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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.32, NO.3, Summer 2001

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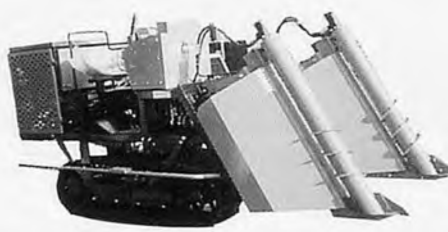

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FARM MACHINERY INDUSTRIAL RESEARCH CORP,
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EDITORIAL

Increasing Food Grain Availability

The grain stock in the Peoples' Republic of China (PRC) has recently been reported to be adequate for a year's supply of that country's 1.3 billion population. No sooner did another report dispute that report stating that the quantity of the food grain in stock was fabricated by government officials as the actual stock is adequate only for three or four months' supply.

That fraudulent report is a serious matter which has a great influence on world agriculture. With such a short supply of PRC's grain stock, that country will inevitably have to increase grain importation - an issue that would place the PRC in an embarrassing situation to reconcile the difference between food grain available and food grain to be imported.

Under the present free trade system of agricultural products, the PRC will be obliged to amend their agricultural policies for the protection of farmers. Otherwise, the problem will be followed by falling food grain prices with the net result that the farm population would be moving from the rural areas to urban areas. This prospect will be chaotic.

From a wider point of view, the world's population continues to grow at the rate of 0.1 billion a year and the number of people suffering from starvation is unlikely to decrease as it seems to be on the increase instead. It is a fact that more and more young farmers abandon agriculture in many countries of the world due to low prices of agricultural products, let alone the fact that ageing farmers in many countries are quitting farming.

Over-production of major food grains in economically developed countries is one reason why food grain prices are adversely affected at the expense of the farmers in developing countries. Japan is no exception in that the self-sufficiency rate of food supply has been falling as low as under 40 percent of the country's annual consumption. With concerns about food supply and world population in the future, one of the major questions is what means we can take in order to have adequate food grain availability. Of course, during unseasonable weather such as drought and floods which hit some countries every now and then, there is not much we can do. Global warming, acid rain and other vagaries of Nature, in particular, make agricultural productivity unstable.

Barring these abnormalities of weather, the development and dissemination of production system/technology which renders agricultural productivity stable need to be promoted. Efficient agricultural practice is a keyword in agriculture these days in advanced countries which maximizes food production. In many cases, mechanization is essential to the agricultural production system, hence the need to promote more advanced mechanization technology in already mechanized areas and to convert animal power to machine power in areas backward in mechanization.

We have very little choice but to play active roles in upgrading mechanization in developing countries - a most important way of increasing food grain availability for the 21st Century.

Yoshisuke Kishida

Chief Editor

Tokyo, Japan
July 2001

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A Microcomputer System for Slip-Based Depth Control of Tractor-Mounted Implements

by
C. Divaker Durairaj
Assistant Professor
College of Agricultural Engineering
Tamil Nadu Agricultural University
Coimbatore,
641 003, India.

V. J. F. Kumar
Professor
College of Agricultural Engineering
Tamil Nadu Agricultural University
Coimbatore
641 003, India

Abstract

The conventional draft control system of tractors senses the soil-tool interaction forces and adjusts the hydraulic response accordingly. The variation in field topography and soil strength drastically introduces errors in these responses, since the soil-tire interaction is never considered in its operation. A foolproof alternative is the slip-based draft control system, which is hard to realize in hydraulic systems. Hence an electronic control module was contemplated and built as an attachment to the existing hydraulic system of a tractor. A novel wheel speed sensor was devised which used a simple dynamo commutator and some basic logic circuits. The front and rear wheel speeds as measured by these sensors were fed into a microprocessor-based control module. The module calculated the slip and connected an on-off controller to raise or drop the implement accordingly. The system was tested on a tractor with an integrally mounted implement. The depth of operation measured in the field had non-significant variation for the preset depth in the control module.

