**). The tube was filled with a mixture of 2-component transparent epoxy and was then left for two days to become sufficiently hard. A suitable cross-section of the kernel was obtained by cutting the tube along with kernel at a position so that the kernel was cut at the mid point. The photograph of the grain cross-section was taken and was enlarged to 100 times with a view to obtaining an accurate measurement of the radii.

Five dimensions (max. width and thickness, spherical radius of cross-section and radii of the crests of two halves) were measured from the projected cross-section of the wheat kernel as shown in **Fig. 2**. Twenty-five randomly selected wheat kernels were used for the test.

Results and Discussions

The mean volume of the kernel was determined by calculating the volume of each kernel from the measured dimension data using both equations (2) and (9). The average volume and solid density

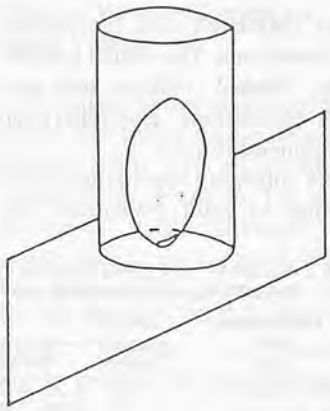

Fig. 1 Wheat kernel packet in a plastic tube filled with a epoxy mixture prepared to get a cross-section of the kernel.

of the same set of kernel were determined (**Table 1**). The correction factors for both the volume equations were calculated by the following equation:

$$C.F. = V_d - V_c \qquad (10)$$

$$\text{Error} = \frac{C.F.}{V_d} \times 100 \qquad (11)$$

where, C.F. = correction factor
V_d = determined mean volume, mm^3
V_c = calculated mean volume, mm^3

The correction factor determin-

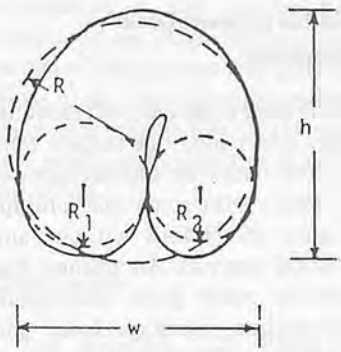

Fig. 2 Projected x-section of wheat grain showing spherical dimensions of halves and grain dimensions.

ed for equation (2) was 57.65 (i.e., error = 69.3%) and that for equation (9) was 3.485 (i.e., error = 10.22%).

From this observation it was concluded that the equation (9) fitted much better than equation (2). Hence the corrected equation used for determining the volume was:

$$V = \frac{\pi}{6} \cdot l \cdot w \cdot h \pm C.F. \qquad (12)$$

Therefore, the volume of wheat kernel was found to be satisfactorily given by the following equation:

$$V = \frac{\pi}{6} \cdot l \cdot w \cdot h + 3.485 \qquad (13)$$

Table 2 Linear Correlation Matrices between Grain Dimensions and Breaking Force and Deformation of Wheat and Paddy

	Remaining all	lwd	Fd	F	d	l	w	h	v	l/a	l/h	w/h
Spring wheat, Sappo variety, 1980												
F	0.72	0.30	–	1								
d	0.62	0.28	–	0.56	1							
l	0.99	–	0.73	0.07	0.05	1				0.18	−0.14	−0.32
w	0.92	–	0.16	0.16	0.13	0.58	1			−0.69	−0.56	−0.56
h	0.84	–	0.31	0.28	0.25	0.68	0.76	1		0.33	−0.82	−0.82
v	0.99	0.99	0.78	0.06	0.01	0.93	0.37	0.32	1	–	–	–
l/w										1	0.55	0.59
l/h											1	0.99
w/h												1
Transplanted Aman Paddy, BR-10, 1979												
F	0.74	–	–	1								
d	0.99	–	–	0.15	1							
l	0.99	–	–	0.66	0.71	1				0.77	0.82	−0.03
w	0.99	–	–	0.04	0.46	0.52	1			−0.69	0.13	0.13
h	0.98	–	–	0.12	0.30	0.04	0.33	1		0.17	−0.61	−0.61
v	0.75	–	–	0.71	0.09	0.03	0.23	0.14	1	–	–	–
l/w										1	0.51	0.51
l/h											1	0.99
w/h												1

F = Force, d = deformation, l = length of Kernel, w = Width of Kernel, h = Thickness of Kernel, v = Volume of Kernel

Relation between Grain Dimensions

The dimension data of individual paddy and milled rice kernels were reported earlier by Bhattacharya et al, (1972) with some relationships of grain dimensions without any statistical analysis. An attempt was made to relate grain dimensions with volume, breakage force and deformation. The regression analysis of grain dimensions with volume, breakage force and deformation resulted interesting interrelations (**Table 2**). The kernel length (l) as an independent variable was not related to any other parameter except volume. The width (w) of kernel was correlated well with kernel thickness (h).

The following approximate relations of grain dimensions of both wheat and paddy were found by linear regression analysis of the experimental data:

$$l_w = 3.30 + 0.702\ w_w \quad (14)$$

$$l_w = 3.36 + 0.790\ h_w \quad (15)$$

$$w_w = 1.20 + 0.740\ h_w \quad (16)$$

$$l_p = 9.50 - 0.200\ w_p \quad (17)$$

$$l_p = 9.40 - 0.233\ h_p \quad (18)$$

$$w_p = 3.80 - 0.562\ h_p \quad (19)$$

The suffix w and p refer to wheat and paddy, respectively. Each of the above equations show individual relationships of length, width and thickness of kernel.

It was observed from correlation coefficients (correlation matrices, **Table 2**) that very few significant correlations exist between the grain dimensions of wheat and paddy kernels. The multiple correlation coefficients of the dimensions of wheat were found quite significant.

Relation between Grain Dimensions and Spherical Radii

Linear correlations were found between the measured grain dimensions by linear regression analysis (**Table 3**). Among all dimensions only width was found relatively better correlated with the remaining dimensions. The results presented in **Table 3** indicate that very poor correlations exist between grain dimensions.

The following approximate relationships of grain dimensions and spherical radii were obtained by linear regression analysis:

$$R = -0.594 + 0.647\ w - 0.0457\ h \quad (20)$$

$$R = 1.062 + 0.536\ R_1 + 0.0267\ R_2 \quad (21)$$

$$R_1 = -0.809 + 0.5077\ w -$$

Table 3 Summary of Various Physical Properties of Wheat and Paddy at 16.5% (w.b.) Grain Moisture Content

Parameters and unit	Nos of sample tested	Wheat[1]		Paddy[2]	
		Range	Mean ± s.d.	Range	Mean ± s.d.
Length, l (mm)	25	6.20–4.80	5.64±0.37	9.70–8.40	8.98±0.35
Width, w (mm)	25	3.91–2.90	3.34±0.31	2.90–2.54	2.72±0.09
Thickness, h (mm)	25	3.46–2.15	2.89±0.31	2.00–1.81	1.91±0.05
l/w	25	2.01–1.50	1.692±0.133	3.57–2.99	3.29±0.176
l/h	25	2.35–1.64	1.961±0.165	5.03–4.20	4.68±0.23
w/h	25	1.37–1.00	1.58±0.088	1.56–1.27	1.42±0.073
(l–w)	25	3.0–1.83	2.296±0.316	6.98–5.61	6.258–0.373
(l–h)	25	3.31–2.15	2.745±0.282	7.76–6.40	7.065–0.361
(w–h)	25	1.05–0.10	0.457±0.200	1.20–0.60	0.806–0.124
Specific gravity	100	–	1.277	–	1.710
Solid density, kg m^3		–	1277.5	–	1710.1
Weight per kernel, mg	100	–	38.312	–	25.471
Kernel volume, mm^3	100	–	30.078	–	14.516

1 Spring wheat, sappo variety, 1980
2 Transplated Aman paddy, BR-10, 1979

Table 4 Grain Dimensions Determined from the Projected Cross-Section

No. of observations	w mm	h mm	R mm	R_1 mm	R_2 mm
1	3.25	2.85	1.25	0.65	0.6
2	3.3	2.9	1.2	0.65	0.8
3	3.2	2.55	1.6	0.6	0.75
4	3.42	2.8	1.3	0.85	0.70
5	3.8	2.9	2.2	1.0	0.8
6	3.1	2.25	1.1	0.6	0.7
7	3.26	2.7	1.6	0.9	0.65
8	3.5	3.14	1.2	0.8	0.8
9	3.6	3.05	2.0	0.8	0.8
10	3.28	3.1	1.7	0.55	0.55
11	3.85	3.2	1.6	0.9	0.9
12	3.6	2.85	1.3	0.9	0.8
13	3.21	2.68	1.4	0.7	0.55
14	3.46	3.05	1.4	0.65	0.85
15	3.45	2.9	1.3	0.8	0.8
16	3.65	3.1	1.7	0.9	0.9
17	3.15	2.6	1.3	0.8	0.8
18	3.35	2.85	1.6	0.7	0.7
19	3.25	2.93	1.3	0.7	0.8
20	3.3	2.4	1.8	0.6	0.8
21	3.6	3.15	1.5	0.8	0.7
22	3.65	3.3	1.6	1.0	0.8
23	3.55	2.05	1.4	0.9	0.9
24	3.55	2.6	1.6	0.75	0.9
25	3.5	2.8	1.5	0.88	0.8

Spring wheat, Sappo variety; Moisture content = 16.5% (w.b.)

Table 5 Linear Correlation Matrix of Grain Dimensions Determined by Projecting Cross-Section of Wheat Kernel

Item	Remaining all	w	h	R	R_1	R_2
w	0.894	1				
h	0.624	0.482	1			
R	0.550	0.481	0.191	1		
R_1	0.746	0.728	0.251	0.274	1	
R_2	0.690	0.577	0.020	0.125	0.426	1

w = width of Kernel; h = thickness of Kernel; R = spherical radius of Kernel; R_1 & R_2 = spherical radii of halves of wheat kernel
Spring wheat, Sappo variety
(Dimensions refer to Fig. 6.5)

$$0.056\ h \quad (22)$$

$$R_2 = -0.175 + 0.374\ w - 0.1217\ h \quad (23)$$

The equations (20) and (21) were the relationships of R, the spherical radius of wheat kernel with the width and thickness of grain, and R_1 and R_2, the radii of two halves of the grain respectively. These equations indicate that width had greater effect than thickness on the magnitude of spherical radii. Also, the magnitude of R was directly proportional to the magnitudes of R_1 and R_2 (Tables 4 and 5).

Effect of Moisture Content on Specific Gravity

The specific gravity and solid density of both wheat and paddy decreased with an increase of grain moisture content. The rate of decrease of specific gravity were much pronounced for winter wheat (Fig. 3) and spring wheat (Fig. 4) within the range of 12% to 18% grain moisture content. There was insignificant effect of moisture content on specific gravity at moisture content lower than 12% and higher than 18%.

By absorbing water the starch molecules became saturated at high moisture content above 25%. At moisture contents below 10% the starch molecules were dry and intermolecular spaces were almost contracted and the grain approached towards true specific gravity of bone dry material.

The effect of moisture content on specific gravity of paddy differed with that of wheat. The change of specific gravity was much faster for paddy (Fig. 5). The effect of moisture content was high within the range of 18 to 28%. The specific gravity decreased faster with the increase of moisture content within this range. The change of specific gravity was less beyond this range both at lower and higher moisture contents.

Effect of Moisture Content on Kernel Volume

The single kernel volume of both winter and spring wheat were high between 8% to 24% grain moisture content (Figs. 3 and 4). The kernel volume of paddy increased very rapidly within the range of 16% to 30% grain moisture content (Fig. 5). At higher moisture level the starch molecule was saturated which resulted in no change of volume.

These differences in changing specific gravity and solid density due to the change of moisture content of wheat and paddy was mainly due to the variation of their morphological and physiological characteristics. The physical properties of paddy-bran was quite different from that of wheat pericarp which was responsible for the variation in physical properties of paddy and wheat.

Conclusion

The equation (13) which was developed to determine the single kernel volume of wheat fitted better than any other equation developed before. It is recommended that this equation can successfully be used for predicting single kernel volume of wheat. Experimental results and

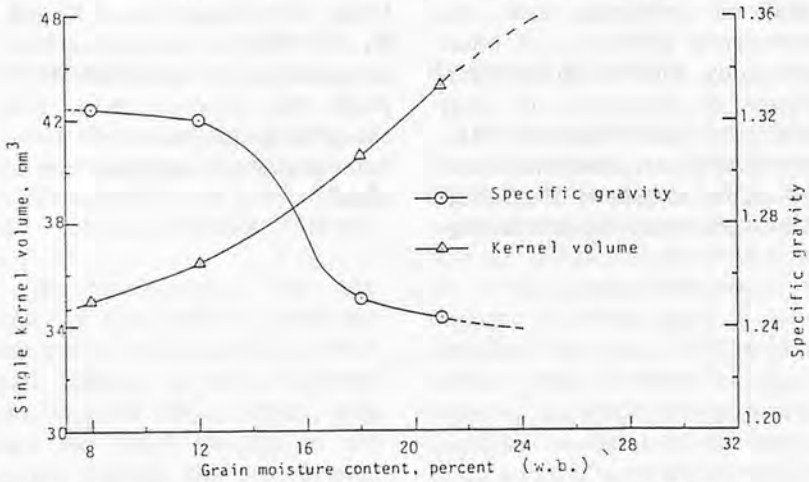

Fig. 3 Kernel volume and specific gravity with grain moisture content of winter wheat, Vuca variety.

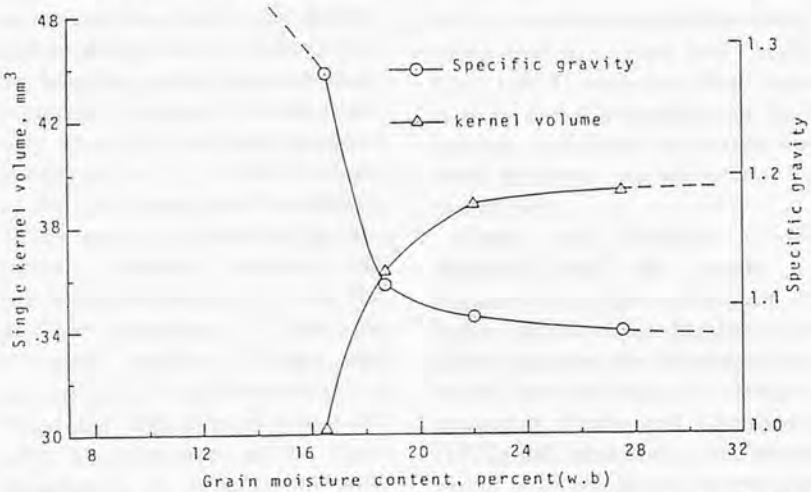

Fig. 4 Single kernel volume and specific gravity with grain moisture content of spring wheat, Sappo variety.

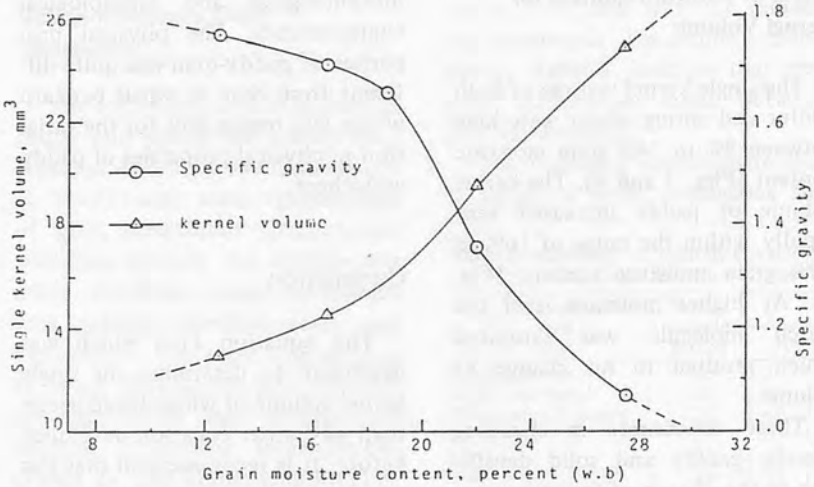

Fig. 5 Single kernel volume and specific gravity with grain moisture content of transplanted Aman paddy, Br-10.

analysis confirmed that very few significant correlation exists between grain dimensions of wheat and paddy. But the multiple correlation of dimensions of wheat was found quite significant, i.e., width had greater effect than thickness on the magnitude of spherical radii of the wheat kernel. The magnitude of R was directly proportional to the magnitudes of R_1 and R_2. The effect of moisture content on specific gravity was different for paddy than that of wheat. The change of specific gravity was much faster in case of paddy than that in wheat.

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Relationship of Grain Shape and Mass to Tensile Strength of Rice

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Abstract

Investigations were conducted on the tensile strength, mass, and the three dimensions of individual rice kernels of six varieties at a moisture equilibrated conditions of 23.3°C and 44.0% relative humidity (r.h.). The tensile strength per unit cross-sectional area of rice was found to vary with variety, and form of rice, and was related to the mass and the shape of individual rice kernels indicated by the ratio of the dimensions.

Rice kernels, in general, are not divided into strong or weak groups with respect to tensile strength but may be formed into two groups according to their shape and tensile strength:

Group A: has a length/thickness ratio of less than 3.8 and a positive correlation exists between this ratio and the tensile strength.

Group B: has a length/thickness ratio of more than 3.8 and a negative correlation exists between this ratio and the tensile strength.

The mass of a rice kernel has a positive correlation with its tensile strength irrespective of any group. In order for a group of rice kernels to be strong in tensile strength it should weigh more than 20.0 g/1000 kernels while the kernels of the group should have a length/thickness ratio between 3.8±0.2.

Introduction

Rice (Oryza sativa L.) is one of the most important cereal foods on which depends about one-fourth of the world's population (Kent, 1966).

The main aim of the rice industry is to produce a maximum amount of whole grain rice from each kilogram of the raw product that is milled. Recent studies indicate that much breakage in rice occurs because the kernels have previously been weakened due to the formation of stress cracks (fissures) resulting from rapid adsorption or desorption of moisture during handling, processing, and transportation. These stress cracks occur only when the developed moisture stresses exceed the tensile strength of the rice (Kunze and Choudhury, 1972). Design engineers in the rice industry, research workers, and rice breeders–all need to know the physical properties of rice for accourate analysis, design and operation of rice processing systems. The objectives of this study were to determine: a) the three dimensions, b) weights (masses), and c) tensile strengths of brown and polished rice kernels, and d) to explore relations that may exist among them.

Review of Literature

The tensile strength of rice was first determined by Choudhury (1970a). He found the effects of moisture adsorption on the tensile strength of rice and observed that the tensile stress condition in a moisture adsorbing grain is very complex. Choudhury (1970b) in a further study observed a large variation in tensile strengths and found that storage time and drying in an artificial environment has an effect on the tensile strength of rice. The phenomenon was explained by a one dimensional theoretical stress analysis. Kunze and Choudhury (1971) indicated that variations in tensile strengths were large between individual rice kernels but small between average groups of like kernels.

Earle and Ceaglske (1949) observed that the cracks in macaroni originate at the point of highest tensile stress. Ekstrom et al (1966) observed that tensile properties of corn were related to thermal expansion. Kunze and Choudhury (1972) indicated that a rice kernel would fail or fissure during the moisture adsorption process if the magnitude of the developed mois-

ture stress exceeds the tensile strength of the rice kernel. One dimensional theoretical stress analysis was used to explain such phenomenon. The tensile strength of a rice kernel is, therefore, of much importance.

Nagato and Kono (1963) in their study of grain texture of rice determined the relations among hardness distribution, grain shape, and the structure of the endosperm tissue of the kernel. Depending on hardness and the length ratio they divided rice grains into five groups of two types. They also observed that positive correlations existed between the ratios of length to breadth and the ratios of thickness to breadth for kernels of Indica rice varieties.

Kunze and Choudhury (1972) further observed that the tensile strength of a rice kernel at a given time could be influenced by previous kernel history, time after exposure to a different environment and the rate of moisture adsorption. Their study also indicated that the fissuring time was longer for a kernel having higher tensile strength. It is of interest to determine if relations exist between the tensile strength and the physical properties of a rice kernel.

Table 1 Tensile Strengths of Selected Rice Varieties Equilibrated at 23.3°C and 44% r.h.