Introduction

Modern tractors have sophisticated hydraulic draft control systems involving mechanical linkages and controls, augmented to complex fluidic circuitry. These systems mainly rely on the draft signals sensed in the top link of the three-point linkage, and account for the soil - tool interaction only. On the contrary, a slip-based control system would work based on the soil - tire interaction to yield better tractive performance. But a purely hydraulic operated slip based control system is difficult to realize. Grogan *et al.*, (1987) and Shroack *et al.*, (1989) developed microcomputer based-tractor performance monitors, which sensed slip, draft and engine speed to optimize gear selection of tractors. They used proximity switches and optical sensors to measure the wheel slip. In this study, an 8085 microprocessor-based electro-hydraulic control system was developed to monitor the wheel slip and control the ploughing depth.

Materials and Methods

Wheel Speed Sensors

An automobile dynamo's commutator was used as the wheel speed sensor (**Fig. 1**). The commutator was mounted on a suitable lug extending from the tractor's chassis and was bushed to accommodate a stub axis extending from the wheel centre. A carbon brush rotating with the wheel was in contact with the commutator. The alternate segments of the commutator were shorted to provide two parallel paths, each one connected to one input of a switch debouncer. The grounded brush riding on the commutator worked like a two-way switch except that it grounded both the terminals, when flipping from one to the other. Instead of the commonly used NAND debouncer used with switches, a debouncer built around NOR gates was developed for the purpose. The NOR debouncer, whose truth table is presented below, was used to suit the characteristics of the developed sensor (**Fig. 2**). The device produced one pulse for every commutator segment passing across the brush. So for each revolution of the wheel the device produced 10 numbers of such pulses. Similar com-

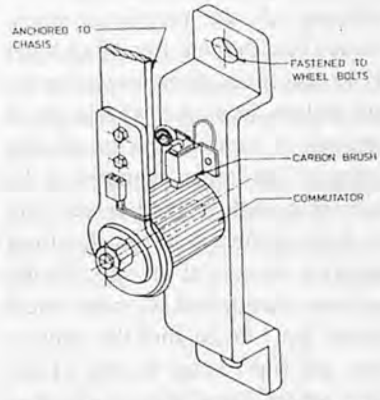

Fig. 1 Commutator type wheel speed sensor.

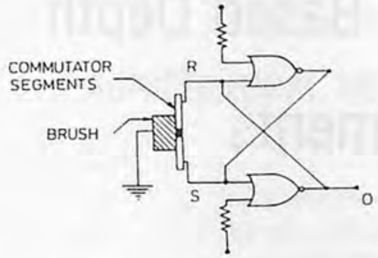

Fig. 2 The nor debouncer.

R input	S input	O output
0	1	1
1	0	0
0	0	No change
1	1	Unstable

mutator switches were mounted one on the front wheel and the other on the rear wheel.

Hardware

An 8085 microprocessor trainer kit similar to the SDK 85 was used to build the control system. The kit's 8253 timer/counter chip was used to count the debounced pulse inputs from the speed sensors. Its 8255 Programmable Peripheral Interface chip was used to activate the tractor's hydraulic system through a solenoid switch and necessary driver circuits. The kit's 8279 display/keyboard controller chip was used to display the percent wheel slip continuously. The software for the system was stored in the EPROM of the system.

Software

The programme (**Fig. 3**) after initializing all the peripheral chips, loaded the counters 1 and 2 of timer 8253 and made them count the input pulses from the wheels for 5 seconds to compute the speeds. By virtue of the larger diameter of the traction wheel, a fixed speed ratio of 1.66 existed between the front and rear wheels at no slip. So the software multiplied the rear wheel counts by 1.66 to find the equivalent 'no slip' count to that of the front wheel. The slip was calculated as per the expression:

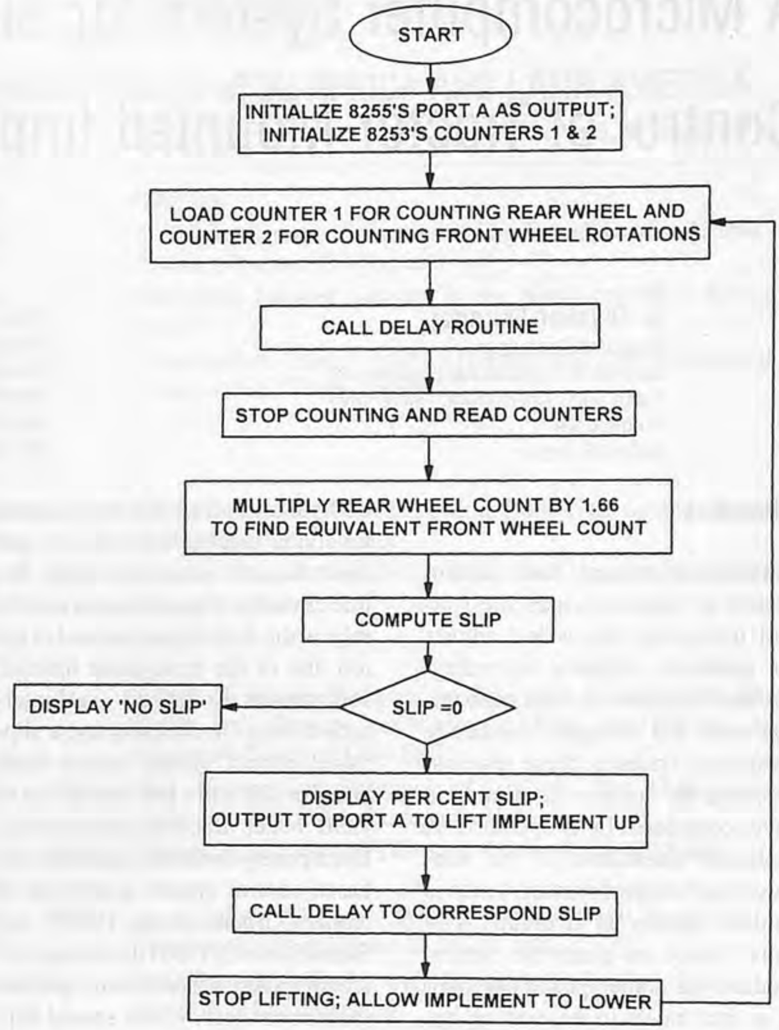

Fig. 3 Control system software.

$$\text{Slip} = \frac{\text{Rear wheel counts} - \text{Front wheel counts}}{\text{Rear wheel counts}} \times 100$$

The result was saved in the RAM and the decimal value computed by a sub-routine was displayed in the right most digits of the kit's display. Under no slip condition, the programme displayed No Slip on the display. If slip occurred due to implement loading, the slip percentage computed and stored, was used to activate the tractor's hydraulic system. The 0^{th} bit of the PPI 8255's port A was made high for a period corresponding to the percent slip. This bit buffered by a 7407 open collector activated a solenoid valve ('YUKEN MAKE') requiring 2.5 amp through a Darlington pair of SL100 and 2N3055 transistors. The solenoid valve in-turn activated the hydraulic system of the tractor to raise the implement. This reduced the slip due to release of load and the control loop was thus completed. The power for the electronics was derived from the tractor's 12 V battery.

The Hydraulic System

This experimental control system was installed on an 'Eicher (INDIA)' 20 hp tractor having a reciprocating hydraulic pump, operating a single ram cylinder to lift the three point linkage. The implement lowers by gravity on release of oil