Variety	Form	Tensile strength N/mm²	Sample size	Standard deviation
Fortuna	P*	9.01	20	2.32
	B**	9.42	20	1.52
	Mean	9.21	40	1.95
Zenith	P	6.32	20	2.03
	B	8.05	20	2.17
	Mean	7.19	40	2.25
Bluebelle	P	5.49	20	1.45
	B	6.69	20	1.57
	Mean	6.09	40	1.61
Bluebonnet 50	P	5.96	20	1.71
	B	6.31	20	1.26
	Mean	6.14	40	1.47
Century Patna 231	P	5.99	20	1.97
	B	6.15	20	2.01
	Mean	6.07	40	1.96
Nato	P	4.77	20	1.11
	B	7.33	20	2.00
	Mean	6.05	40	2.05
All varieties	P	6.26	120	2.25
	B	7.32	120	2.09
	Mean	6.79	240	2.23

*P : Polished rice, **B : Brown rice

Materials and Methods

Rice of six varieties (**Table 1**) in brown and polished forms were used. The polished rice was already milled while brown rice required hand hulling from rough rice. Previous history of the rice was not known. But the rice was grown and handled according to good production practices.

A controlled environment walk-in chamber was used to conduct the experiments and to store the rice before use. One-half gallon plastic freezer containers with appropriate trays and saturated solutions of potassium carbonate salt were used to equilibrate the grains in an environment of 43.6% relative humidity (r.h.) at 23.3°C.

A slide caliper (Brown and Sharp) graduated to read 0.0254 mm (0.001 in.) was used to measure the linear dimensions. Grain masses were taken on a 0–200 g balance (Mettler, Model B5) calibrated to read 0.0001 g. A tension apparatus having a movable carriage and holding devices similar to that used by Choudhury (1970a) was used to determine the tensile strengths of rice kernels. The carriage speed was maintained at 0.195 mm/sec. The transducer beam of the tension apparatus was coupled to a Sanborn amplifier and recorder to plot force-time curves to within ±0.454 N (1.0 lb). The paper speed was fixed at 2.5 mm/s.

Kernels for tensile strength determinations were prepared using the same method as Choudhury (1970a), i.e., using two pieces of synthetic electrical spaghetti and an adhesive (Cyanoacrylate cement – Eastman 910). An optical comparator (Wilder, Model AF) with 20 times magnification (linear) was used to project areas of cross-section of fractured kernels. A planimeter was used to measure projected areas.

An air-separation method was used to remove broken parts and other light materials from the rice grains. The polished grains were inspected directly while the rough rice was hand-hulled to brown rice and then inspected. The inspection was conducted by viewing the grains individually and collectively under various types of lights through a magnifocuser having a magnification of 2.75. All damaged, deformed, cracked, immature, non-vitreous or discoloured kernels were discarded. The remaining grains were equilibrated in a single layer thickness for six months or more in the plastic vapor tight containers with the saturated salt solutions. This period of equilibration time was used to relieve any residual stresses and to bring the rice grains to neutral stress conditions as was observed by Kunze and Choudhury (1972).

Two samples of 10 kernels from each of the brown and polished forms of the six varieties of rice were used in the experiments. One dram vials initially equilibrated to the equilibrating environment of the kernels for at least 24 h were used for handling the kernels and

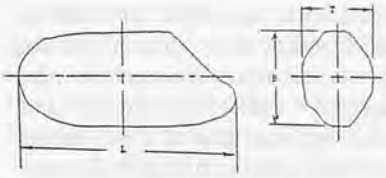

Fig. 1 Dimensions of rice kernel. L = length, B = breadth and T = thickness

ruptured specimens. The vials were tightly capped when they were out of the equilibrating environment.

After initial equilibration, the kernels in each sample were weighed individually. The following dimensions of each kernel were then measured (**Fig. 1**):

Length, L, the longitudinal length,

Breadth, B, the dorsaventral length, and

Thickness, T, the maximum lateral width.

The individual kernels of a sample were then prepared for tensile tests individually in the tension apparatus. The broken parts of the kernels after tensile tests were placed vertically on the platform of the comparator so that cross-sectional areas of the broken sections could be determined. The tensile force required to break a kernel was read directly from the force-time curve and the tensile strength was calculated by dividing the tensile force by the area of the fractured cross-section.

Results and Discussions

The study of physical and engineering properties of agricultural products is relatively new. Choudhury (1970b) indicated a large variation in tensile strengths of rice kernels. The results of this research also show such variation. **Table 1** indicates that the tensile strength of rice varies with variety and that brown rice is stronger than milled rice. One of the causes for this may be that the bran and aleurone layers of brown rice may add tensile strength to the grains. Researchers (Rhind, 1962; Little and Dawson, 1960) have also shown that structure, texture, and chemical composition of various parts of a rice kernel vary to a large extent. Generally, the protein distribution within a rice kernel cross-section is higher at the periphery than at the center (Barber, 1966). The concentration of protein in the peripheral cells suggests that these areas are substantially stronger physically and are, therefore, as Rhind (1962) suggested, capable of resisting stresses of greater magnitude than the cells in the center of the kernel. In the milling process, the surface cells are removed during polishing with the result that the tensile strength may be reduced.

Table 2 Average Values of Some Physical Characteristics of Six Rice Varieties and Their Coefficient of Variation

Physical characteristics*	Mean value	Standard deviation	Coefficient of variation %
Natural Characteristics			
Length, mm	6.75	0.77	11.41
Breadth, mm	2.35	0.24	10.21
Thickness, mm	1.71	0.06	3.82
Mass, μg	20.25	2.64	13.05
Calculated Characteristics			
Length/breadth ratio	2.93	0.53	19.11
Length/thickness ratio	3.96	0.39	9.85
Breadth/thickness ratio	1.37	0.12	8.76
Area of cross-section, mm^2	3.04	0.38	12.50
Tensile force, N	20.65	7.84	37.97
Tensile strength, N/mm^2	6.79	2.23	32.84

*For a sample of 240 grains

Table 3 Simple Correlation Coefficients Between Different Physical Characteristics of Rice Kernels of Six Varieties

Physical characteristics	Breadth (mm)	Thickness (mm)	Mass (μg)	Tensile force (N)	Area (cm^2)	Tensile strength (N/mm^2)
Length, mm	0.689	0.034	0.489	−0.037	−0.566	0.551
Breadth, mm		0.545	0.221	0.488	0.879	0.244
Thickness, mm			0.783	0.480	0.598	0.327
Mass, μg				0.550	0.308	0.504

Note: Sample size = 240, $r_{0.01}$ = 0.1807 for 238 degrees of freedom (Steel and Torrie, 1960).

There is also a large variation in other physical characteristics of rice (**Table 2**). Of all the measured variables, thickness shows the least variation indicating that rice kernels are of similar dimensions in thickness when all the varieties are considered together. The coefficient of variation was found to be the largest for the tensile forces required to break a rice kernel. This was followed by tensile strength, length/breadth ratio, and mass, respectively.

A simple correlation analysis of different physical characteristics (**Table 3**) shows that the mass of a rice kernel is more closely related to its thickness than either its length or breadth while the area of cross-section is more closely related to the breadth of the kernel than its thickness or length. The tensile strength per unit cross-sectional area of a rice kernel is more closely related to its mass than its length, breadth or thickness.

Figure 2 shows the relation between the mass and the ultimate tensile strength per unit cross-sectional area of rice kernels. This relation may be expressed as:

$$S_t = 0.44\,M - 2.03 \quad \ldots\ldots\ldots (1)$$

where, S_t = ultimate tensile strength per unit cross-sectional are of a rice kernel, N/mm^2, and

M = Mass of the kernel, μg.

Nagato and Kono (1963) used ratios of different physical dimensions of a rice kernel to indicate grain shape. When such a ratio

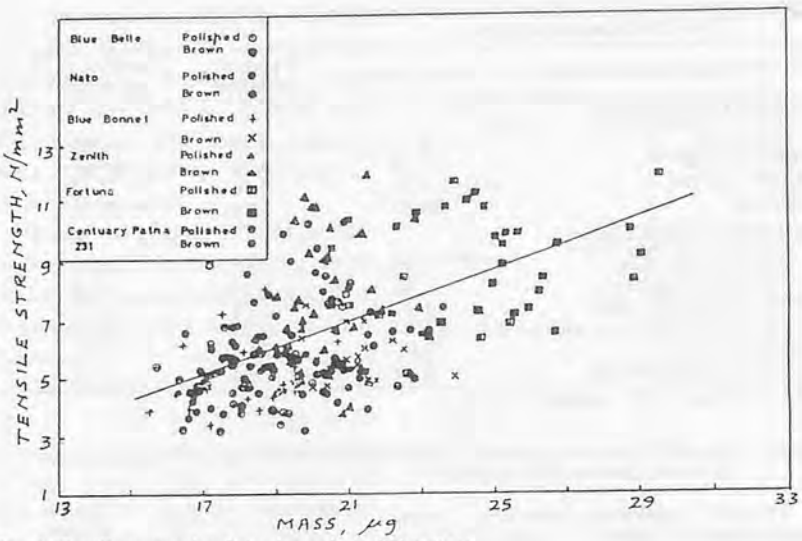

Fig. 2 Tensile strength of rice kernels and the mass.

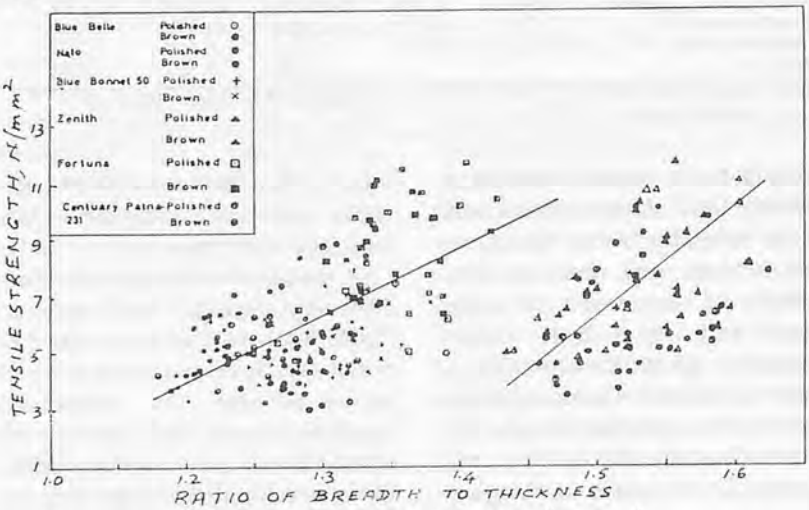

Fig. 3 Ratio of breadth to thickness and the ultimate tensile strength.

(breadth/thickness) vs tensile strength was plotted, rice varieties of this research were found to group themselves into two groups showing two different positive regression lines (**Fig. 3**). These relations are given by:

$$S_t = 20.39\ (B/T) - 24.51 \quad \ldots (2)$$

$$S_t = 20.18\ (B/T) - 19.28 \quad \ldots (3)$$

where, S_t has the same meaning as before and B/T is the breadth/thickness ratio.

These two lines suggested that rice varieties may be grouped into two groups depending on their kernel shape such as indicated by the breadth/thickness ratio. One group has a ratio of 1.43 or more (Zenith and Nato varieties: Group A) while the other grou has a ratio of 1.43 or less (remaining varieties: Group B). This separation of rice varieties into two distinct groups led to further correlation analysis by groups. Some of the correlation coefficients are given in **Table 4** which again shows that a positive correlation exists between the mass and the tensile strength per unit cross-sectional area of a rice kernel for both groups. A significant correlation exists between the mass and the shape characteristics indicated by the length/breadth and length/thickness ratios but they are in opposite directions. Group A has positive correlations while the Group B has negative correlations. With respect to the breadth/thickness ratio and the mass, the Group B has a significant positive correlation while Group A shows non-significant correlation. But for tensile strength and breadth/thickness ratio a significant correlation exists for both groups. **Table 4** further shows that the correlation coefficients for tensile strength and length/breadth or length/thickness ratios are positive for Group A and negative for Group B. The correlation between tensile strength and length/breadth ratio is significant for Group B but non-significant for Group A while the correlated between tensile strength and length/thickness ratio is significant for both groups. This peculiar alignment of rice varieties into two distinct groups is difficult to explain physically. However, the results are in agreement with those obtained by Nagato and Kono (1963) who divided rice grains into five groups of two types depending on hardness ratio and incidentally by length/breadth ratio. According to these workers the Type I (assumed by them as characteristics of Indica

Table 4 Some Correlation Coefficients between the Shape, Mass and Tensile Strength per Unit Cross-sectional Area of Rice Kernels

Shape characteristics	Mass (μg)		Tensile strength (N/mm²)	
	Group A	Group B	Group A	Group B
Length/breadth	0.579	−0.444	0.209	−0.485
Length/thickness	0.667	−0.275	0.410	−0.284
Breadth/thickness	0.156	0.441	0.403	0.495
Mass	–	–	0.416	0.549

Group A: Kernels have breadth/thickness ratio more than 1.43 (n=80).
Group B: Kernels have breadth/thickness ratio less than 1.43 (n=160).
Note: For 78 degrees of freedom, $r_{0.01} = 0.286$, $r_{0.05} = 0.220$,
For 158 degrees of freedom, $r_{0.01} = 0.207$, $r_{0.05} = 0.156$.
(Steel and Torrie, 1960–Table A.13)

varieties) has two groups: Ia or hard type which has a length/breadth ratio of more than 2.5 and Ib or semi hard-type which has a length/breadth ratio between 1.9 and 2.5. Type II (assumed by them as having characteristics of Japonica varieties) has three groups: IIc, IId, IIe and are semi-soft, soft and extra-soft, respectively, having length/breadth ratios all less than 2.0. Although no Japonica variety was included in this research, the results also show that rice varieties could be grouped according to the ratio of the dimensions of the kernels and tensile strength. The above analysis shows that the length/thickness ratio of a rice kernel has significant correlation with the tensile strength per unit cross-sectional are for both the groups. The semi-hard type (Ib) has a positive correlation between the tensile strength and the length/thickness ratio.

Further regression analysis between the tensile strength and shape characteristics was conducted in an effort to fit the data with linear, quadratic, cubic and quartic equations but the results indicated that the linear equations fit the data best. These equations are:

$S_t = 23.05 - 4.91\ (L/B)$ ..... (4)

$S_t = 3.41\ (L/B) - 0.80$ ..... (5)

Also

$S_t = 21.16 - 3.36\ (L/T)$ ..... (6)

$S_t = 4.52\ (L/T) - 8.48$ ..... (7)

Where, S_t has the same meaning and L/B is the length/breadth ratio while L/T is the length/thickness ratio.

Figure 4 shows the plots of equations (4) and (5) while the **Fig. 5** shows the plots of equations (6) and (7). A dashed line was drawn in **Fig. 4** for Group A as the correlation is non-significant but a solid regression line was drawn for Group B to show a significant correlation. In case of **Fig. 5** both the regression lines were drawn solid as they were both significant.

Equations (4) and (5) may be equated and we obtained L/B = 2.87 = 2.9 (8)

Similarly, from equations (6) and (7), we get L/T = 3.76 = 3.8 (9)

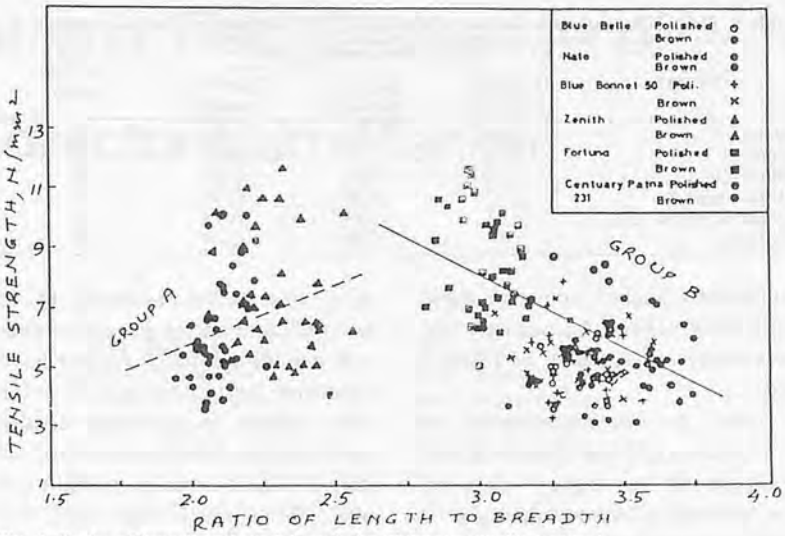

Fig. 4 Ratio of length to breadth and the ultimate tensile strength.

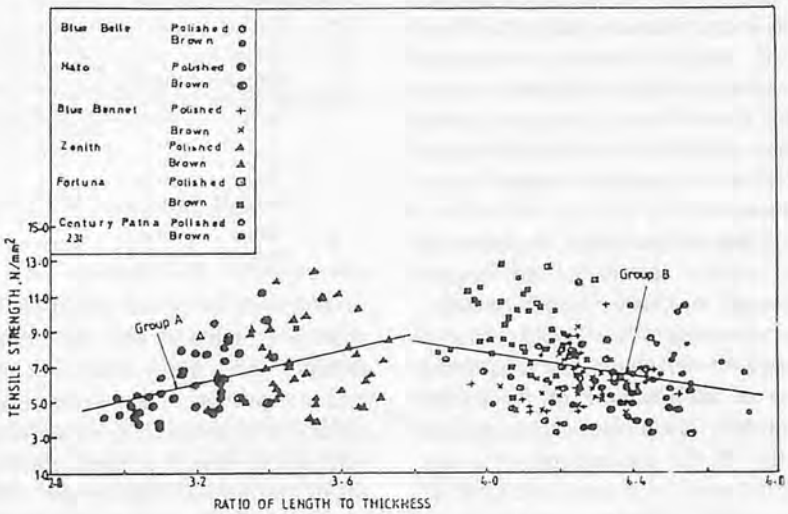

Fig. 5 Ratio of length to thickness and the ultimate tensile strength.

This analysis and **Figs. 4** and **5** suggest that a rice kernel may have a high tensile strength if it has length/thickness ratio around 3.8 and to a limited extent if it has a length/breadth ratio around 2.9. Kunze and Choudhury (1972) indicated that rice kernels, when exposed to a higher – r.h. atmosphere, do not fissure immediately but require a lapse of time (referred to as fissuring response time) which was assumed to be related to the initial tensile strength of the rice kernel. Therefore, after exposure to a higher r.h., the weakest kernel would fissure first and the strongest kernel would fissure last. Thus a kernel which has a length/thickness ratio around 3.8 is indicated to have a high tensile strength and may be able to withstand changes in the environment which otherwise may create stresses in the kernel that would cause it to fissure from tensile stresses.

Table 5 shows shape characteristics of kernels of the different rice varieties and their respective groupings. Some varieties of rice have

Table 5 Shape Characteristics of Kernels of Six Rice Varieties and their Groupings

Variety	Shape characteristics ratio			Related group
	Length/ breadth	Length/ thickness	Thickness/ breadth	
Nato	2.20	3.19	0.66	A
Zenith	2.28	2.50	0.65	A
Bluebelle	3.44	4.23	0.80	B
Bluebonnet 50	3.22	4.28	0.79	B
Century Patna 231	3.39	4.35	0.78	B
Fortuna	3.09	4.08	0.74	B

consistently higher values of these ratios than others. Accordingly the six varieties of rice may be divided into:

Group A: has lower values of ratios (L/T less than 3.8), and

Group B: has higher values of ratios (L/T more than 3.8).

Physically, Group A is the short or small grain type while Group B is the long or slender grain type. However, **Fig. 1** does not show these groupings which indicates that a rice kernel having a high mass will have a high tensile strength irrespective of the group to which it may belong.

Table 3 shows that there is little correlation between the tensile strength and either length, breadth, or thickness. This implies that a single kernel dimension would not be useful indicator of its tensile strength. The shape, expressed as a ratio of the dimensions of a rice kernel may be a good indicator of its tensile strength particularly its breadth/thickness ratio (**Table 4**). A high value for the ratio of breadth/thickness of the rice kernel of a specific group/variety would be expected to have a high tensile strength per unit of cross-sectional area. However, for the ratio of length/thickness this value should be about 3.8 ± 0.2 (**Fig. 5**).

Conclusions

Equilibrated kernels of six varieties of rice at 23.3°C and 44% r.h. were used to determine the length, breadth, thickness, mass and tensile strength per unit of cross-sectional are of individual kernels. The shape of a rice kernel indicated by its ratio of dimensions was determined and was found to be related to its mass and tensile strength. Rice kernels cannot be generally divided into strong or weak groups with respets to their tensile strength per unit of cross-sectional area, but may form two groups according to their shape and tensile strength:

Group	Length/ thickness ratio	Breadth/ thickness ratio	Corelation between tensile strength or mass and length/ thickness ratio
A	Less than 3.8	More than 1.43	Positive
B	More than 3.8	Less than 1.43	Negative

The mass of a rice kernel has a positive correlation with its tensile strength per unit cross-sectional area irrespective of any group. According to this research, rice kernels with a high tensile strength should weigh more than 20.0 g per 100 kernels while their length/thickness ratio should be about 3.8 ± 0.2.

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Development and Field Evaluation of a Stubble Collector-Cum-Planker

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Introduction

Preparation of stuble-free field is a prerequisit for sowing of seeds with a seed-cum-fertilizer drill. Stubbles and grasses are a hindrance in the line sowing of wheat in particular, as it is done after harvesting cotton, pearl millet, sorghum or paddy, the roots of which are either collected manually or left in the field itself. The collection of stubbles manually to the desired extent and then burning the same in heaps may require about 20 mandays per ha apart from being tiresome, laborious and time consuming.

The seed-cum-fertilizer drill works properly only in well prepared, stubble free and levelled seed beds. It is also a fact that 15-20% higher yields are possible with the mechanised sowing. So, if the full advantage of sowing machines is to be taken, it is imperative to remove the stubbles, roots and grasses from the fields.

Objectives

Considering the problems of the farmers, work was initiated on the development of a stubble collector-cumplanker. The prototype was developed keeping in view the following considerations: suitability for collecting stubbles of various crops; capacity to break clods and to level field; simple in construction; easy and simple tilting mechanism; easy to operate and adjust; high capacity and low cost; and better collection efficiency and easy sliding action of stubbles over the rake teeth.

Methods and Materials

The material of construction consists of a wooden planker fitted with mild steel spikes to an angle iron frame and has a tilting mechanism (**Fig. 1**).

The planker is made from two wooden battons of 2 100 x 90 x 65 mm jointed together with wooden spacers. A gap of 100 mm is kept between the two battons. The weight of the planker is about 15 kg. The main frame having raking mechanism is fitted on both ends of the planker by two supports made of mild steel angle iron 50 x 50 x 6 mm with the help of bolts and nuts. To control the raking mechanism, a device is also provided in the centre of the planker.

The main frame is 2 m long and is made by welding together two mild steel angle irons 50 x 50 x 6 mm. Regular holes of 12 mm diameter are drilled at a spacing of 100 mm in the angle iron of box type frame. Two pins of 25 mm diameter are welded on both the ends of the frame for support and easy pivoting of the raking mechanism with respect to the planker. Nine spikes of 250 mm and 10 spikes of 350 mm are made from mild steel square rods of 10 mm. The small and longspikes are fitted alternatively on the main frame at an interval of 100 mm with nuts and bolts. The whole raking mechanism is supported on the planker with the help of two angles having bushes (**Figs. 2, 3 and 4**).

Tilting/depth control device: The tilting/depth control lever is supported by two 550 mm long ms angle 40 x 40 x 5 mm bent at an angle of 110° with the horizontal

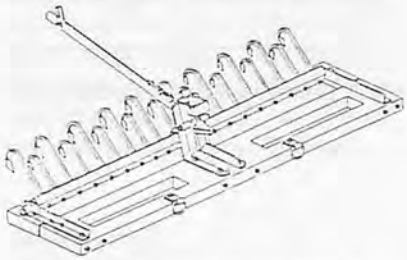

Fig. 1 Stubble collector-cum-planker, isometric view.

Specifications – Type of machine: Bullock/camel/tractor drawn stubble collector-cum-planker with arrangement for transportation, depth control and a dog clutch mechanism for actuating the raking device, Purpose: To make the field stubble-free before sowing wheat, Source of Power: One pair of bullocks/one camel/tractor, Effective working width: 2.0 m, Depth of racking: 5.0 - 7.5 cm, Effective field capacity: 0.4 ha/h (Single operation), Average draft: 60 -70 kg, Labour requirement: 5.0 man-h/ha, Operating cost: 15 - 17.5 Rs./ha, Approximate price: 600 Rs.

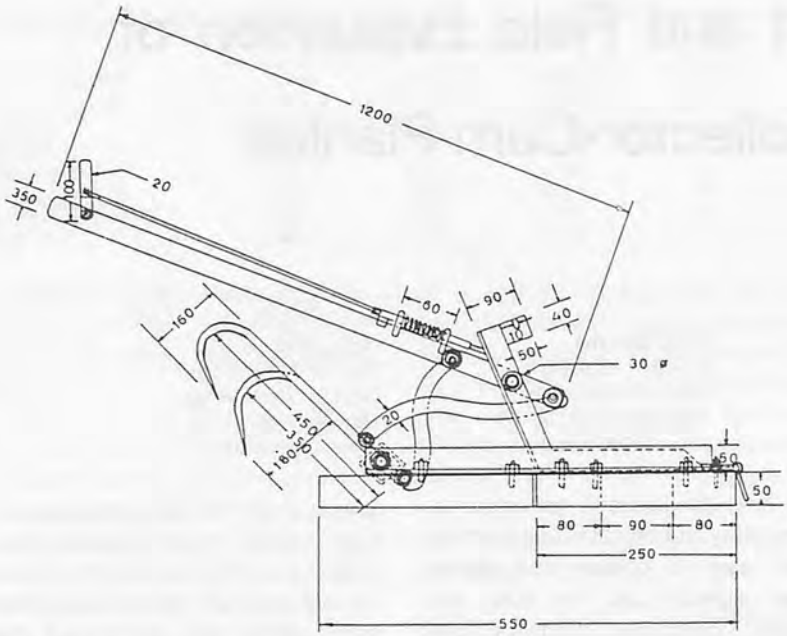

Fig. 2 Stubble collector-cum-planker, side view.

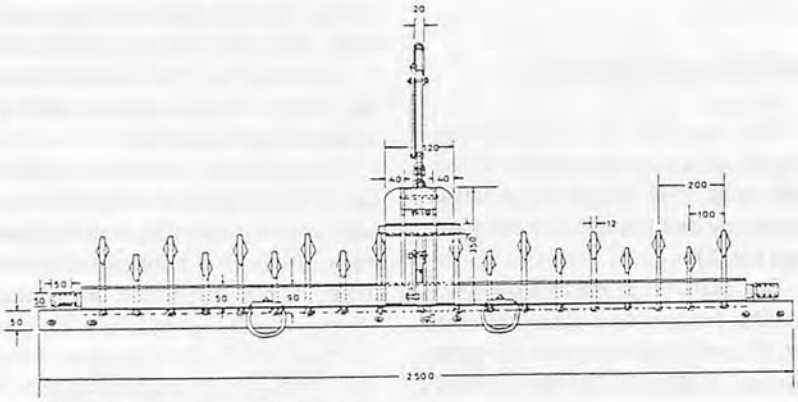

Fig. 3 Stubble collector-cum-planker, front view.

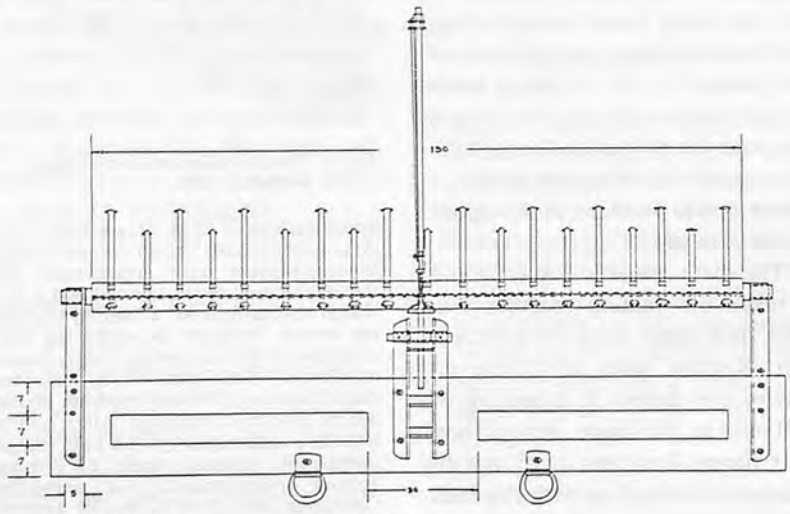

Fig. 4 Stubble collector-cum-planker, top view.

and fitted at the centre of the planker. The total height of the supports is about 300 mm and the distance between them is 40 mm. The lever is fitted on a shaft 18 mm diameter and 150 mm long at a height of 250 mm from the base of the supports. The size of the mild steel lever is 1 100 x 50 x 6 mm, which is used for activating the raking mechanism during field operation. The raking mechanism is connected with the main lever with the help of mild steel flats 25 x 6 mm (drawing Nos. FMGD-2 & 3). The flats guide and actuate the main frame with the help of dog-clutch arrangement provided in the system. When a large quantity of stubbles gets collected in the rake, the lever is lowered and the rake gets lifted above the ground and thus the stubbles are released at one place.

On the front side of the planker two mild steel hooks 300 mm long made from 15 mm diameter bar are provided for hitching the implement with the bullocks or tractors.

Detailed trials on stubble collector-cum-planker (Patela-harrow) were carried out under actual field conditions for three years (1982-84). It was tested for preparation of seed bed for sowing of wheat after harvesting sorghum and cotton crops. The amount of stubbles/roots present before use of the implement and after one, two and three operations were recorded. The observations on its draft, time required to complete the operation, depth of raking and area covered were also recorded. The raking/collecting efficiency of the implement was calculated by using the following formula.

Collection efficiency

$$= \frac{W_1 - W_2}{W_1} \times 100$$

Where W_1 = Amount of stubbles before raking

W_2 = Amount of stubbles after raking.

Table 1 Test Results of Stubble Collector-cum-Planker in Sorghum Fields, 1982

Area (ha)	Amount of stubbles (q/ha)			Collection efficiency (%)		No. of roots of sorghum crop (lacs/ha)			Collection (%)	
	Before operation	After operation		Operated	Operated	Before operation	After operation		One operation	Two operation
		Once	Twice	Once	Twice		Once	Twice		
0.5	10.25	1.34	0.00	86.92	100	0.56	0.34	0.24	39.28	57.14
0.4	7.00	2.36	1.04	66.28	85.14	1.08	0.96	0.50	11.11	53.70
0.5	21.2	8.0	–	62.26	–	1.84	1.28	0.48	30.43	73.91
Average	16.82	3.90	0.5	71.82	92.57	1.16	0.86	0.40	26.94	61.58

Table 2 Test Results of Stubble Collector-cum-Planker in Cotton Fields, 1982

Area (ha)	Amount of grass roots/stubbles (q/ha)		Efficiency (%)
	Before operation	After operation	
0.2	18.0	2.15	88.05
0.4	4.40	2.26	48.63
0.1	13.75	2.25	83.63
0.2	4.0	1.08	73.00
Average	10.03	1.935	73.32

Table 3 Performance of Stubble Collector-cum-Planker in Cotton Field, 1983

Area covered (ha)	Amount of stubbles/grasses (q/ha)				Collection efficiency (%)		
	Before operation	After operation					
		Once	Twice	Thrice	Once	Twice	Thrice
0.4	95	36.5	15.0	5.3	61.57	84.21	97.26
0.4	85	30.0	13.5	5.2	62.5	84.11	93.88
0.4	60.5	28.0	14.0	5.6	53.71	76.85	90.74
Average	80.16	31.50	14.16	5.36	59.26	81.72	93.96

Table 4 Performance of Stubble Collector-cum-Planker in Cotton Fields (1984)

Area covered (ha)	Amount of stubbles/grasses (q/ha)			Collection efficiency (%)	
	Before operation	After operation		One operation	Two operation
		Once	Twice		
0.4	3.12	0.68	–	78.20	–
0.4	7.4	1.72	–	76.76	–
0.4	23.0	4.6	2.0	80.0	91.3
Average	11.17	2.33	2.0	78.72	91.3

Results and Discussion

The prototype of the stubble collector-cum-planker was tested for removing the stubbles of sorghum, cotton and grass roots and prepare the field for sowing of wheat. Its performance test results are given in **Tables 1 to 4**. It is shown in **Table 1** that the unit could collect stubbles/grasses upto 62-87% in a single operation and 85-100% after the second operation. Its average collection efficiency varied from 71 to 92% depending upon the number of operations. The collection efficiency in sorghum varied from 11 to 40% in a single operation and 53.7 to 73.9% after the second operation. The lower collection efficiency may be due to the fact that the roots of sorghum were not large enough to get entangled in between the spikes of the rake.

Table 2 indicates the performance of the collector-cum-planker in cotton fields. The implement was tested at four different locations. Its collection efficiency varied from 48.6% to 88% in a single operation. The average collection efficiency was 73.7% which is almost equal to its efficiency in collecting grass roots (71-82%). This is certainly higher than in sorghum which was only 28.7% in a single operation. Higher efficiency as compared to the efficiency in the sorghum fields may be due to different type and structure of roots.

Table 3 shows the performance of the implement in cotton fields during 1983. The prototype was tested as three different locations on acre basis. The average collection efficiencies after one, two and three operations were 59.3, 81.7 and 93.9%, respectively. More than 82% of the stubbles could be removed after the second operation an so there was no need to operate the implement the third time.

Three demonstrative trials were conducted for the collection of stubbles in cotton fields under actual field conditions during 1984. The test results are given in **Table 4**. The average cellection efficiency after one and two operations was 78.7% and 91.3%, respectively. The implement is very effective in removing the stubbles/roots of cotton crop which helps in preparation of a fine, smooth and stubble-free seed bed for wheat.

The field capacity of the prototype was 0.4 ha/h, i.e. about 2.5 h are required to collect the stubbles/roots in 1 ha (single operation). The average draft of the unit was 70-90 kg depending upon the type of soil and extent of stubbles/roots present in the soil. The depth of raking was 5-7.5 cm depending on the quality of seed bed. The draft of the implement was further reduced by modifying the planker and the tilting mechanism. The tilting mechanism is provided in such a way that the operator can operate it by moving behind the collector instead of standing on the planker when the bullocks are walking. With this system the operation of prototype became easy and the draft was considerably less (60-70 kg).

Conclusions

The stubble collector-cum-planker was very effective in collecting the stubbles/grasses/trash roots to an extent of 70% in a single operation and 90% in two operations depending upon the type of soil and field conditions. It required about 2.5 h to cover 1 ha (single operation) and cost of operation was nearly Rs. 15/ ha. The average draft of the implement was 60-70 kg. ■■

Low-Cost Peat Production and Gasification

by
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Abstract

One dollar a ton (35% moisture) peat production cost!! Peat is attractive because of it's potential as a low cost energy source. A common error was, and still is, the search for methods of briquetting or artificial drying which by their nature make the product unnecessarily expensive. Satisfactory drying can be achieved by availing of the natural processes (i.e., sun and wind) particularly in tropical countries. Employment will be generated via the energy hungry industries which will be attracted to the low-cost energy source. The potential for peat is considerable. However there is a considerable shortfall in conventional high volume production methods giving rise to long lead times and unnecessarily high production costs. Notwithstanding the necessity for efficient, economic production methods, the same criteria apply to the methods of conversion to useful energy.

This paper outlines a novel, but practical, integrated production system; efficient methods of converting peat to useful energy for the markets which pay the highest price for energy – the domestic and small industrial sectors; a new energy marketing concept.*

*Keywords that need to be taken into account early in this paper are: sod-peat production, transporting peat, gasification, turning peat, storage of peat, energy marketing, energy farming, conveyor system, drainage system, and low-cost production.

Introduction

Traditionally, peat production on a large scale has required long lead times and very high initial costs for both preparation and development of the peatland and the necessary plant for production, handling and transport of the raw product. Lead times of five years from start of bog preparation to first cut are not uncommon. Expensive road systems and deep drainage with constant maintenance costs require high capital outlay before any cash inflow commenced.

In 1981 Herbst introduced a new system designed to overcome these problems. First they introduced the successful chain type Herbst peatcutter to be mounted on an agricultural tractor. Cutter blades from 0.5 to 2 m long made it possible to dig the deep layers of good quality peat and mix these with the upper layers. Therefore, wasting no peat and producing a high quality energy product. 700 of these units are working throughout the world. In Ireland alone 1 million t of peat were produced last year with this machine. This system allows farmers and small energy producers to produce large quantities of peat from small areas. The output of these machines is more than 100 t per day.

Tropical countries rich in peat have the advantage of the longer and more intensive sunny days. In these countries harvesting can take place shortly after cutting. For example, in Burundi harvesting is commenced 7 days after cutting thus making up to nine harvests possible. In Burundi a U.S. Aid project managed by the Irish semi-state company, Bord Na Mona, utilizes agricultural tractor mounted Herbst cutters and in 1984 more than 20 000 t of peat were produced with these units.

Fig. 1 Tractor-mounted Herbst cutter in Africa.

The Bogmiser System

The Bogmiser system is based on the same proven technology and claims that:

One vehicle to handle up to 80 000 t of peat per year;

Up to 1 000 t peat at 35% moisture produced in 24 h;

No bridges or roads;

Shallow drainage;

Full production in the second year;

Harvesting with the same personnel 3 000 t/24 h;

Storage on the bog, no long delays for multiple cutting;

Effective drainage as the drains are at 5 m centres; and

Cutting can be carried out on unprepared peatland.

This is a mobile and highly ver-

satile 'power plant' – a super -low ground pressure swampland vehicle with the following features:

Air cooled 320 hp diesel engine.
PTO speeds 400 – 1200 rpm.
Infinitely variable forward speed < 4.0 mph (1.76 m/s)
Working speed 0 – 0.8 mph (0.35 m/s)
Ground pressure 0.65 psi (4.5 kN/m^2)
Machine width 4.4 m
length 8.6 m
height 3.5 m
(to top of cab)

All of the equipment necessary for preparation of peatland and peat production with the Bogmiser system can be attached to the Bogmiser.

Operation Sequence with Bogmiser Attachments

A 5m blade is used to level any major unevenness and remove trees etc.

A mulcher is used to reduce the surface growth to small particles.

A tree mulcher can be mounted if necessary.

A screw drainer is used to dig all field drains every 5 m to a maximum depth of 1 m and a width 75 cm.

The field drains are collected into the main drains, approx. 1.6 m deep, which are created with the twin disk drainer.

Because of its length the Bogmiser can travel over all drains. A headland of 60 m width on the perimeter of the bog is cut last, similar to the agricultural ploughing system. This system permits the use of narrow fields – 5 m for all transactions – as the Herbst cutting system does not require deep drainage. The result is better, faster drainage giving a drier bog and little time lost in preparation.

The screw leveller (5 m wide) will clear the bog and profile at one angle. This results in a faster, easier

Fig. 2 Bogmiser preparing virgin peatland.

and better profile for weather protection and surface water dispersal.

It is important to note that cutting can be carried out on virgin peatland to get immediate cashflow. If this is done the product must be sorted to remove the small quantity of inferior material.

The peat is cut with the BM 5 peat cutter and kept in long 'sausages' on the bog. A marker attached to the cutter marks the peat every 150 mm (6 inches); this ensures an even length of product, minimises breakages and accelerates drying.

The first drying is done in carpet form to allow quick formation of the weather protecting skin. The turning is carried out as soon as possible to get the peat into 'chaotic' form and accelerate the fusion drying process. Turning can be done with the Bogmiser or a special low-cost, self-propelled gentle turner.

When the peat has reached a moisture content of about 40-45% the windrower / harvester is used to harvest at a rate of about 200 to 300 t /h and to transfer the product to the adjoining field. The contents of 4 adjoining fields are then transferred into the 5th field and this operation is then repeated from the other side. In this manner a stockpile on every 9th field is constructed, thus leaving 8 fields ready for a repeat cutting run.

The stockpile is the final storage area before dispatch. Here the peat continue drying and maturing. Pending location and product use it is covered with plastic for the

Fig. 3 Bogmiser cutting energy peat on unprepared swampland.

winter months. The plastic is a new product, in use it is weighted down with water tubes and is therefore easy to use. The Bogmiser stockpile system permits harvesting at a higher moisture content due to the long and narrow storage on the field allowing a high level of exposure to the wind and sun.

From the stockpile the peat is transferred with the loader onto the Herbest conveyor system which moves the peat to the dispatch area at a rate up to 20 t/h, as and when it is required. Minimum handling avoids breakages.

Any conventional conveyor can be used but the Herbst group have under development a new patented conveyor system. It is of lightweight, but sturdy construction and is stabilized when working by two polythene tubes filled with water (from the bog). The complete unit can be erected and disassembled by two men. For moving, the water can be released, the conveyor rolled up and the tubes refilled in the new location.

Peat for Energy

In relation to its potential sod peat has received little credit as a fuel in the form in which it normally comes off the bog, that is 35 – 40% moisture by wet weight, 350 – 450 kg/m^3, in sods 300 – 450 mm long with a net calorific value of 12.6 MJ/kg.

As an extension of the principle of low cost, efficient and practical peat production methods Herbst

have identified and developed means of converting the peat to useful energy which are acceptable to a wide range of users and also require a minimum of alteration to its cut form. The users are in the domestic and small commercial/ industrial sectors; users who, by tradition, pay the highest prices for energy.