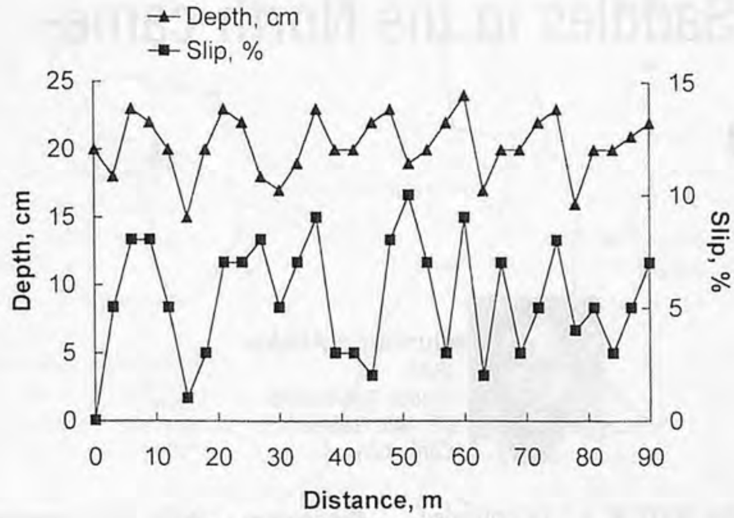

Fig. 4 Performance of the control system.

pressure to the sump. The solenoid valve was inserted in this existing hydraulic circuit such that, on activation, it opened the pump to the ram so that the implement was lifted up and on closure, by-passed the pump delivery to the sump. The control on the hydraulic system was hence an on-off control to either lift or lower the implement.

The control system was tested in the field for its capability to maintain a constant 20 cm depth of operation on a two bottom mould board plough. Observations on the depth of operation of the implement were recorded at intervals of 3 m on the ploughed furrow. The slip history of the control system with respect to the distance traveled was logged in the microprocessor kit and retrieved after each test run.

Figure 4 illustrates the plot of variations in the depth and the corresponding slips. It was clearly evident that the system responded only when the wheel slip was encountered. It was found to respond satisfactorily maintaining the depth within ± 3 cm from the preset level.

Conclusion

The main advantage of using an micro processor-based electro-hydraulic system was its simplicity, eliminating the need for complicated hydro-mechanical elements. In future works, a minimum microprocessor system could replace the trainer kit. Refinements such as position control could also be incorporated with ease.

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New Co-operating Editor

S. M. Ilyas

Nationality: India
Birth Date: July 25, 1947
Qualifications:

B.Sc. degree in Agricultural Engineering and Technology, 1967.

M.Sc. degree in Agricultural Engineering, INdian Agricultural Research Institute (IARI), 1969

Doctor of Science in Agricultural Engineering, University ofNovi Sad, Yugoslavia,1973

Experience:

1985 - 1991: Head of Division of Agricultural Engineering, IARI.

1989 - 1992: Project Co-ordinator, Promotion of Agri-Electronics (Coop. Centres in six State Agricultural Universities), IARI.

1996 - 2000: Assistant Director General, ICAR HQ presently holding charge of Plan Implementation and Monitoring also held Additional charges of Technical Co-ordination and Intellectual Property Rights.

Current Position:

Director of Central Institute of Post Harvest Engineering and Technology (CIPHET), Ludhiana. P.O.:P.A.U, Ludhiana - 121 004 (India), Tel:+91-161-808669, Fax:+91-161-808670, E-mail: ciphet@satyam.net.in

Perfecting Donkey Saddles in the North-cameroon Savanna Zone

by
Eric Vall
CIRAD-EMVT,
BP 5035, 34032,
Montpellier
France

Oumarou Abakar
IRAD
Station Polyvalente
BP 415, Garoua
Cameroun

Abstract

The use of donkeys in draught activities is strongly developping in the North Cameroon cotton producing savannas, principally in the less than 5 ha small farms of the stony and broken zones around Maroua and Guider. This development essentially based on ploughing is not much concerning transport which is practiced with a poor know-how and rudimentary tools (bare back carrying). The consequences are packing limitation, in one hand, and disastrous effects on donkey's health on the other.

At the request of a development project, the IRAD (Institut de la recherche agricole pour le développement) has perfected two models of donkey saddles which have been tested in farmers conditions by some users.