The most appropriate use for peat and other forms of biomass for energy purposes is heat production, especially where it can replace fuel oil.

A volatilizer has been developed and is now being manufactured by Servotherm Ireland Ltd., a member of the Herbst group of companies. It is marketed under the name Herbst Gasmiser. The outstanding features of this system are:

1. Suitable for retrofitting to most existing oil, gas or solid fuel fired heating plant.
2. Efficient in operation – seasonal thermal efficiencies for complete space heating systems (boiler, burner, distribution system and controls) of 70% are attainable.
3. A high degree of automation is possible:
   (a) auger feeding from intermediate storage
   (b) auger removal of ash
   (c) vibramotors for grate shaking and for preventing hopper bridging with certain fuels.
4. A variety of fuels can be used, including woodchips, woodcubes, sawdust and crushed sod peat. In most cases the only alterations required for switching fuel are a change of grate and adjustment of primary and secondary combustion air settings.
5. Crushed sod peat with moisture content up to 45% wet weight can be utilised efficiently.

The main components of the Herbst Gasmiser are:

1. The reactor chamber – this is a monolithic refractory mass surrounded by high density insulation. Located in the main chamber are a grate and grate bearers and over the grate is the reactor. All components in the high temperature zone are cast from a high grade iron alloy.
2. The fuel hopper – this is a gas tight construction of mild or stainless steel (dependent on main fuel used).
3. The combustion tunnel – again a monolithic casting from the same refractory material as the reactor chamber.

A series of units are manufactured in the range 30 – 600 kW and in certain circumstances multiples of these units can be installed.

Producer Gas Generator

This is a downdraft gasifier with an integrated gas cooling and scrubbing train. The system can be used with a wide variety of fuels and is especially suitable for gasification of peat.

Generally, it is supplied as part of a total energy package including a modified diesel engine driving an asynchronous generator. Various options are available for heat recovery from the producer gas, engine and generator. The engine can be converted fully to producer gas by lowering the compression ratio and installation of spark ignition. The end result is in effect a gas engine. Alternatively a standard diesel engine with little alteration can be run in a dual fuel mode. In this case about 85% of the engine power output is drawn from the producer gas, the remaining diesel being necessary for ignition.

Fig. 4 A 60kW Gasmiser installed in a leisure centre in Ireland.

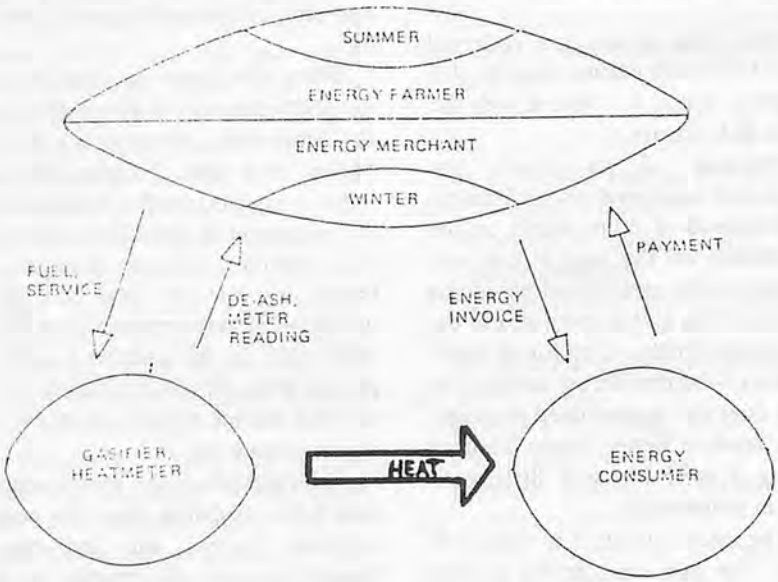

Fig. 5 The Milkman system.

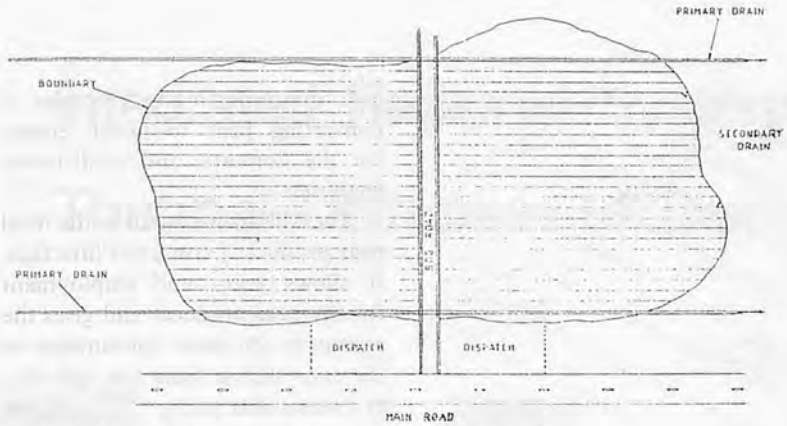

Fig. 6 Herbst Difco peatcutter system –Drainage network.

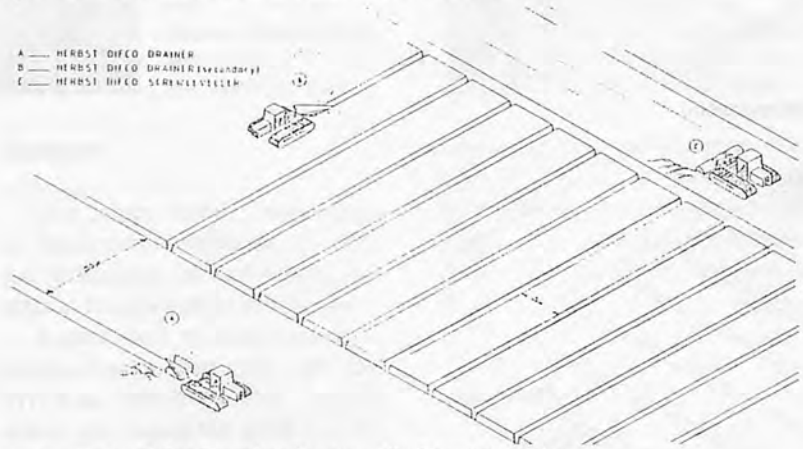

Fig. 7 Herbst Difco Bogmiser System – Surface preparation.

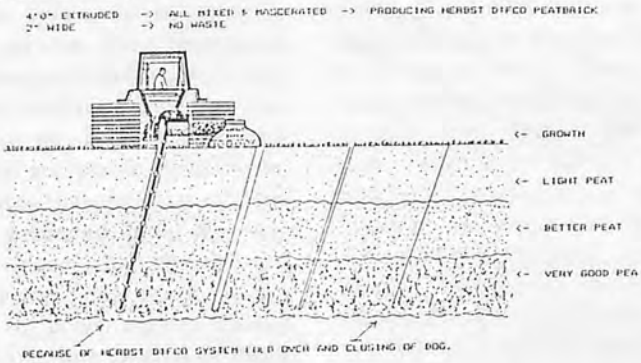

Fig. 8 Producing peatbrick.

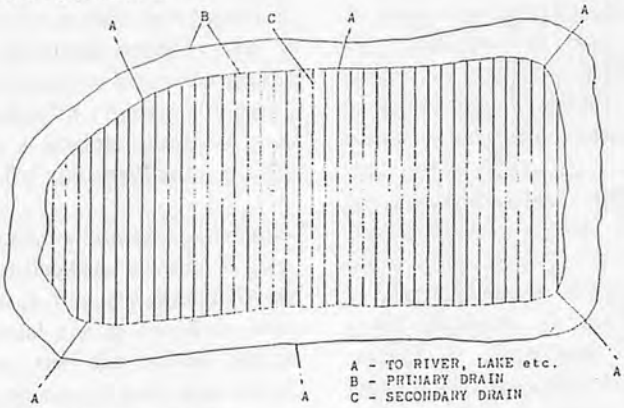

Fig. 9 Herbst Difco Bogmiser System – Drainage network.

The standard unit can be matched with engines to give outputs up to 100 kW. If higher output is required, multiple units are set up, this permits the maintenance of the proven and low cost technology.

Energy Marketing Concept – The Milkman System

The Milkman system is the logical extension of the principles referred to throughout this paper. It was developed for the peat industry but can equally be applied to biomass production especially energy forestry.

The purpose of this approach is to simulate the convenience of fuels. The components of this concept are:

1. The producer / distributor of locally sourced rawfuel, i.e., an Energy farmer / energy merchant supplies, installs and services the necessary combustion equipment and heat flow meters. He will guarantee fuel availability and supply of energy to the consumer at an assured discount from reference energy costs, e.g., heating oil / natural gas.
2. The consumer is charged for metered energy use over fixed periods in similar manner to utility energy producers.

Concluding Remarks

With the Bogmiser system it is possible to produce the maximum output of peat with minimum labour and bog preparation at the lowest cost possible. No internal road system or expensive bridges are required, there is no panic in the brief good weather season, and permanent employment for all people involved on the bog can be guaranteed.

The Herbst Gasmiser and the producer gas generator are low

cost solutions to the problems of converting peat to useful energy for the domestic and small industrial users.

The Milkman system is the ideal peat producer / consumer interface. It allows year-round employment for the peat producer and gives the consumer the same convenience as the convenience fuels (oil, gas etc.) at a reasonable price. ■■

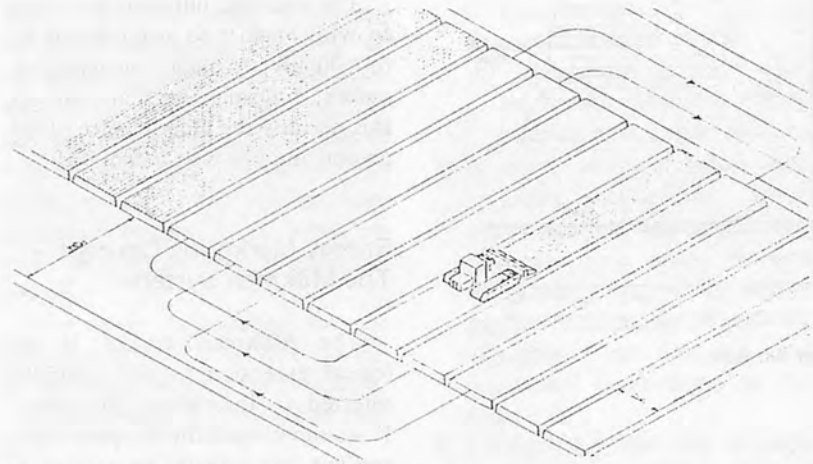

Fig. 10 Herbst Difco Bogmiser System – Cutting procedure.

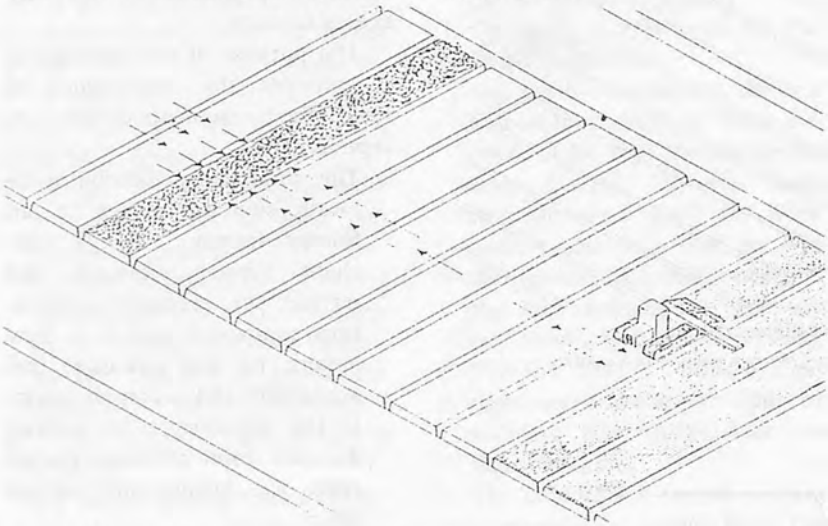

Fig. 11 Herbst Difco Bogmiser System – Windrowing.

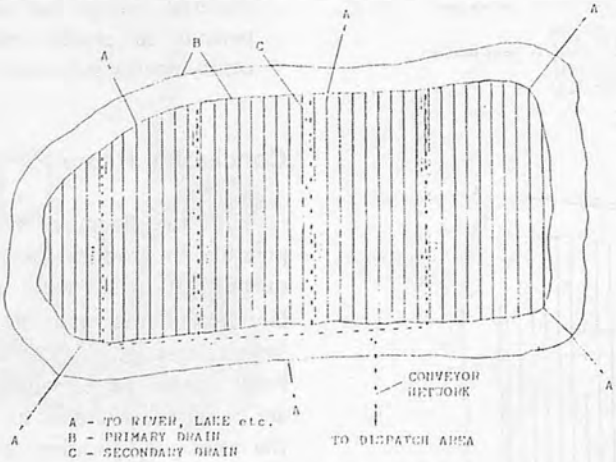

Fig. 12 Herbst Difco Bogmiser System – Peat extraction.

Integrated Regional System of Thermal Utilization of Biomass Resources

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Abstract

This paper reveals some results of fundamental research on effective utilization of agricultural biomass at its location of production.

A great deal of experimental research has shown that biomass pyrolysis produces five components: gas, liquid tar, solid tar, fixed carbon and ash.

In this paper, the composition of each of the five components were determined under a particular pyrolysis condition which is supposed to be economically and practically acceptable. One of the results show that the total calorific value of generated liquid was considerably higher than that of gas. Therefore, the liquid could be used as a fuel for power engines if some proper processing method of distillation was applied to it. Based upon this fact, the authors investigated a feasible pyrolysis condition for a greater recovery of liquid, an appropriate design for a pyrolysis furnace, and also a feasible condition and method for the distillation of the liquid.

The authors consider a comprehensive utilization system of biomass energy that the generated gas and thermal energy could be consumed at the very places where they are processed, and other useful products such as liquid for power and solids for thermal energy that could be used not only at the location of production but in its neighbouring area as well, since it is relatively easy to store and handle them.

Introduction

Developing countries such as some of those in Asia and Africa depend largely on biomass resources as an energy source. They include steam engines fuelled by rice hulls at rice mills, heat utilization of waste wood at an oil-palm plantation and household use of charcoal burnt in a remote forest. However, the energy efficiency needs a drastic improvement, because the above-mentioned manner of utilization does not allow efficient extraction of intrinsic energy contained in these resources. For example, in the utilization of rice hulls for steam engine, low efficiency of a monocylinder steam engine is added to low efficiency of a rice hull fuelled boiler. It is important to aim at maximum derivation of the potential intrinsic energy of biomass resources.

The utilization of biomass and other resources as energy source instead of dependence on petroleum is also advocated in industrial countries such as Japan. However, developing countries depend even at present on biomass resources more seriously than industrial nations. Saving of foreign currencies does not permit easy-going dependence on petroleum. These countries are faced with a vital need for effective development of biomass utilization. The ESCAP and FAO experts in these countries are, therefore, undertaking various studies on efficient thermolytic gasification of biomass resources[1]. Systematic studies on utilization of charcoal are also encouraged.[2]

The series of studies reported in this paper are based on previous development of a rice-hull combustion furnace which has been undertaken by Shimizu since 1964.[3] [4] The study of Shimizu refers to a combustion furnace for pyrolytic gasification of biomass. Since some achievements have been attained on the process of biomass pyrolysis, the study is now not restricted simply to utilization of heat by combustion but has proceeded into a practical phase of attempting production of energy products that can be used as a power source as well and that can also be transported and stored as necessary.

The latter half of these studies was supported by a grant-in-aid from Japanese Ministry of Education for special researches on energy development.

Development of Gasification Combustion Furnace

Rice-hull furnace – As early as 1964, we commenced a study on the development of a furnace that can be applied to generation of heat using rice hulls for drying of rough rice. A similar furnace intended for the same purpose was already in use from approximately 1918 in Japan. The oil crisis in the early 1970s encouraged the development of new devices. However, devices introduced at that time into the market had defects and hence required the following improvements; (1) resistance to heat, (2) control of flying dust; (3) reduction of power consumption (especially blower) and (4) the economics of the innovation.

During the process of trial fabrication that began from 1964, Shimizu developed a gasification combustion furnace. A large-sized furnace (200 kg/h, 500 Mcal/h) constructed in 1971 was introduced in an FAO report.[5] **Fig. 1** shows an improved type designed into a more compact size, which was constructed in 1979. After repeated experiments, it has a capacity of 53 kg/h and 130 Mcal/h. This furnace has already been introduced into many rice-drying plants.

In the figure, (a) designates a cyclone which feeds airborne materials from a hull storage chamber into an oblique-lined area of the furnace (b); (c) is a fire grid which drops a constant amount of char by means of intermittent shaking and which passes a small amount of suctioned primary air to gently activate an imperfect burning of piled fuel, as indicated by arrows; (d) is a secondary combustion chamber which achieves perfect combustion of gas with the aid of a ceramic plate; (e) is a blower which sucks a mixture of high-temperature gas and air and distributes via ducts the gas air mixture at optimal temperature to 4 to 6 driers after removing a small amount of dust by means of

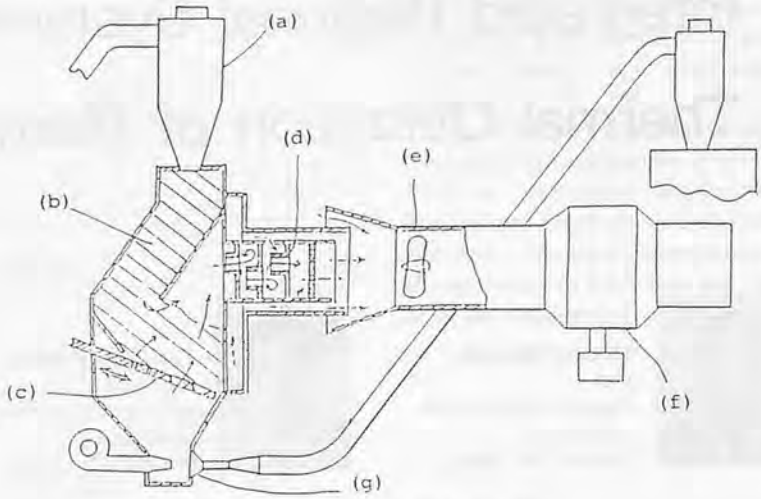

Fig. 1 Construction of rice hull burner.

an axial flow cyclone (f). It is a direct burning system because complete combustion is required; (g) indicates an ejector which aircools residual char during transport through a tube. Char can be collected directly into a polyethylene bag. All these are operated automatically. Half of the carbon content is used and the burned char is reduced to approximately ¼ of the original material by both the volume and weight ratios.

Bark-pellet furnace – Pelletization of waste bark for fuel (drying – crushing – compressive molding) is already a developed technology. In Japan, the development of a bark-pellet furnace has been promoted since about 1980 only. **Fig. 2** shows a furnace developed in 1983 in compliance with the need of the time and later improved. The operational principle is almost identical to the above-mentioned rice-hull furnace. The only differences are as follows.

The outlet of blower(a) is separated into two sections. The primary outlet is used for pyrolysis by supplying a mixture of high-temperature gas and air to(b) (piled fuel) after reducing the total pressure. The secondary outlet is used for converting the hot-temperature gas-air mixture into a warm air current by air-cooling the furnace. The current is then rapidly ejected by(c) (ejector) so that complete burning is accomplished by suctioning pyrolyzed gas. A fire grid(d) works in intermittent sextant action. The total carbon content is burnt and the ash is automatically discharged by a screw(e). The furnace is still smaller in size having a capacity of 100 Mcal/h. The performance can be adjusted by a primary valve to 40 Mcal/h. In collaboration with Prof. Kitani, Department of Agricultural Engineering, University of Tokyo, the authors pursued more efficient utilization of biomass resources as a power source.

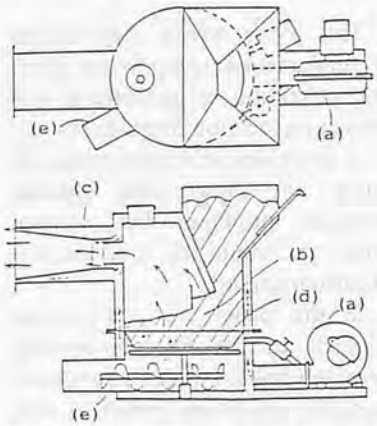

Fig. 2 Construction of bark pellet burner.

Wooden chip furnace – Utilization of whole timber, unlike that of bark alone, is faced with an increased difficulty in crushing pro-

cess. This entails an increased cost for pelletization and thus becomes less advantageous. A combustion furnace that directly uses timber chips as a fuel was devised. The development of the furnace was started in 1981, prior to the development of bark-pellet furnace. Unutilized timber resources such as timber wastes from lumber mills and plants culled from forests are far more abundant than bark. Therefore, timber chips are predicted to play a major role in thermal utilization of timber.

The bulk density of chips is approximately 1/3 of that of pellets. Because of the flatness and irregular angularity, chips have a poor flowability. This precludes automatic feeding into a furnace. Furthermore, chips are raw with a very high moisture content, in contrast to pellets that are dried to a moisture content of approximately 12% db. These disadvantages must be overcome in the furnace. At present, chips with moisture content of 55% db can be burnt in a furnace without difficulty by drying them at the same time.

Fig. 3 shows an experimental apparatus designed for a chip-fuelled furnace. The biomass contains approximately 6% oxygen which is converted into water by combustion. The latent heat by evaporation of the moisture and oxygen contents causes energy loss. For thermal exchange of the calorific power into hot water, a plastic, large-surface heat exchanger is mounted on the rear section of the furnace. It was confirmed that this heat exchanger accomplishes condensation of the evaporated water content and almost complete recovery of latent heat by cooling the exhaust to 45°C. This device was thus found to overcome the disadvantages of timber chips of a high moisture content. Furthermore, as acids generated during combustion can be recovered together with condensed water, the cause of acidic rain is eliminated.

The structure of the furnace shown in **Fig. 3** is substantially identical to that shown in **Fig. 2**. Illustration is omitted, because the differences were only dimensional. A furnace of a new structure that can be used commonly for all biomass resources was designed in 1986. It is at present put into experimental operation for evaluation of its performance. Further improvement is in the process.

Performance and characteristics – The characteristics of the gasification combustion furnace fuelled by timber chips (**Fig. 3**) are described in this section. **Table 1** shows the measurement data. As only a small amount (approximately ¼) of primary air is used, floating of dust at the time of primary combustion was considerably suppressed. As recovery of flying dust into a large amount of exhaust gas consumes a tremendous amount of power and requires a large capital outlay, burning of dust is most preferred. Primary combustion consists in pyrolysis with a small amount of air. It is, therefore, carried out under a relatively low temperature condition. Furthermore, as secondary air is flowed into the space of dual structure, the furnace is kept cooled as illustrated. Even a simple iron-plate structure can maintain heat-resistance. By this mechanism, heated air improves secondary combution mediated by induction of volatile gas, and allows complete burning at uniform temperature even with a minimal air ratio of 1.3. A high thermal efficiency was also obtained. The device thus overcame the previously mentioned disadvantages (a – d) which are commonly encountered in combustion of biomass resources.

These developmental studies were combined with basic researches on matters that required solution. Such basic researches included, for example, explication of the mecha-

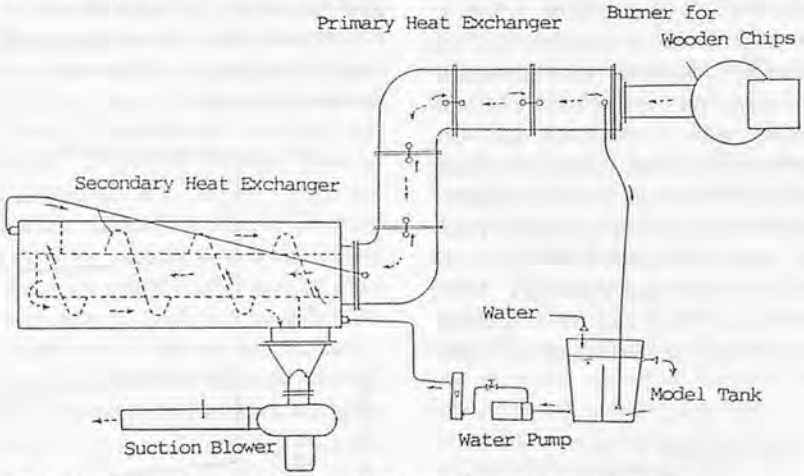

Fig. 3 Apparatus of heat exchanging experiment for wooden chip burner.

Table 1 Examples of Performance Tests of Biomass Furnace (Wooden Chips)

Item	Experiment No.			
	1	2	3	4
Moisture content, %d.b.	29.0	33.7	44.1	54.2
Combustion rate, kg/h	32.0	31.8	29.0	34.5
Mcal/h	91.0	87.4	73.0	79.0
Primary air rate. Nm^3/min	0.51	0.47	0.53	0.59
Secondary air rate, Nm^3/min	1.43	2.74	1.15	1.47
Excess air ratio	1.34	2.31	1.23	1.30
Primary comb. temp., °C	450	470	360	340
Secondary comb. temp., °C	1050	737	930	840
Maximum wall temp., °C	324	311	350	225
Average wall temp., °C	218	155	221	149

nism of abnormally high temperature generation which occurs during combustion of rice hull charcoal and the establishment of countermeasures.[6] The mechanism of complex burning of volatile components and fixed carbon contents was also explicated.[7]

Basic Experiments of Biomass Pyrolysis

Pyrolysis constitutes the main process of a gasification combustion furnace. Fundamental data were accumulated. This study was expanded to overall application of biomass pyrolysis. The mass ratio at normal temperature of pyrolytic products from agricultural biomass was determined at first.

An instrument shown in **Fig. 4** was used in this experiment. A heating furnace *l* was heated at constant temperature. A stainless steel air-tight vessel (a) was inserted into the heating furnace. Prior to the experiment, a specimen (b) had been placed in the vessel (a) which had then been evacuated by (i) and sealed with a stopcock (g). On opening (g) when a pressure gauge reading reached a constant pressure, volatile gas is discharged after passing through a guide-tube (f), cooling tube (m) and flask (h). After cooling (f), (m) and (h) to normal temperature, adhesions unto (f) and (m) were analyzed and determined as solid tar, and a substance existing in (h) as liquid tar. From the ash and fixed carbon contents in the specimens, the amount of gas was determined as a difference from the total volume. (d) is a safety value. (T_1) was automatically controlled. The time courses of (T_1) and (T_2) were recorded.

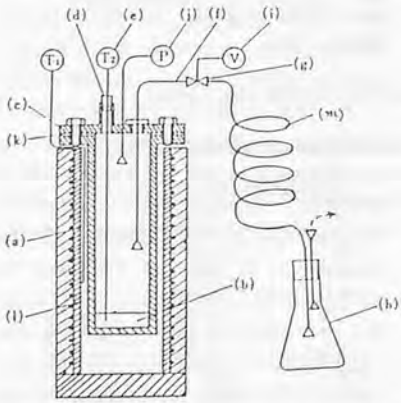

Fig. 4 Experimental apparatus for pyrolysis of biomass.

Table 2 shows the results in terms of mass ratio. The values of rice hulls represent those of the regression curve obtained at various heating temperature T. The other values indicate the mean values. As shown in the table, liquid tar demonstrated a high mass ratio. Rice hulls were mostly reduced to ashes and hence the ratio was relatively low. The mass ratio of timber was higher in the xylem tissues than the cortex, and the ratio was approximately 45%. The timber used in the experiment consisted of low-quality broad-leaf trees such as beech. A higher mass ratio was predicted for pine trees that are enriched with a resin content but the measurement results indicated otherwise, as shown in the table.

Table 2 Average Composition of Pyrolized Biomass

(Unit: %)

Item	Rice hull	Wooden chip	Bark pellet
Ash	19.02	0.23	3.59
Fixed carbon	22.9	23.15	30.33
Solid tar	7.1	7.19	6.18
Liquid tar	21.8	45.47	29.86
Gas	29.2	23.96	30.04

The mass ratios are expressed in terms of the calorific values in **Fig. 5**. The figure shows the results of rice hulls in relation to T. The preparation of **Fig. 5** was based on the following: In calorimetric measurement of a number of hull samples collected from many species and from many rice-producing districts, the mean calorific value was 3845 kcal/kg and that of the fixed carbon content 7642 kcal/kg on dry bases.[8] With respect to the calorific value of gas, gas formed under the experimental condition shown in **Fig. 4** was analyzed by gas chromatography. The analysis results are shown in **Fig. 6**.[9] The calorific values in relation to T in **Fig. 5** were obtained by calculation of the calorific power of each

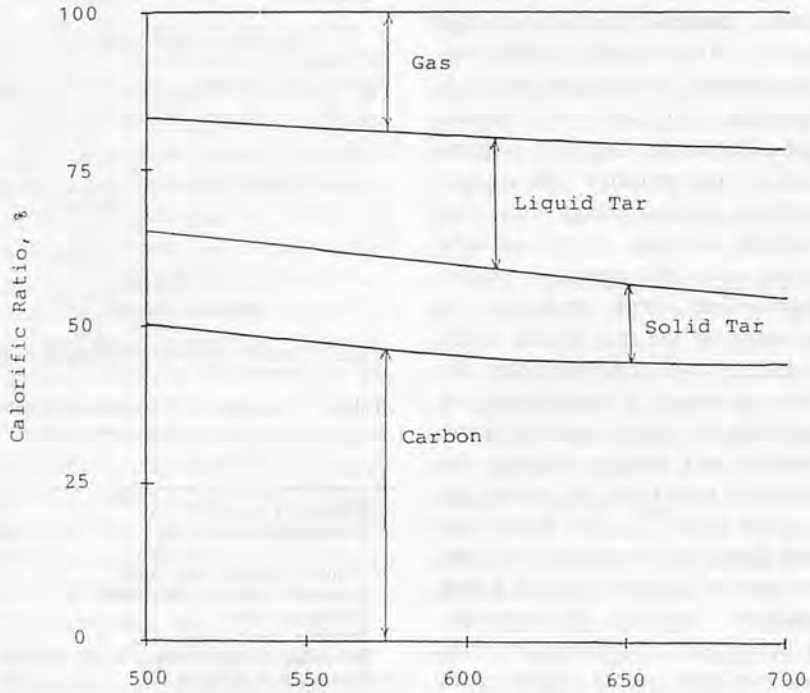

Fig. 5 Classification of volatile tar by distillation.

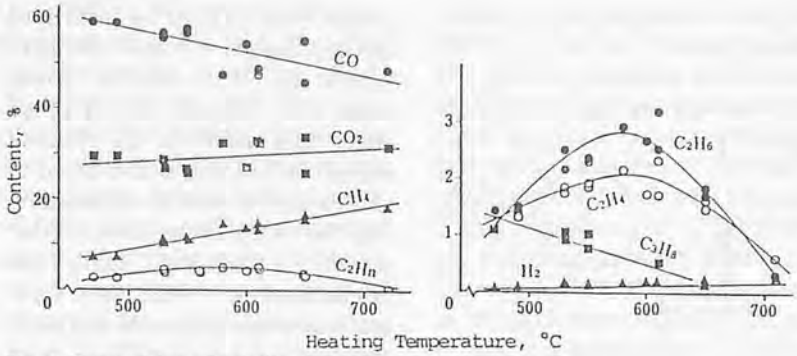

Fig. 6 Composition of volatile gas generated by pyrolysis.

component. The calorific value of liquid tar is at present studied, but has recently been estimated to be approximately 4500 kcal/kg. This value is used in the figure. The calorific value of solid tar is expressed by a balance quantity.

When viewed from the calorific values, the ratio of fixed carbon, which has a larger specific calorific power, increased when compared with the mass ratio. Tar was found to have a high calorific value and this strongly indicates the need for more effective utilization of tar. Because gas was a low pyrogenic substance, the calorific value was further reduced when compared with the mass ratio.

Liquid tar is blackish in color and highly acidic (pH 2.5). It seemed to contain a mist of solid tar but solid tar could not be well separated by centrifugation. Therefore, distillation was carried out using a Vigreaux distillation column and Graham condenser. The results are shown in **Table 3**. The liquids obtained at various distillation temperatures were slightly yellowish, clear and pure. Liquid fuel is advantageous in that storage and transportation are easy. Utilization of liquid tar was considered to be a promising line of study. The mass ratio of the purified liquid products from the timber used was high and amounted to 32% per dry weight of timber.

As the purified liquid was not ignitable alone, it was burnt with charcoal of known properties for calorimetric determination. The calorific power was calculated by conversion. As earlier described, the value was approximately 4 500 kcal/kg. Accurate values in relation to destruction distillation temperatures will be reported later.

Utilization of the purified liquid as a fuel for an internal combustion engine is the final goal of the study. However, a number of problems still remain to be solved. The calorific power of the purified liquid may be approximately equivalent to that of alcohol. As the purified liquid contains a large amount of carbonic acids, separation by esterification may be necessary to open a path to application to useful purposes. A difficult problem may be committed to future solution. Earlier utilization should be contrived for whatever immediate uses it can be utilized. If it can be purified into a fuel corresponding in properties to heavy oil, an immediate use may be expected, provided a utilization system is established.

Concept of Integrated, Regional System of Biomass Utilization

Prerequisites – Processing of biomass in small lots at the area of production is needed, because firstly, transportation of bulky material to remote destinations is disadvantageous and, secondly, a processing equipment, if large-sized, needs a large transportation cost if installed at a distant place and also requires storage of material for efficient, uninterrupted operation. Long storage may lead to deterioration of material.

Table 3 Weight Distribution after Distillation of Liquid Tar (Unit: %)

Item	Wooden chip	Bark pellet
Distillation temp., °C		
RT – 50	2.55	1.06
– 70	4.08	1.85
– 90	15.90	7.58
– 105	45.51	72.82
Higher than 105	0.55	0.74
Measurement loss	4.95	2.80
Total distilled liquid	73.54	86.85
Rest	26.46	13.15
Total	100	100
Distilled liquid	0.4431× 0.7354× 100	0.2824× 0.8685× 100
Content in raw material	=32.59	=24.53
Solid tar	20.15	9.92

On the other hand, a large advantage is obtained, if crude materials are collectively handled at or near the site of processing. **Fig. 7** shows an example of plans.

The conditions of location of processing plants are multifarious. Power and heat requirements for the processing of biomass resources collected differ depending on the types of biomass and processing ways. A flexible concept is recommended, so that if the quantity of raw materials collected exceeds the processing capacity, and surplus can be utilized as a processed product in neighboring communities.

Integrated utilization for general purposes – If utilization of a part of agricultural biomass resources as power and heat sources at agricultural processing plants and a remainder in a wide community area is intended, a device shown in **Fig. 8** is an example recommended. In this figure, (a) denotes a pyrolysis furnace, (i) an air inlet for combustion and (c) an exhaust outlet of ash. Material (A) goes through

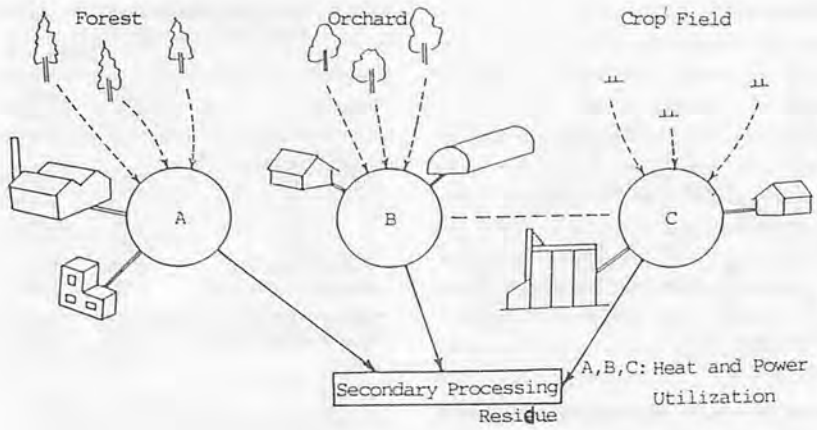

Fig. 7 Model for integrated, regional system of thermal utilization of biomass.

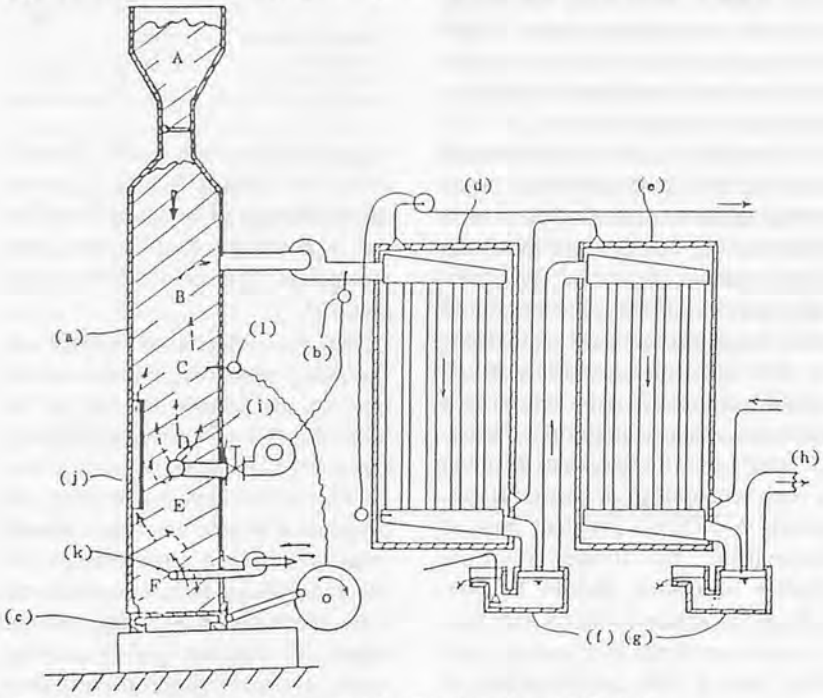

Fig. 8 Conceptional design for integrated utilization plant of biomass.

drying (B), distillation (C), combustion (D), reduction (E) and extinghishment (E) and is discharged. Gas flows upward. It is sucked by a blower as shown by a broken arrow and is fed from (h) into a gas engine via heat exchangers (d) and (e). If the exhaust temperature of (d) is controlled at a little below 100°C, the moisture content is mostly collected into (f). If the exhaust temperature of (e) is sufficiently reduced (e.g., 45°C), liquid tar is collected into (g). Gas discharged from (h) can be converted into tar-free clean gas. The performance of heat exchanger (e) has already been verified as described under "Wooden chip furnace" already cited. Warm water from (e) may be utilized for green-houses or fish-breeding. Hot water discharged from (d) is a multipurpose energy source that can be used, for example, in drying and processing of agricultural products.

An appropriate volume of water or steam is added from (k) in accordance with the power requirement at a processing plant. Water gas (CO and H_2) is generated at this reduction stage. The calorific power of gas from (h) can be intensified by skipping the (D) layer through a bypass (j). The calorific power retained in ash can convert added water into steam as an effective energy source. Ash is discharged in a dried state of normal temperature. Fig. 8 is an apparatus that rather resembles a rice-hull gasification device developed by the Japan Agromechanization Research Institute. This gasification device uses dried rice hulls and is operated at 60°C at point (b), because extraction of liquid tar is not intended. Though temperature setting at (b) is still one of the basic problems, approximately 150°C is estimated to be suitable for procuring most of the solid tar into (a).

Utilization as a power source — When processing of biomass consumes a large amount of power (e.g., rice mill in an industrial area), a system different from the above would be more effective. The authors consider that a gas turbine would produce a better effect. Gas of approximately 500°C obtained by primary combustion in the above-mentioned gasification combustion furnace is pressure-fed into a turbine so that power is derived by combustion using secondary air. This enables on-the-spot total utilization of heat even including tar (liquid as well as dry), exactly in the same way as the gasification combustion furnace. Waste heat from the turbine can be used for drying of rough rice or of raw timber, if raw timber is used as a fuel. Depending on the condition of a processing plant, biomass can either be thoroughly utilized by primary combustion until it is reduced to ashes or be partially utilized as a char for the benefit of regional industry. This was also already corroborated in test operation of the furnace. It can be regulated at will.

Utilization of biomass as a power source is at present studied ordinarily as a system of gas generation

(gas engine) in not only ESCAP-stationed countries but also occidental countries as well as Japan. A downward gas flow system is often adopted, unlike the system shown in **Fig. 8**. A downward gas flow system permits condensation of CO gas in a reduction chamber and is, therefore, expected to improve the output and calorific power of gas, compared to those shown in **Figs. 5** and **6**. However, this system seems to have the following disadvantages; (1) an exceedingly large equipment is needed, because removal of tar and fly ash is otherwise difficult, (2) the calorific power retained in pyrolytic gas, ash and waste gas from the engine is utilized but not that in tar removed; (3) a gasification rate is also limited because carbon is retained in a reduction chamber and (4) overheating of an ash outlet affects the durability.