- The *IRAD W* model: a wide spreaded saddle built in eucalyptus blockheads or in red wood rafters, 11 kg unloaded, high capacity of load, cost prices between 29 and 33 USD.
- The *IRAD X* model: smaller than the *IRAD W*, 4.5 kg unloaded, made in white or red slats, cost prices ranging from 20 to 22 USD, a reduced loading capacity but very practical in mountainous paths.

Users' advice collected by survey after utilization in farmers conditions have shown, regardless of the model, a real interest in this new tool that does not cause wounds on the animal although the large diversity of load that it can be used to carry. Farmers estimate that they have discovered a new interest in their donkeys for the dry season. A spotless preference was manifested for the *IRAD W* model which is found easier to handle, more multipurpose and efficient. Cost prices were judged a little too high for both models. The majority of the farmers wished to get the equipment in a short term credit.

Finally, farmers declarations were full of satisfaction for their first experience with donkey saddles and a wider popularization of the equipment is to be pursued.

Introduction

In the savanna cotton producing zone of North Cameroon, the use of donkeys as draught animals is in strong increase since 20 years. As one might, say, non-existent in 1970, the yokes of donkeys are estimated to about 21,000 in 1997 (Sodécoton, 1997). The working donkeys are especially used in yoked farming (ploughing essentially, weeding and ridging secondarily). The small farmers appreciate donkeys in particular because they are inexpensive to purchase and to maintain (a donkey can cost about 40 USD). Moreover, a yoke of donkeys is easy to handle in stony and broken fields. In the area between Maroua and Guider the soils are very stony and the farms are of small sizes, often less than 5 ha (**Figure 1**) - reason why about 80 p.100 of working donkeys' population are found in that zone.

Meanwhile, draught donkeys are little used for transport in the dry season. The majority of small farmers, having low incomes, are unable to buy a donkey cart. The few donkeys used for transport are loaded almost bare back. This practice leads to packing limitation, on one hand, and to frequent wounds on the donkey, on the other. Bare back transportation challenges both the health of the animal and its working capacity.

To solve this problem, the DPGT (Projet de développement paysannal et gestion des terroirs), a rural development project, financed a study aimed at perfecting donkey saddles. In Europe and America in the past, packing saddles are largely used (during alpine transhumances, military campains, and American rush to

Acknowledgments: The authors wish to express their gratitude to the IRAD (Institut de la recherche agricole pour le Développement); to Sodécoton (Société de Développement du Coton au Cameroun); to DPGT project (projet de Développement Paysannal et Gestion des Terroirs) for having promoted and funded this study.