A small gas turbine (150 PS) as an automobile engine has been introduced. Although some problems such as a pyrolytic furnace to be used in combination still remain to be solved, these problems are very much worthy of utmost efforts for solution.

Improvement of charcoal burning in forest – This section describes an example which can be applied to cases where products are least utilized at the site of processing as either a heat or power source but can be utilized as an energy source in distant areas. Charcoal burning is a transformation of bulky wood into compact charcoal. Charcoal transport from the depths of a mountain to places of consumption is at present a most important form of biomass utilization in devoting countries. The yield of charcoal from raw wood amounts to no more than 20 – 30% by the dry ratio. The rest is usually diffused in a white smoke into the atmosphere. This study can be applied to improvement of output.

A kiln built with local soil in a mountain as commonly used at present needs no reconstruction. The authors propose a contrivance by which an adequate amount of liquid tar can be extracted. A heat exchanger is attached to the chimney of a kiln for cooling the exhaust. It may be cooled, for example, using a mountain stream. Liquid tar amounts to 45% of the dry content of wood as shown in **Table 1**. It can be put in a polyethylene container and carried on a horseback. Compared to the production of charcoal alone, the total yield increases to 2.5 times. Utilization of natural resources may thus be highly promoted. A small blower is required in combination with a heat exchanger. A simple tube placed in a stream will function for the purpose intended. Generated gas that cannot be transported may be used at the site. It may be most simply utilized as heat for maintenance of kiln temperature or pyrolysis of raw wood. This may increase the yield and imrpve the quality (hardness) of charcoal produced.

Postscript

Continuous long studies on thermal utilization of biomass resources were outlined in this paper. The achievements so far obtained were summarized. The goals of studies now in progress were also reported. improvement of individual instrumentations for biomass utilization is important. However, equally or more important is an integrated, regional utilization system in the area of biomass processing. Studies on such integrated utilization methods should be encouraged. The authors' previous papers have so far been published in Japanese. However, since the subject of the present studies has gained international importance, the results will henceforth be reported in English. The details may not be justified by the descriptions, hence, readers are requested to refer to the publication references listed below.

International collaboration is anticipated. It is the earnest desire of the authors that utilization of natural resources and maintenance of natural environments are best pursued to the best of human benefit.

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Abstract

Sugarcane leaves are useful and indispensable by-product of the crop. While green leaves are used as fodder, dry leaves also known as trash have many uses to the Indian farmers.

Detrashing the standing sugarcane plant during July and August is an essential recommendation of entomologist and plant pathologists. Trash burning before harvesting is a common practice in the western countries.

The Agricultural Engineering Division of the Indian Institute of Sugarcane Research at Lucknow is trying to develop a package of practices for trash management, including equipment for trash handling.

Introduction

The productivity and the production of sugarcane has increased significantly during the last few decades. In 1980-81 the cane production was recorded 150 million t with an average yield of 56.8 t/ha out of a total of 2648 million ha. This was a net increase of 110% than the cane produced during 1950-51. The by-products also increased in the same proportion. One of the main by-products are the sugarcane leaves, may it be dry or green. Green leaves are being used as fodder. Dry leaves are also known as trash. The trash management is a simple but yet mismanaged package of practice in itself.

There is an urgent need of detrashing the standing cane in the month of July/August. This is the most vulnerable time for the development of sugarcane pests and insects beneath the foliage. Entomologist and plant pathologists recommend for defoliating the standing cane during this period. Tying the canes togather in a bunch of 10-15 stalks is another common practice recommended by agronomists to prevent lodging due to strong wind and heavy rain. A huge amount of manual power is required to handle this job. Srivastava and Singh (1982) developed a simple manual detrasher-cum-collector which increases the efficiency of labour by 5 to 7 times. The process of detrashing with the help of this equipment is not strainuous. The exertion is not localized.

The Mechanical Harvester

Detrashing before or after harvesting has been of great concern to the scientists. There is a general practice of trash burning before harvesting. Clayton (1971) et al reported that in one early season-experiment the cane had 29.1% trash and after the field was burned the trash content was 23.9%. Only 5.2 percentage points of dry trash was removed by the field burning. A comparison of mechanical harvesting and hand-cut cane was made (Table 1). The mechanical harvester consisted a chain slot conveyor which moved the cane at 100 m/min and an upward air blast of 1500 m/min at the nozzle. Yamaguchi and Yabu (1982) reported that in-stalks burnt after harvesting, the sucrose content (of fresh weight) gradually increased six days while the reducing sugar showed little change. Post-havest burning is considered useful for removal of cane trash without lowering the sucrose content.

The percentage of trash in field cane is dependent on several factors, the main ones being the system of cutting and loading, the height of topping, weather conditions at harvesting, sugarcane variety, age of the crop, efficiency of burning, etc. Fernandes et al (1963) reported that the cane cut by chopper-harvesters showed a total trash, 2.7 times higher than the hand-cut, mechanically loaded canes. Fanjul (1971) found that the trash content of machine cut cane can be 2 or 3 times as high as hand cut cane

Table 1 Percent Trash Content of Standing Unburned Canes, Mechanically Harvested Cane and Hand-cut Cane as Sampled at a Mill in Bellegrade, Florida, U.S.A.

Year	Standing cane	Mechanically harvested	Hand cut
1964	22.0	15.2	5.2
1965 (Early)	32.0	25.4	13.9
1965 (Late)	23.8	17.5	6.4
1966	20.0	13.7	5.6
1967	23.9	8.5	5.0
1968	32.0	9.5	4.8
1969	37.8	13.4	5.0
1970	39.0	13.3	5.1

Ref: Clayton et al (1971)

depending on the condition of the cane and the amount of lodging. The blower on the machine is a help and will eliminate approximately 10-15% of the trash in the cane as it is loaded. In another comparative study conducted by Tambosco et al (1975) the combine harvesters delivered 8.40 to 12.74% and 9.42 to 14.05% of total trash in clay and sandy soils, respectively. The immature tops, leaves and trash for both soil types ranged from 6.35 to 10.86%, 1.56 to 4.05% and 0.14 to 0.26% respectively.

All the mechanical sugarcane harvesters used in Western countries employ blower or suction fans to remove trash from sugarcane as it discharges from a conveyor. Too much power is expended in moving air and only the lighter particles of trash are being removed. To obtain maximum trash removal in a vertical air stream without significant cane loss, strict control of air flow rates will be required. The air velocity required to convey leaves ranged from approximately 580 to 792 m/mt as the density of the leaves increased (Clayton et al, 1974).

The type of cleaning system selected will depend on the type of trash, the degree of cleaning desired, and whether cleaning will be done in the field or at the factory. For light, high density leaf and top, the feeding rolls are the most efficient. An air blast will remove loose material from the cane which is recommended for unburned cane. The rubber husking rolls would be suitable for cleaning of tight trash and for use on seed cane where eye damage should be kept low. For cane containing soil and rocks, a combination of cleaning systems will be required.

The trash cleaning system selected for the Indian cropping system would be dependent mainly upon the economics of trash handling. On one hand, the trash is systematically removed from harvested cane manually and are bundled for using it in preparing the shelter for poor folk of the country. On the other hand, the trash is removed and either left spread in the field for burning or collected for use as source of heat for "jaggery" or "khandsary" production. On the average, the total trash production per hectare ranges between 2.5 to 3.5 t with an average density of 7.86 kg/m^3. Undoubtedly it is a huge volume for collection and storage. The purpose of collecting and storage may get defeated if the trash could be managed right there inside the field with an equal or greater benefit. There are reports of using trash for burning or mulching.

Trash Burning

Trash burning serves two purposes; one is killing the insect pests and the other to increase the soil temperature. Increase in soil temperature has shown an increase in the nutritional up-take whereby the germination is improved. This may be very useful in ratoon cropping, where early germination has a significant effect on the increase in cane yield. A group of people in western Kenya cut thin slices of the top soil with the sod and spread to dry. The slices are then piled up on conical heaps and burned alongwith the certain collected vegetation. The burned material is then spread and mixed with the rest of the seed bed preparation. This practice improves crop production, especially for millets. A similar practice is called"guie," performed in some parts of Ethiopia as reported by Wehrmann and Johannes (1965) and Sertsu and Sanchez (1978). They reported that soil heating in Ethiopia increased the growth of plants. The increase in the pH, potassium, calcium, magnesium, manganese and ammonia was attributed to the heating of soil. Gustafson (1922) pointed out that it was a common practice among tobacco growers in Kentucky to heat or burn soil of tobacco beds to kill weed seeds and diseases usually by burning wood on top of soil.

In Brazil Baldangi (1960) reported that burning is a common practice because if they do not burn of the great mass of grass residue (10-15 t/ha), they have to plough it in which is laborious. Furthermore, the residue will depress yield unless nitrogen fertilizer is applied which is expensive.

Such reports are yet to be confirmed and established for sugarcane cultivation, especially ratoon farming or other successive crops under Indian conditions.

Mulching is done for increasing water infiltration, reducing soil drifting, reducing evaporation, modifying soil temperature, controlling weeds and increasing yields. Sugarcane dry leaves as such contain N = 1.0-1.5%, P = 0.005-0.01% and k = 1.5-1.8%, respectively. In addition to its own nutritional value, trash used as mulches incease the biological activity, modify the level of available materials and maintain or increase the organic matter level through decomposition. Decomposition is arbitrarily defined as breakdown of organic matter to simple organic compounds. It depends on the activities of numerous different populations that reside in the soil. Dhar and his team members have been carrying on an extensive research work for the last 50 years on this phenomenon of nitrogen fixation in soils as a result of decomposition. To explain the mechanics of nitrogen fixation he suggested that the organic materials like sugar cellulose, fats and other carbohydrates undergo oxidation both in the presence and absence of light on soil surface with liberation of energy,

$$C_6H_{12}O_6 = 6CO_2 + 6H_2O + 676\,Kcal$$

The energy liberated is utilized

Table 2 Economics of Trash Utilization

Selling	Burning	Surface mulching*	
		a) same inputs	b) less inputs
Total amount of trash per ha = 3 t	Increase in yield = 2-3% Say = 2 t/ha	Increase in yield = 15-17% Say=10t equivalent to 2000/=	Saving of 2 irrigation = 500/= Saving of 100kg Nitrogen=500/=
Sold for=450/=	Profit=400/ha.	Trach requirement 8-10 t for 7-8cm thickness equivalent=600/– labour charges=300/= Net profit=1100/=	Total saving=1000 Trash mulching charges=900/= Net profit=100/=
Collection and storage charges=100/= Net profit Rs.350/ha	Remarks: Yield increase found only in potash dificient soil otherwise no gain		Remarks. Good for water management and salinity control.

*Source: Singh, K., M.P. Motiwale. 1981. Use of Sugarcane Trash in Agriculture. Seminar on Sugarcane Management at Junagarh (Gujrat).

in fixing nitrogen from the air:

$H_2O + 112$ k Cal $- H + OH$

$N_2 + 6H - 2NH_3 + 24$ K cal

The ammonia formed in this reaction undergoes exidation forming nitrates and nitrites useful for plant growth. NO_3 and NO_2 react with the carbohydrates and form amino acids and then protein in the soils. Consequently, there is an increase in the nitrogen status of the soil (Dhar, 1961). Singh et al (1982) found an increase in the total N content during decomposition of different organic materials under laboratory conditions. This phenomenon thus promises a better use of trash in the form of mulch. Bowen (1982) emphasised the need for reduced tillage farming system. Various techniques of reduced tillage system are; 1) planting directly in plowed soil; 2) planting in once-tilled plowed soil or in a light stubble; 3) strip tillage and 4) no tillage or zero tillage. In ratoon cropping, the new crop was permitted to grow from the existing stools through the surface cover of leaves and cane trash. No till sugarcane planting was done in crop residue from previously harvested crop. The difference in yield was significant while the cost of production was lower in these systems than the normal sugarcane cropping system. This finding explores the possility of a new strategy of trash management.

Economic Survey

An economic survey of the trash utilization was conducted by the authors. The findings are indicated in **Table 2**. It was observed that each method of trash utilization has its own benefits in a specific region. For example, trash burning saves labour besides increasing the productivity of the soil which is deficient in potash content. Similarly, surface or vertical trash mulching with less inputs is the only alternative for the region with water management problem and for the region turning to be saline (hypothetical). This practice saves i) number of irrigation reducing evapotranspiration which reduce the soil content being deposited on the surface; and ii) amount of chemical fertilizer. In general, surface mulching seems to be a better proposition over other uses of the sugarcane trash. It is however left for further investigation.

Conclusion

Nonetheless the detrashing of harvested cane has to be done. A single row sugarcane harvestor developed at this Institute is on the way of getting finalised. The need of the time calls for developing a detrashing unit: manual-operated and or power-operated. The agricultural engineering division is trying to devise simple and efficient equipment to handle this job. Next phase of this experiment will be an inter-disciplinary approach in formulating a package of practices for an efficient trash management.

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(Continued on page 82)

Delivery System for Farm Machinery Technology in India

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Abstract

Improved implements play an important role in increasing agricultural productivity, but these are not easily available to the farmer like other essential agricultural inputs. The existing constraints have to be removed so that the farmers may accept and adopt these implements for their advantage.

The village artisans still supply the bulk of traditional farm hand tools and implements to the farmers but they have not been provided the technology of improved designs developed in the country due to lack of effective delivery system. A Farm Machinery Service Centre has been suggested at Community Block Level which will improve the skills of rural population and provide the farm machinery requirements of the farmers. The centre will function as a part of institutional framework in the production and popularization of farm equipment at the block.

Introduction

The Sixth Five-Year Plan of India gives more emphasis on development of agriculture and allied activities through integrated rural development programmes. The earlier project or sectoral approach of the rural development has proved inadequate in promoting the overall development of the rural area and, therefore, the efforts are now to augument the local resources for area specific block level planning having production-cum-employment opportunities. The integrated rural development is to be achieved through the development of primary, secondary and tertiary sectors. The primary sector includes programmes for development of agriculture, animal husbandry, fisheries and forestry, the secondary sector—development of village and cottage industries and small scale industries and tertiary sector promoting organized processing and marketing activities (1).

It is in this context a Farm Machinery Service Centre has been suggested to be established at Block Level which will promote the production and popularization of farm machinery, training of village artisans, farmers and rural youths. The centre will help in accelerated adoption of the improved farm machinery by the farmers and generation of self-employment in rural areas. The scheme envisages the coordination of various R & D institutions, training institutions, industry promoting organisations and extension agencies. This may, however, require strengthening of infrastructure (physical facilities as well as manpower) for the transfer of technology, wherever it is weak, to affect effective delivery system.

The community blocks in the country numbering about 5123 have played a major role in transferring the technology to the farmers for rural development. These blocks are the only link between rural developmental agencies below district level, which covers about 100-150 villages in a particular area (Fig. 1). Various programmes of District Rural Development Agencies (DRDA) sponsored by Ministry of Rural Development and District Industries Centres are already under operation through these blocks. It is envisaged that State Governments through their Directorate of Agriculture/Agricultural Engineering and with assistance from District Industries Centres and Agro-Industrial Development Corporations can provide an effective delivery system for the popularization and adoption of technology to the farmers through these blocks.

Village Artisans

Village artisans mainly blacksmith and carpenters, are the chief source for supply and repair of

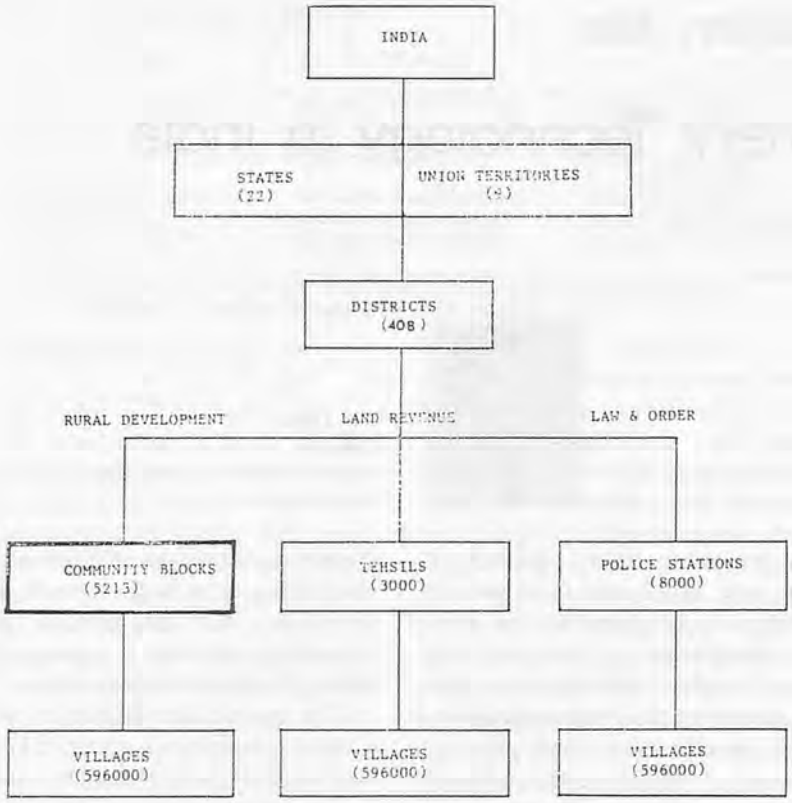

Fig. 1 Administrative divisions of India.

farm machinery to the farmers. These artisans fabricate and repair traditional hand tools and implements like sickles, spades, had hoes, country ploughs, bullock carts, etc (2, 3). It is estimated that there are more than one million village artisans who learn the fabrication art by experience through their family trade. They have no formal training of any kind. Their fabrication technology is primitive and they have hardly any knowledge about improved farm implements. It is visualised that, although small scale farm machinery industries are increasing, village artisans will remain the chief sources of supply of farm machinery inputs to the farmers for many years to come because of easy accessibility.

There are various programmes sponsored by the Ministry of Rural Development, Ministry of Industries, Khadi and Village Industries Commission (KVIC) and voluntary and private organizations to improve and upgrade the skills of the village artisans. Under the Integrated Rural Development Programemes (IRDP) and Training of Rural Youths for Self-Employment (TRYSEM), the Ministry of Rural Development provides finance for strengthening the infrastructure to train the village artisans, rural youths and farmers. The main thrusts of the schemes are to equip rural population with necessary skills and technology to enable them to seek self-employment (4).

Status of Technology Transfer to the Village Artisans

There are number of training centres established and monitored by Small Industries Service Institute (SISI), Polytechnics, Industrial Training Institute, KVIC and other organisations to upgrade the skill of village artisans. However, these organisations conduct stereo-type training which no doubt improve their fabrication skills but without bringing any change in their outlook for improved implements. Thus these artisans continue to fabricate traditional farm tools and implements. They do not get any exposure as well as the appreciation for improved implements.

The District Industries Centres (DIC) have the major responsibilities of promoting the small industries and village industries in their command area of the district. The DIC managements have not been represented by the Agricultural Engineers having experience in farm machinery and rural technology and, therefore, the design of the improved farm machines/implements could not be made available to them. Even the R & D centres of Central and State Governments have no effective liaison with the DICs.

The Indian Council of Agricultural Research (ICAR) through All India Coordinated Scheme on Farm Implements and Machinery has started training village artisans in the fabrication of improved implements and machinery developed under the scheme. These schemes are being operated at 8 places in different agro-climatic regions with Central Institute of Agricultural Engineering, Bhopal as coordinating centre. Under the scheme the artisans are provided with adequate stipend to meet their food expenses and a set of implements fabricated by them during the course of their training. It is hoped that the artisans will be able to demonstrate these implements to the farmers to create awareness amongst them. The set of implements help the artisans in duplicating the same in their own workshop as they do not understand the manufacturing drawings and product specifications.

The ICAR is also arranging the training of village artisans through the Farm Science Centres establish-

ed all over the country. In addition agricultural universities have programmes for training of small scale manufacturers and artisans (5, 6).

The Regional Network of Agricultural Machinery (RNAM), a programme of Economic and Social Commission for Asia and the Pacific (ESCAP) financed by the United Nations Development Programme (UNDP), while promoting the local production of farm machinery by small scale manufacturers has recognized the importance of village artisans in the fabrication of farm machinery and, therefore, given due emphasis in providing training to them. The RNAM Programme in India is being coordinated by the Central Institute of Agricultural Engineering, Bhopal.

The Tractor Training and Testing Station established by the Ministry of Agriculture at Budni and Hissar and Extension Training Centre at Niloheri have also been offering training courses to village artisans since last two decades and their contribution has been very significant.

All the above agencies involved in providing the technology to the village artisans are too inadequate. The National Commission on Agriculture (Report X-Input, 1976) estimated that the country needs about 30 000 Service Centres to cater to the need of repair and maintenance of farm machinery and tractors. This may require about 10 million skilled technicians, workers and engineers (7). Such vast number of skilled manpower is unlikely to be trained by the existing training centres.

The major responsibility of production and popularisation of improved farm implements and machinery rests with the state Government. But it is observed that many states have not provided adequate infrastructure either at District Level or at lower levels to transfer the technology to the users effectively. A centralized agency like state Agro-Industrial Development Corporation, however large it may be, is unlikely to serve the rural farmers directly for providing the improved implements and machinery and creating service and repair maintenance facilities. Due to transportation problems in rural areas agricultural machines, in general, have low mobility and, therefore, localized sales and service outlet must be created for larger adoption of the technology (8). In the past many farm implements and machines remained in the backyard of the farmers for want of repairs and after sales services.

Farm Machinery Service Centre (FMSC)

The Farm Machinery Service Centre being proposed is a training-cum-production unit at the block level to provide effective delivery system of the technology of improved farm equipment to the farmers. In states where similar system is already in vogue such as the Tamil Nadu Agro-Engineering and Service Co-op. Federation Ltd (ENCOFED). The activities may be reviewed and strengthened if necessary (9). But in other state such an organisation should be created to assist the farmers.

There are two distinct programmes of the Farm Machinery Service Centre:

1. Training of village artisans, farmers and rural youth in maintenance of farm machinery;
2. Production, sale distribution and servicing facilities through the Farm Machinery Repair, Maintenance Manufacturing Society (FMS). The Society will be formed with the cooperation of village artisans.

   The main objectives of the Farm Machinery Service Centres are:

   - Improving the skills of the artisans in the fabrication of simple hand tools and implements using modern simple workshop equipment;
   - Organizing production, sale and distribution of improved machinery to the farmers;
   - Organizing demonstration and popularization of improved farm implements and machinery to the farmers;
   - Providing simple repair and maintenance facilities to the farmers for the repair and maintenance of tractors, diesel engine and other farm machines which do not require sophisticated equipment and human skill;
   - Assisting village artisans in establishing Rural Workshop and Village Industries with the assistance from District Industries Centres and Agro-Industrial Development Corporations.

Organizational Structure

It should not be the intention to create a separate organization to carry out the activities of the Farm Machinery Service Centre but to coordinate, reorganize and strengthen the facilities of the existing agencies operating under various rural development programmes. This may be necessary in the light of the Sixth Five Year Plan where the emphasis is more on area specific block level planning. The area specific planning is possible only if various programmes in vogue such as SFDA, DPAP, MFAL, IRDP, TRYSEM, CAD, VIP, Tribal and Hills Development Programmes are coordinated effectively through Integrated Rural Development Programme and if required reorganized. At block level, however, additional technical and managerial staff may have to be provided. A suggested organizational structure is shown in **Fig. 2**.

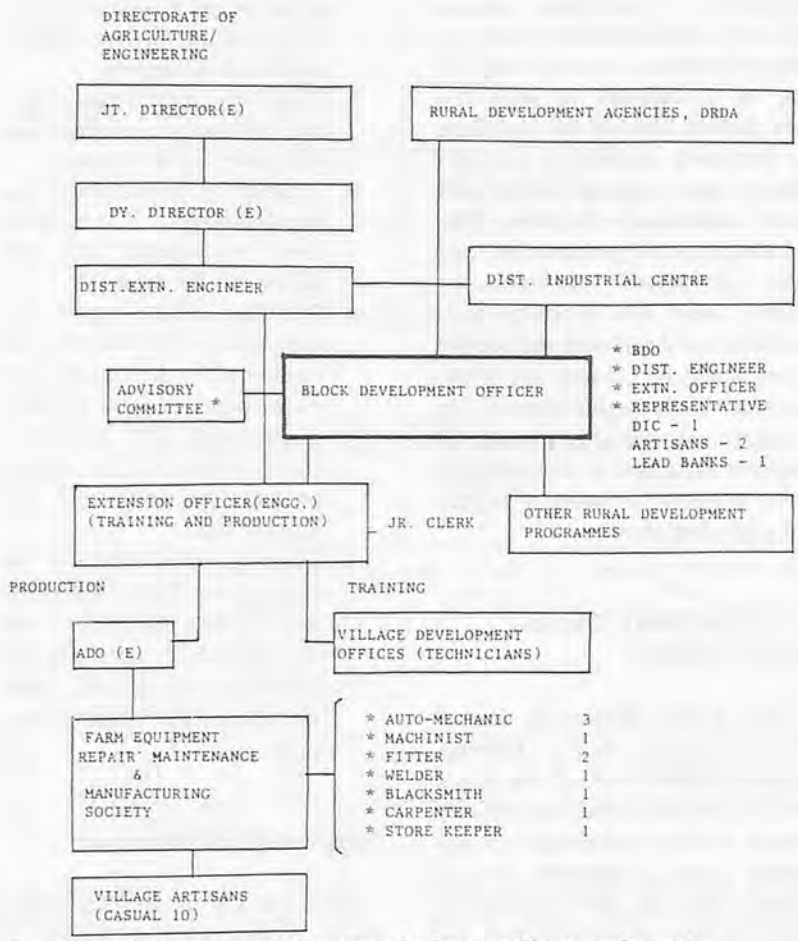

Fig. 2 Proposed organizational structure of a farm machinery service centre.

Block Level Organizational Structure

Block Development Officer (BDO) – The Block Development Officer has already been provided by the State Government at each block under the Rural Development Programmes. He will be the overall in charge of the FMSC.

Extension Officer (engineering) – The Farm Machinery Service Centre will mainly handle the engineering programmes and, therefore, BDO's will require a technical person to manage the affairs of the centre. It is, therefore, proposed to have a Extension Officer (Engineering) at each centre. He should be diploma holder or graduate in agricultural/mechanical engineering with adequate experience of workshop technology and manufacturing of farm machinery. He should also have experience in repair and maintenance of power operated farm equipment. He will be in charge of the FMSC under the administrative control of BDO. He will plan his technical programmes, however, under the supervision and guidance of the District Agricultural Engineer/Rural Industries Officer. The Extension Officer (engineering) should be sent for training in the manufacture of improved agricultural implements being organised by the R & D centres.

Assistance Block Development Officer (ADO) (Engineering) – One of the activities of the FMSC will be the production and popularisation of farm machinery through the FMS. Each centre will have an ADO (Engg.) who will be responsible for managing the affairs of the FMS. He should be diploma holder in agriculture/mechanical engineering or IIT-trained with minimum of 5 years experience in repair, maintenance of tractors, engines and farm machinery. The ADO must be sent for practical training for a minimum period of 3 months in any R and D centres, TTC, TTTS, SISI or any other similar organisation before he is entrusted with the responsibilities of the FMS.

Village Development Officer (VDOs) (technicians) – The VDOs, basically trained technicians, will be the permanent core staff attached to the workshop of the FMSC. These VDOs will assist in imparting training to the village artisans, farmers and rural youth in various trades of workshop technology, operation, repair and maintenance of farm machinery. They will also organize demonstrations on the use and maintenance of farm machinery. They will also organize demonstrations on the use and maintenance of farm implement and machinery to the farmers. A suggested number of VDOs (technicians) to be employed at a centre is as follows: 3 auto mechanics; 1 machinist; 2 fitters; 1 welder; 1 blacksmith; and 1 carpenter.

Supporting staff – The FMSC will be a part of the Community Development Blocks and, therfore, the existing staff may have to share the additional responsibility of FMSC. However, a junior clerk and store keeper may have to be provided exclusively for FMS activities at each centre.

Village Artisans – Ten artisans trained at the centre will be encouraged to form a society (FMS) which will undertake the production, sale distribution, repair and maintenance of farm machinery. These artisans will be hired on daily paid basis at the rate of Rs. 15 per day for a period of 8 months. During the remaining period they are expected to be engaged in their farming operations. A minimum of 9 months training should be pro-

vided to these technicians before they are employed as daily paid technicians. The training could be provided to these artisans under TRYSEM Programme.

District Level Organizational Structure

A number of states have provided agricultural engineers at district levels who are responsible for executing the development activities related to agricultural engineering such as minor irrigation, soil conservation, land development and agricultural engineering extension. The Ministry of Rural Development has also suggested to appoint a rural industries officer at each district. It is suggested that the agricultural extension engineers or rural industries officer at district levels may be assigned this additional responsibility of Agro-Industrial Extension. In states where agricultural extension engineers are not stationed at the district level, it is advisable to appoint one in each district. He will be responsible for the overall planning of the technical programmes of each block in consultation with BDO and Extension Officer (Engineering). He will also coordinate with other developmental agencies such as District Industries Centre for procuring and alloting raw naterials and finance. He will be required to coordinate the activities of R & D centres, Agro Industries Corporation, etc for design of improved implements and machinery which have proven their techno-economic utility and are within the fabrication capabilities of the Farm Machinery Service Centres.

State Level Organizational Structure

Joint director (engg.) – The Directorate of Agriculture under the Ministry of Agriculture have already been established in all the states. Under the Directorate, majority of the states have created the post of Joint Director (Engg.) and Deputy Director (Engg.) who are responsible for the overall planning of the programmes related to the popularization of farm equipment in addition to other responsibilities related to agricultural engineering. States like Tamil Nadu and Arunachal Pradesh have created each a separate Directorate of Agricultural Engineering. Although the establishment of separate Directorate of Agricultural Engineering will depend upon the quantum of Development programmes in the states in the field of agricultural engineering, it is suggested that the Joint Director (E) and Deputy Director (E) may be assigned the responsibility of establishment of Farm Machinery Service Centre at block level.

As stated earlier, the Joint Director (Engg.) should coordinate the efforts of production of farm machinery by village artisans, small-scale manufacturers and Government Agricultural Implement Workshops, and Agro-Industrial Development Corporation in the State so that the farmers can get quality farm machines and services at reasonable costs (10).

Advisory Committee

Each FMSC will have an Advisory Committee consisting of the District Engineer, BDO, Extension Officer (Engineering), a representative from DIC and two representatives of artisans as members. Where Leads Banks are operating a representative from the Bank will be included in the Advisory Committee. The Committee will guide and advice the affairs of the FMS. The Committee will also monitor the progress of work of the centre and suggest ways and means to improve/expand their activities. They will meet at least 4 times in a year. The BDO ex-officio will be the Chairman of the Committee and the Extension Officer as Secretary.

Physical Facilities and Resource Mobilization

The establishment of the FMSC

Table 1 Infrastructure for the Establishment of an FMSC

Unit: Rs

Infrastructure	Cost	Central Govt. contribution	State Govt. contribution	Artisans contribution
Workshop building and furniture	1 50,000	75,000	75,000	–
Workshop equipment	1 05,000	1 00,000	5,000	–
Display and demonstration of machinery	80,000	–	80,000	–
Stipend	60,000	60,000	–	–
Salary of the staff at block level	89,000	–	89,000	–
Artisans salary (casual basis)	36,000	–	36,000	–
Raw material contingencies	60,000	–	10,000	50,000*
Total	5 80,000	2 55,000	2 95,000	50,000

*Crecit facilities to be provided by DRDA and DIC.

Annexure–I

Financial Requirement for Establishment of a Farm Machinery Center at Community Block Level

	Monthly salary (Rs.)	Annual expenditure (Rs.)
A. Man power		
Salary		
1. Extension Officer (Engg.) (1)	1,000	12,000
2. ADO (Engg.) (1)	800	9,600
3. Technicians (9)	500	54,000
4. Store keeper (1)	500	6,000
5. Clerk	500	6,000
6. Village artisans* (10) (@ Rs. 15/-per day)	450	36,000
	Sub-total	1 23,600
Stipend		
1. For training 100 artisans, farmers and rural youths per year @ Rs.200/-per month (300 man months)		60,000
	Sub total (A)	1 83,600
	Say Rs.	1 85,000
B. (i) Building, office furniture and equipment		1 50,000
(ii) Workshop equipment		
1. Benches and vices		60,000
2. Compressed air equipment (compressor $0.5m^3$/min with $10kg/km^2$ and other accessories)		5,000
3. Lifting and moving equipment mechanical or hydraulic jacks 3 or 5 tonnes capacity		1,500
4. Cleaning equipment (washer)		1,500
5. Lubrication and fuel handling such as grease gun (hand lever) oil cane ½ lit. capacity, hand operated fuel transfer pump etc.		1,500
6. Welding equipment set, electric arc 300 Amps., gas welding set.		10,000
7. Mechanical tool kit		
i. Open end spanner metric 8 to 36 and British 3/16" to 7/8"		
ii. Ring spanners Metric 8 to 36		
iii. Socket set Metric and British		
iv. Adjustable spanners 6" and 12"		15,000
v. Pipe spanners 25 mm to 75 mm		
8. Machine shop equipment: drilling machine, 1½ hp Lathe machine, shaper, grinder, shearing machine (hand and power), spray painting gun, portable drills and grinders.		50,000
9. Carpentary tools: Wood working bench, saws, planes, draw knife, mallet, hammers, chisels, ratchet brace, auger, files, measuring rule metering gauge, carpenters square, trisquare, bevel gauge, divider, plier, nail puller, clamps, oil stones, hatchet, wood saw (power) etc.		
10. Blacksmith tools Anvil, sewag block, forge with electric blower, hammers, chisels, punches, fullers, fly press (100 kg.), spring hammer, soldering equipment etc.		7,000
	Sub total B Rs.	2 55,000
C. Tractor, trolley and agricultural machinery for demonstration		8,000
Recurring Expenses (yearly)		
**A. Raw material, iron and steel, spares etc. DOL		40,000
B. Contingencies		10,000
	Total Rs.	60,000
Summary		
Salary and stipend		1 85,000
Building		1 50,000
Working equipment		1 05,000
Display and demonstration		80,000
Raw materials		50,000
Contingencies		10,000
	Total Rs.	5,80,000

* Village artisans will be recruited on daily wage basis for 8 months during a year. During the remaining period they are expected to be engaged in their farming operations.

**To be shared by the artisans.

at the block level throughout the country will require a considerable amount of resources. This will be difficult for the Centre as well as State Government to provide exclusively for farm machinery promotion. There are, however, various programmes sponsored by the Ministry of Rural Developments (IRDP, TRYSEM etc) and Ministry of Industries (VIP) for the benefit and upliftment of the rural population (11). The FMSC will be a medium to mobilize the resources at the block level. In the process, additional physical facilities and institutional framework may have to be provided by the State Government.

Table 1 gives the details of the infrastructure required for the FMSC and the agencies that will provide the finances. The details are included in the **Annexure I.**

Training Facilities

Workshop – A simple structure constructed with local materials having 15 x 20 m floor area will be enough to house the workshop equipment. Additional two rooms of 7 x 8 m and 4 x 5 m each may be necessary for store and sitting space for supervisors. Workshop tools and equipment required can be procured under the IRDP and TRYSEM Programmes. The detailed list is given in the **Annexure I.**

Display of agricultural machinery – The centre will procure improved farm machinery not being manufactured at the centre for demonstration to farmers. Assistance from the Agro-Industrial Development Corporation and leading farm machinery manufacturers can be obtained for this purpose.

Stipend – The trainees will be paid stipends at the rate of Rs.200 (or rates applicable under TRYSEM) during the training. This can be arranged under TRYSEM or through ICARs artisans training schemes

like NVK or All-India Coordinated Scheme on Farm Implements and Machinery.

Farm Machinery Repair, Maintenance and Manufacturing Society (FMS)

Workshop and Service Facilities – The facilities available at the FMSC will be used by the FMS. For this they will pay the hiring charges. This will be one of the major services rendered to the village artisans. The workshop facility can be extended to other local artisans at a cost. The existing fabrication facilities available in the nearby towns such as heat treatment, casting, etc will be utilized.

Raw material and spare parts – Non-availability of good quality raw materials in smaller quantities to the village artisans is one of the major constraints faced by them. It is suggested that Agro-Industrial Development Corporations and District Industries Centres should provide the required quantity of steel to these centres. The corporation may also provide spare parts for the running repairs of tractor, diesel engines and other machinery.

The cost of the raw materials and spares will have to be born by the artisans. Under the IRDP and VIP Programmes, they can be provided credit assistance and subsidy to a maximum of Rs.3 000 per artisan at differential interest rate (DIR) of 4%. This money can be used by the artisans as seed money or as a share capital to secure further credit assistance. (4, 11).

Activities

The FMSC will not only provide direct assistance to the farmers by way of farm machinery inputs but also will act as a liaison between the other farm machinery manufacturers in the organised sector and the farmers. Under the new 20-point programmes of the Prime Minister the Ministry of Agriculture has decided to provide subsidy to encourage the farmers to use better and improved farm implements and machinery (10). The programme can be executed through these centres. The major activities of the centre are:

i) Training of village artisans, farmers, rural youths in fabrication, repair and maintenance of farm machinery
ii) Fabrication and sale of simple hand tools and implements such as hoes, sickles, weeders, ploughs, harrow and seed-drills. **(Annexure II, III).**
iii) Sale of farm machinery manufactured by other organised farm machinery industries.
iv) Provide workshop facilities on custom basis to village artisans who wish to fabricate improved farm implements but cannot afford to purchase expensive workshop equipment.
v) Demonstrations and popularisation of improved farm implements and machinery to the farmers. The centre will keep a set of improved farm implements and machinery and will arrange regular demonstrations on the farmers field.
vi) The centre will provide simple service repair and maintenance facilities for the repair of tractors, diesel engines pump sets and other farm machinery. For major repairs, however the facilities available with the dealers/distributors may have to be utilized.

Annexure–II
Suggested Agricultural Tools and Implements for Fabrication and Sale by the Farm Machinery Service Centre

Manual:

Spade, pick axe, hoes, rakes, weeders, fork, wheel hoe, fertilizer broadcaster, sickle, maize sheller, groundnut decorticator, knives etc.

Animal-drawn:

Plough, bakhar (blade harrow) puddlers, disc harrows, tool carriers, levellers, seed drills, planters, weeders, potato diggers, groundnut diggers, threshers, bullock carts etc.

Other implements:

(Fabricated by Agro Industrial Development Corporation or Small Scale Industries and sale by Centre)

Ploughs, cultivators, seed drills, sprayers, dusters, threshers, groundnut digger shaker, potato digger, groundnut decorticator, storage bins, biogas plants, solar water heaters, solar cookers etc.

Annexure-III
Most Essential Tools and Implements Commonly Used by Small Farmers

1. Plough/blade harrow/disc harrow
2. Leveller [Wooden planks]
3. Sowing device/Seeder
4. Hand sprayer
5. Hand tools: Hand hoe, sickle, pick axe, spade, etc
6. Thresher
7. Bullock cart

Conclusions

The Sixth Five-Year Plan gives more emphasis on the development of agricultural and allied activities and for this, area specific block level planning is required instead of project specific. It is in this context that an institutional frame work has been suggested at the State, District and block level which will coordinate the efforts of the various agencies engaged in the rural development programmes for effective delivery of technology to the rural people.

As a part of the institutional

framework, a Farm Machinery Service Centre (FMSC) has been proposed at the Community Block level which will deliver the technology of improved farm equipment to the artisans, farmers and rural youth. It is envisaged that the FMSC will help the farmers in accelerated adoption of improved agricultural practices by providing better tools, implements and repair and servicing facilities. The centre will also help the artisans in self-employment in rural areas by providing them with training and workshop facilities.

The following outputs are expected from the Farm Machinery Service Centre:

i) Improvement in the skills of the rural artisans, farmers and rural youths.
ii) Production and distribution of improved tools and implements,
iii) Promotion of rural industries,
iv) Demonstration of improved implements and machinery in the villages,
v) Accelerated adoption of the technology of improved farm equipment.
vi) Employment generation in rural areas for technicians, rural youths, artisans and engineers.

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Highlights of the Recommendations for Action at the International Conference on Egyptian Agricultural Mechanization Strategy
April 25-30, 1986, Cairo, Egypt

(1) The development of a successful farm mechanization system in Egypt must be within the framework of the following principles:

– The self reliance, by locally manufacturing most of the farm equipment extensively used in Egypt.

– The non-renewable fuel saving by exploiting the agricultural tractors most economically and by encouraging and promoting the multi-farm use of farm equipment.

– Farm mechanization to be of the labor extensive type that does not affect labor employment as much as raising the labor standard and efficiency.

– Mechanization to be built around a sound management and a continuous training of all levels of technicians. Man being the central focus of any development should be provided with adequate training, education, health and financial care and service.

(2) The local manufacture of agricultural machinery should be the priority issue to the Ministries of Agriculture, Industry and military production within a homogenious and integrated framework.

While the role of the Ministry of Agriculture centers around extension activities, provision of basic data, agricultural machinery research, testing and experiments as well as the development of agricultural machinery prototype, the role of the Ministry of Industry would center around the assistance needed in materials procurement and the production of some basic components in addition to the support and promotion of the private sector in the assembly, production and marketing activities.