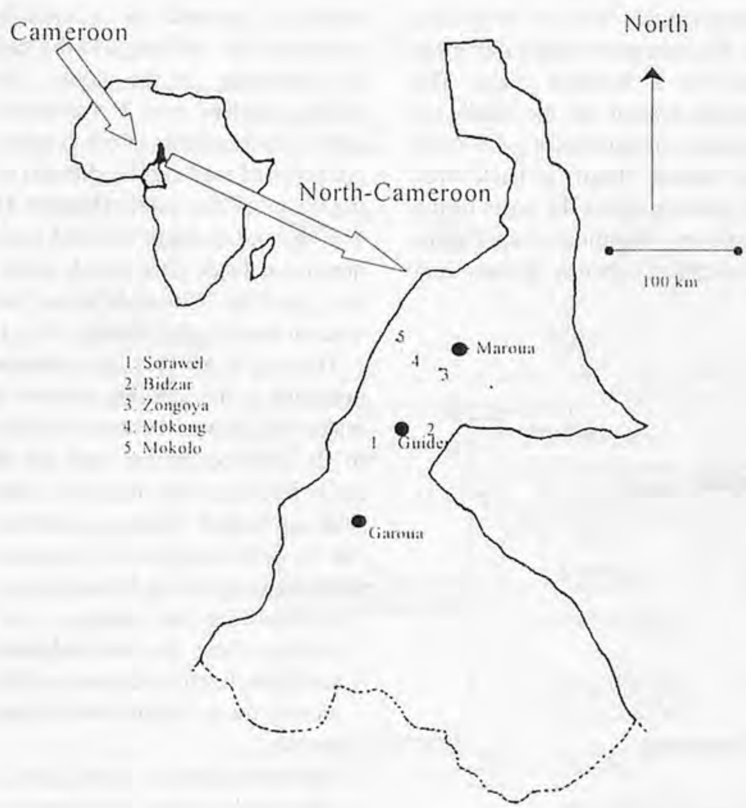

Fig. 1 North Cameroon and testing sites of donkey saddles.

the west). Presently in some zones of East and North Africa, donkey saddles are in current use. In Europe, it is the tripping tourism that causes a revival of interest in donkey saddles. Thus, many styles of saddles yet exist (Charvin, 1981 ; Raveneau and Davèze, 1996). To realize the study commanded to IRAD (Institut de la recherche agricole pour le développement), the matter is not to invent a new tool but to adjust the pre-existant models to the needs of the North Cameroon rural environment.

The specifications of the study were for the research to perform an equipment that can be made with locally available materials suited to the size of the majority of North Cameroon working donkeys; comfortable enough to avoid wounds on the back of the animals; its cost price must range from 17 USD to 34 USD and the equipment has to be multipurpose to carry any load not exceeding 80 kg (the weight of a millet bag). It has also been asked to research to perfect different models of the same equipment so as to give to farmers more possibilities of choice according to their financial capabilities and their preferences.

Materials and Method

The method comes in two elements : an on station work during which prototypes are perfected and tested. The second part of the study is a pre-popularization of the saddles in farmers' conditions in order to collect users advice and improve the equipment.

Building and Testing the Prototypes on Station

The objective is to perfect two types of packing saddles: one big-sized, easy to handle and having an important loading capacity; the second small-sized one, with a reduced spread, must be suited to mountain paths.

After an inventory in the markets, the following available materials were chosen: industrial red and white wood, eucalyptus blockheads for the frame of the saddles (saddle bow); nylon strips of 5 cm wide for the straps; cotton fiber and linen for paddings (cushions and small cushions).

Dimensions of the saddles are fitted to measure local donkeys and to the desired loading capacity. A recent study (Ebangi and Vall, 1998) show that in North Cameroon, an adult donkey has the following body characters: liveweight (LW) = 125 kg; trunk length (TL) = 110 cm; and height at withers (HW) = 100 cm. A total load of 80 kg represents about 65 p.100 of the mean animal liveweight. This value is high as to military service records (cited by Charvin, 1981) which recommend a maximum load of 30 p.100 of liveweight. It is, therefore, suitable to advise farmers to reduce the maximum load for long compared-distance trips.

The prototypes have been tested for forage transportation: 30-40 kg of forage on a distance of 5-10 km. This on station test allowed the set and to strenghten the prototypes in order to make them operational. Following the test, 8 specimens of each model were made.

Pre-popularization in Farmers' Conditions

To be acquainted with users advice, the packing saddles were given to some voluntary farmers in 8 villages (**Figure 1**) in the vicinity of Guider and Maroua-South Sodécoton Régions (Bidzar, Guider center and Sorawel sectors for Guider; Mokolo, Mokong and Zongoya sectors for Maroua-South). To familarize the volunteers to the use of the equipment, a demonstration meeting followed by a practical session was organized with each of the volunteer in each village. After the testing period which lasted 6 months during the 1997-98 dry season, users' advice was collected by survey.

Results

Saddling Principles

A packing saddle is supported by a frame (saddle bow) in wood pattern. The two parts of the frame are joined by a wooden ridge. The strapping system fits the saddle on the donkey, it comprises a foreward strap (breast strap), a backwards strap passing under the basis of the tail and an abdominal strap(**Figure 2**). Interface between donkey and saddle is assured by a padding (cushions) free or linked to the saddle depending on the model. The loading system uses a synthetical rope (two fragments of 6.5 m each). All types of load can be charged by the mean of two knots (**Figure 3**). The "Noeud de fagot" is used to tie horizontal loads (fire wood, straws etc...) and the "Noeud de bidon" for vertical loads (cans, baskets, etc...).