Laws, regulations and formalities should be examined and revised to improve farm-gate prices, simplify customs formalities and reduce duties on spare parts and other vital components and to provide advantages to local manufactures of both public and private sectors.

(3) The Ministry of Industry was unable to concentrate on one tractor type and model during the last 25 years of tractor local production. On the other land the door was let quite open to the import of all tractor types and models from all over the world.

This situation has resulted in having on the market more than 40 tractor types and models with their related problems of spare parts, maintenance, repairs and equipment out of order.

In the framework of realizing a part of the self relience policy, the assembly or possibly the manufacture of a NATIONAL TRACTOR should start as soon as possible.

Latest trials and researches have shown that a tractor ranging from 35 to 45 hp will successfuly meet the farmer's basic needs in addition allowing him to provide a custom hire service to his neighbours.

(4) The role of the universities in carrying out research is unique and distinctive. The departments of Agricultural Engineering related to different universities in Egypt should be equipped with better research equipment and facilities.

The Agricultural Mechanization Research Institute has the prime role of coordinating the research activities and intensifying contacts between universities.

The institute should commission the departments of Ag. engineering/mechanization to undertake, through contracts, some important research topics as listed in the institute's five year plan.

(5) Extension role in promoting successful mechanization is of prime importance. Extension field support efforts should be expanded in all areas of Egypt. A farming system approach that draws on expertise from farmers, local machinery dealers and researchers should be adopted.

The existing extension training facilities should be upgraded to improve the capabilities of the subject matter specialists. A public awareness program on the benefits and problems of mechanization needs to be intensified through on farm trials, demonstrations, radio broadcast and special television programs.

Intensive Weed Management Course
July 13-31, 1987, at Corvalis, Oregon, U.S.A.

The International Plant Protection Center at Oregon State University (U.S.) will again conduct an intensive 3-week Weed Management Strategies shortcourse in 1987.

The 1987 WMS course again will utilize university facilities including a nearby research farm where participants will, after reviewing field research methods, conduct experiments they design themselves. Research results will be reported in a classroom where activities are more "interactive information sharing sessions rather than stiff, one-way directed lectures," according to IPPC training coordinator, M.D. Shenk.

Each WMS course participant receives a mini-library of weed management technical publications (worth approx. $US250) for use during the course as well as free

shipment to the participant's duty post following the course.

The WMS course is purposefully designed for researchers, graduate students, and government specialists involved with conducting or administering weed management programs, particularly in situations where available resources are often severely limited. Participants need a command of spoken English and minimum of a bachelor's degree or equivalent.

The basic course fee is US$2,600 and covers matriculation, single occupancy lodging, meals, and all supplies and transportation during the course. Participants are responsible for their own financial support including the course fee, transportation to and from Oregon, and personal expenses. Scholarships are not available.

A free information brochure is available from: WMS Course, International Plant Protection Center, Oregon State University, Corvallis, OR 97331/USA.

Agro China '87 – The 2nd International Agro-Technologies Exhibition

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Agro China '87 is targeted to create an effective interface between the supplier and the end-users. A human interface who are responsible to bring western advanced technologies to China's countryside and to teach the millions of peasants how to use and apply them; people who will serve as the suppliers' vehicles to introduce new equipment to the end-users' level in the communes, brigades and collectives; people whose opinion and recommendation weighs heavily in the end-users' purchasing decisions. Without this human interface, it is impossible to create demands in the end-users' level who may not even aware of the existence of such equipment and technologies.

Although there are bound to be end-users' presence, Agro China's main objective is to provide an effective media to establish and improve this essential information flow. Agro China '87 is a market penetrating event for those foreign suppliers who have both the foresight and insight to open this important channel which brings their advanced equipment and sophisticated technologies to China's end-users.

The Ministry of Agriculture, Livestock and Fishery is responsible for the administration, policy and management of all agricultural sectors. The Chinese Academy of Agricultural Sciences is a research institute of agro-technologies serving the entire agro-industry. The National Center for Rural Technology Development is an organization under the State Science and Technology Commission and is responsible for the analysis of policies in agriculture, forestry, animal husbandry, sideline production and fishery. Their mission is to formulate strategic plans and coordinate multi-departmental, multi-regional science and technology development in agro-production, agro-chemicals, food and their processing technologies; organize training in agro-technologies, offer consultation; coordinate resources in rural development. Under the center are 5 departments each responsible for management, agriculture, regional development, agro-engineering, agri-processing.

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Participation in this conference and presentation of papers, films and machinery are invited. Papers presented at the conference will be published in the proceedings of the 7th conference. The registration fee, which includes one copy of the proceedings, as well as lunch and dinners, is US$180 for members of IAMFE and US$200 for non-members.

For details contact:

IAMFE 7
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NEW PRODUCTS

Massey-Ferguson 68 BS hp M-F 365 Tractor

This is one of seven models in the 300 series range (52-105 BS hp) of tractors.

A new range of tractors, which gives a choice of more than 10 000 variants to meet the operational requirements of farmers in any country world-wide, is launched by Massey-Ferguson.

The new 300 Series is the culmination of a nearly £5 million investment at M-F's Coventry tractor plant in new factory equipment, plus another £3.2 million in new computer software, which revolutionises the way the new tractors can be specified and ordered by customers.

In the past, because of the vast number of variants in the type of tractor wanted by farmers in different parts of the world, the plant has built largely standard machines to suit the majority requiremtns of individual markets, with a limited choice of optional equipment.

Now, farmers everywhere will be able to 'build-up' the exact specification of the tractor they want by choosing from a whole series of product features and options that will be available for all markets world-wide.

For further information contact:

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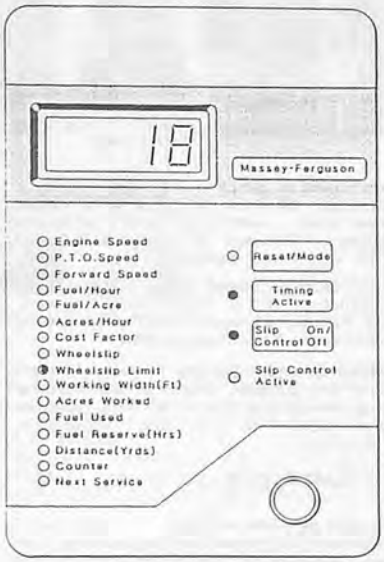
Massey-Ferguson Introduces 'Intelligent' Tractors



The 'Datatronic' information console in the cab of Massey-Ferguson's 'intelligent' 3000 Series tractors. The range of information that can be displayed is listed on the left, and the subject chosen for display is identified by an indicator light. Selection is made by rotating the knob (bottom right). In this example, the information being displayed is the wheelslip limit that has been pre-set by the operator. The "Slip Control Active" light on the right will come on the show that the automatic system is working whenever it cuts-in to reduce wheelslip if the pre-set limit is exceeded. Also on the right are the "Reset/Mode" touch sensor; a "Timing Active" touch sensor, which when pressed will monitor, for example, area worked and fuel used; and the 'Slip Control' touch sensor for switching on or off the automatic wheelslip control function.

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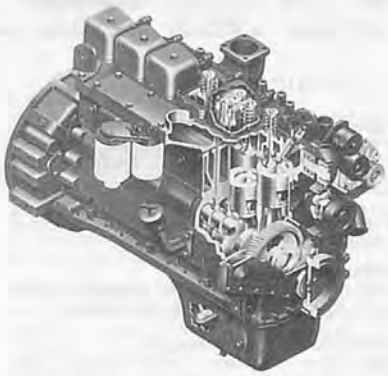
New Case Diesel Engine



The new Case engine line includes models with three, four, and six cylinders. The four- and six-cylinder engines are available in naturally aspirated, turbocharged, and turbocharged/aftercooled versions. (Turbocharging "packs" air into cylinders for greater horsepower; aftercooling cools packed air before it reaches the cylinder, for greater density – giving even higher horsepower, fuel economy, and faster warmup.)

The six-cylinder version of this dynamic new engine made its debut in the Case IH 1896 and 2096 two-wheel-drive agricultural tractors. In the 1896, a 5.9 *l* turbocharged engine provides 116 DIN ps horsepower (85 kW). The turbocharged/aftercooled 2096 engine delivers 128 DIN ps horsepower (102 kW). The 4-cylinder configuration already powers several models of Case IH construction equipment.

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INDEX TO ADVERTISERS

Arab Water World 5
Agric, S.A. Maquinaria Agricola 5
Iseki & Co., Ltd. 2
Kobashi Kogyo Co., Ltd. 6
Mametora Agric. Machinery Co., Ltd. 91
Matsuyama Plow Mfg. Co., Ltd. 6
Toyosha Co., Ltd. 90
Yamamoto Mfg. Co., Ltd. 4

BACK ISSUES

(Vol. 17 No. 1, Winter 1986~)

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 17, No. 1. Winter, 1986)

Editorial (Y. Kishida) 9
Problems of Agricultural mechanization in Developing Countries (A. Gego) 11
Performance of Power Tiller Blades (J.M. Baloch, J. Kilgour, S.B. Bukhari, A.Q.A. Mughal) 22
The Combi-Plough–An Animal-Drawn Implement System in Kenya (H.C.P de Vries, O.J.T.M de Weert) 27
Tractor-Drawn Combination Tillage Tool (V.J.F. Kumar, R. Manian) . . 31
Float Harrow and its Performance (P. Dutt, B.C. Parida, A.K. Choudhury) 37
Groundnut Crop Moisture Content and Rotor Speed in Stripping (S. Thangavelu, K.R. Swaminathan) . . 39
Field Investigation on the Direct Seeding of Coated Rice in Thailand (M. Koike, V. Manthamkan, K. Agarwalla, L. Ganjoo) 42
Performance and Vibration Control of Tractor-Mounted Oscillatory Potato Digger (A.P. Sharma, S.R. Verma) 47
Improvement of Manually-Operated Water Lifting Device (M. Ahmed, C.M.A. Khan) 51
Analysis of Forces Acting on Mole Plough in Mole Drainage Practice (R. Malik, P.B. Harrison, M. S. Soomro, G.A. Shah) 55
Hill Land Mechanization in Puerto Rico (E.J. Ravalo, F.R.R. Negron, M.R. Goyal, C. Almodovar) 59
Graphical Determination of Cost of Operation on Agricultural Machines (M.M. Pandey, T.P. Ojha) 63
Optimization of Machinery Systems (E.J. Hetz, M.L. Esmay) 68
Agricultural Machinery and Implements Industry: Problems and Status Quo (M.A. Sargana, S.I. Ahmad, J. Kishwer) 77
A Moral Story Handed Down in Europe (Tanoue) 81
News 83
New Products 84
Book Review 85

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 17, No. 2, Spring, 1986)

Editorial (Y. Kishida) 9
A Pole-Drawn Toolbar for Animal Traction (J.W. Dogger, M. Kersten) . . . 11
Zero-Tillage in Wheat Crop under Heavy Soils (S.D. Dhiman, A.P. Sharma) 15
Economic Evaluation of Tillage Operations in Some Mechanized Farms in Nigeria (J.C. Igbeka) . . . 17
Work Capacities and Fuel Consumptions of Hand Tractors Manufactured in the Philippines (C.J. Ancheta, R.C. Bautista) 23
Photoelastic Investigations for Stresses Due to Soil-Tillage Disc Tool Interaction (R.N.S. Yadav, C.P. Gupta, B. Pradhan) 27
Seed Distribution Performance of the Furrow Openers Used on Drill Machines (A. Özmerzi) 32
Design, Construction and Performance of a Manually-Operated Seeding Attachment for an Animal-Drawn Cultivator (K. Kumar, N.K. Naresh, T.P. Ojha) 35
Some Fundamentals of Electrostatic Spraying (Md. D. Hussain, E. Moser) 39
Irrigated Agriculture: Making the Most of Available Resources (J.O. Duru) 46
An Improved Cutting and Bunching Machine for Harvesting Grain Crops in Bangladesh (Md. M.R. Mollah, J. Kilgour) 49
Large-Scale Drying System for Paddy (Z. Sheng-yu) 55
Improved Nomographs for Estimating Efficiency and Capacity of Agricultural Field Operations (H. Lal) . . . 57
Mathematical Model for Selecting Wheat Threshing Systems for Farms in North India (M.L. Gupta, G. Singh, P.K. Gupta) 61
Agricultural Mechanization Facilities in Sind, Pakistan (A.A. Channar, B.T. Devrajani, A.Q.A. Mughal, S.B. Bukhari) 68
Comparison of USA and Japanese Agricultural Mechanization Models (F.S. Sial) 71
Indigenous Production of Agricultural Machinery in Pakistan (M.A. Sargana, A.P. Chaudhary, Md. Afzal) 75
Abstract 79
News 81
New Products 82
Book Review 84

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 17, No.3, Summer, 1986)

Editorial (Y. Kishida) 9
Soil Bin Studies of Tillage-Line Forces (J. Md. Baloch, S.B. Bukhari, B. Koondhar, A.A. Channer, A.N. Mirani) 11
Drilling of Pelleted Paddy Seeds in Puddled Field (K.T. Maru, S.C.B. Siripurapu) 15
Optimum Composition of Rubber Rolls for Paddy Shellers (R.P. Misra, C.P. Gupta, S.K. De) 19
Storability and Germination of Pre-Harvest Desiccated Paddy (P. Pillaiyar, S. Sethuraman, M. Nagarajan, R. Vaidhyalingam) 23
Simple and Low Cost On-Farm Paddy Dryer (K. Uyeda) 27
Mechanization of Paddy Cultivation in West Malaysia (G. Singh, L.C. Kiong) 32
Losses of Rice During Milling in Commercial Rice Mills of Sri Lanka (W.V. Jayasena, S.G. Ilangantileke) 37
Mechanization of Small Farms in Tropical Africa (N.G. Kuyembeh) 41
Agricultural Mechanization as a Catalyst for Rural Development (U.G.N. Anazodo) 47
Influence of Natural Resources on Agricultural Mechanization (N.H. Laghari, A.Q.A. Mughal, B.T. Devrajani) 53
Intensity of Tillage Operation in Bangladesh (Md. S. Uddin, Md. R.I. Sarker) 57
Design, Development and Field Evaluation of a Oscillatory Potato Digger (A.P. Sharma, S.R. Verma, A.S. Bansal) 60
Maintenance of Tree-Crop Plantations Using a Portable Motorized Weeder (L.O. Fawole, A.A. Agboola) 63
Agricultural Structure Problems in Tropical Countries (I. de A. Nääs) . 67
Delivery System for Farm Machinery Technology in India (G. Singh, T. Ojha) 72
Abstract 59
News 81
New Products 83
Book Review 85

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 17, No. 4, Autumn, 1986)

Editorial (Y. Kishida 9
Studies on Evolutional Steps for Plowing and Tractorization in Japan (J. Sakai, S. Phongsupasamit, T. Kishimoto) 11
Effect of Restrained Linkage-Geometry on Tractor Performance (J.M. Baloch, S.B. Bukhari, A.Q.A. Mughal, A.N. Mirani) 20
Animal Draught: A Source of Power for Agricultural Development in a Developing Country (A. B. Fashina, J.C. Igbeka) 25
Draught Animal Power Potential in North-Eastern Hill Region of India (S.D. Sahu) 29
A Simple Recorder for Monitoring Irrigation Water Flow (T.B.S. Rajput) 32
Factors Affecting Choice and Use of Tillage Implements: Pakistan Setting (K.A. Hussain, H. Md. Munir) . . 35
Factors Influencing Threshability of Maize in Nigeria (K.C. Oni, M.A. Ali) 39
Needs and Availability of Agricultural Machinery in Chile (E.J. Hetz) 45
Farm Mechanization in Turkey (A. Özmerzi, B. Gökçebay) 49
Agricultural Engineering Potential in Caribbean Basin (M.R. Goyal) . . . 51
Useful Gadgets for Manufacture of Low-Cost Agricultural Machinery (S.R. Verma, J. Singh) 59
Performance and Tomato Yield in Cooled Greenhouse at Al-Hassan, Saudi Arabia (A.M. Abdalla, G.M. Al-Hassan, A.S. Al-Ghamdi, K.A. Sallam) 63
Nomographs for Sensible Heat Carried out of Furnace by Products of Combustion (K. Kumar, S. Bal) . . 68
Factors Influencing Effectiveness of Radio-Frequency Dielectric Heating on Rice Bran (V.V. Sreenarayanan, P.K. Chattopadhyay) 71
Simple and Low Cost on-Farm Paddy Dryer (Part-II) (K. Uyeda) 75
News 78
Book Review 79

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (Vol. 18, No. 1, Winter, 1987)
Editorial (Yoshisuke Kishida) 9
Study on Basic Knowledge of Plowing Science for Asian Lowland (Paddy Field) Farming (Jun Sakai, Surin Phongsupasamit, Tadashi Kishimoto) 11
Preparation of Medium-Textured Soil for Rice Production (Abdul Razzaq) 19
Effect of Field Dimensions on Energy and Labour Consumption for Rotary Cultivating Small-Sized Plots (Md. Wali Ullah, S. Sonne Kofoed) 22
Flat and Broadbed-and-Furrow Systems of Cultivation (Harbans Lal) 27
Energy Consumption in Rice Processing Operations in Nigeria: Selected Case Studies (G.O.I. Ezeike) 33
Stabilization of Rice Bran by conduction Heating in a Continuous Rice Bran Stabilizer (A. Chakraverty, D.S.K. Devadattam) 41
Some Physical Properties of Wheat and Paddy and their Relationships (Md. Nurul Islam, T.T. Pedrsen) . . 45
Relationship of Grain Shape and Mass to Tensile Strength of Rice (M.S.U. Choudhury) 51
Development and Field Evaluation of a Stubble Collector-Cum-Planker (N.K. Bansal, D.N. Sharma, M.L. Jain) 57
Low-Cost Peat Production and Gasification (M.E. Herbst) 60
Integrated Regional System of Thermal Utilization of Biomass Resources (Hiroshi Shimizu, Toshinori Kimura, Rattanachai Pairintra) 65
Sugarcane Trash Management in India (A.C. Srivastava, R.D. Singh) 72
Delivery System for Farm Machinery Technology in India (Gyanendra Singth, T.P. Ojha) 75
News 83
New Products 85

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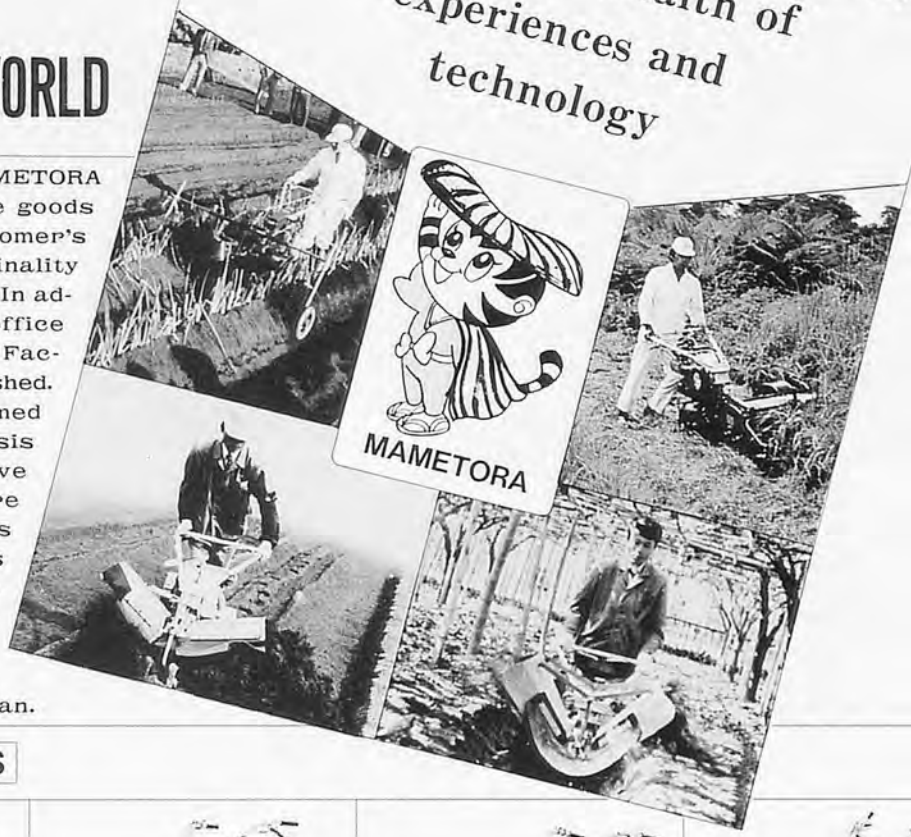

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