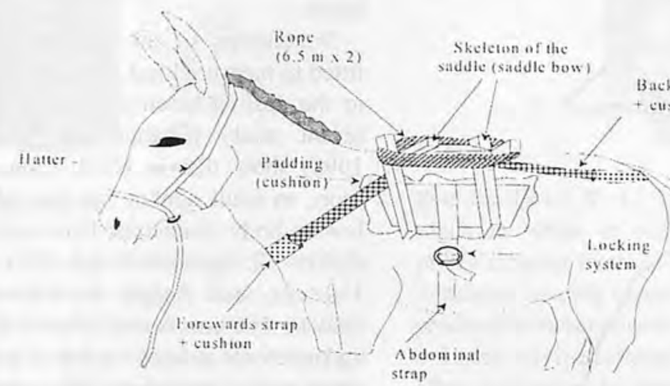

Fig. 2 Donkey saddle and properties.

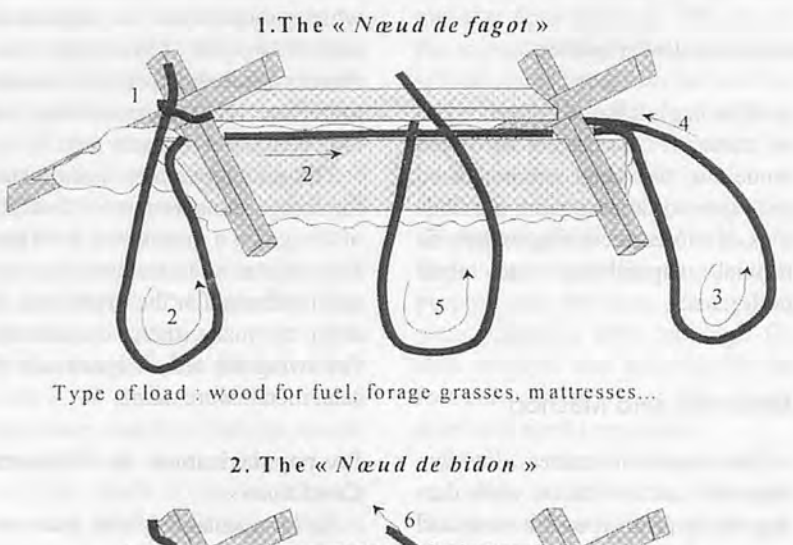

Fig. 3 The two types pf knots used of fix loads.

Training is an easy but essential operation in the saddling process. It makes the animal become familiar to its new equipment and get to know how to avoid obstacles when walking loaded. Training a donkey can be achieved in a few days and three major steps can be suggested:

1. *Accustoming the donkey to its saddles*- Just let the unloaded saddle be fixed on the back of the animal for a certain time (some hours).
2. *Apprenticeship to walk with a light load*- Allows the animal to acquire some reflexes by helping it not to turn too short or conter-balance a load tending to fall over (two or three days).
3. *Finish of the training*- Increase progressively the load and the distance covered (two days of an intensive work are necessary for this purpose).

The Two Models of Saddles

The big model (11 kg unloaded) takes from the Ethiopian saddle (**Figure 4**). It has been named *IRAD W* due to the shape of its saddle bow. The minor model, named *IRAD X* for the same reason is drawn from the saddle of the equestrian trippers Federation of France (FREF) (**Figure 5**).

The saddle bow of the *IRAD W* model (**Figure 4**) is made of two lateral uprights crossing in a 86° angle (uprights' length = 75 cm). It is made in a red wood rafter (6 cm square) or in eucalyptus blockheads (6 cm diameter). Two small planks driven in the uprights and resting on the upper parts of the donkey's flanks serve as

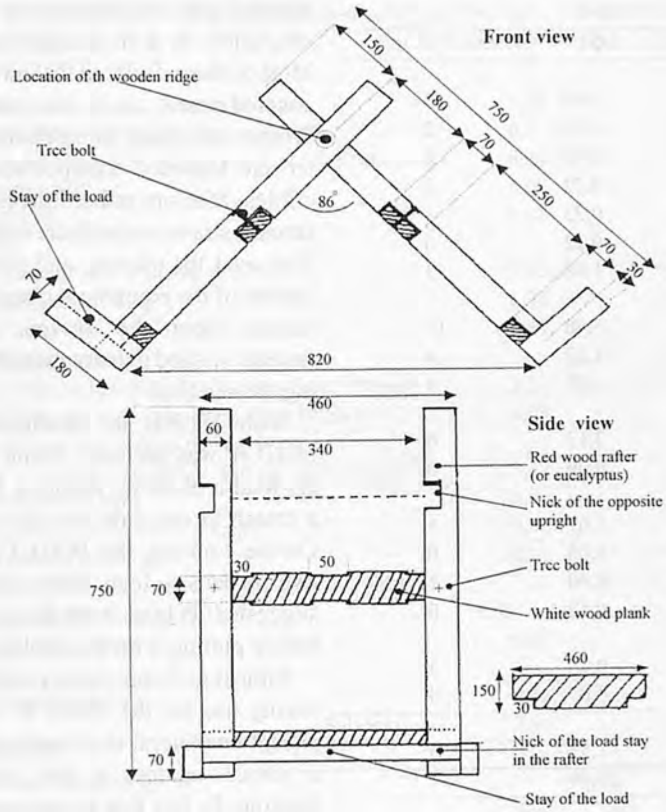

Fig. 4 IRAD W model of donkey saddle (in mm).

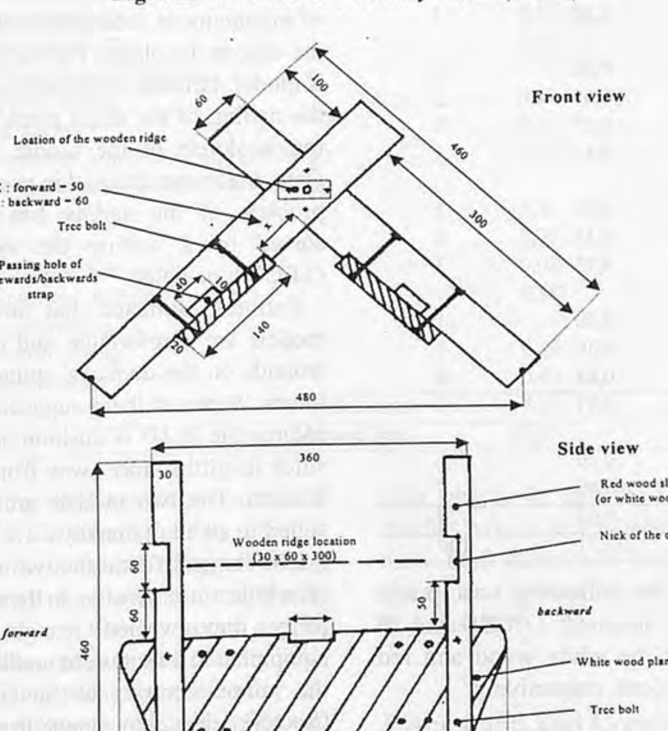

Fig. 5 IRAD X model of donkey saddle (in mm).

stay of the saddles. Over the wooden ridge, the uprights form a crosspiece on which are tied up the loading ropes. At the bottom of the saddle bow two other small planks, nicked perpendicularily in the uprights serve as stay of the load. The padding is made by a cushion (75 cm * 85 cm) filled with cotton fiber; it is straddled on the back of the donkey. On the side of the cushion in contact with the animal the cotton linen is doubled. The abdominal strap is made with a doubled nylon strip (5 cm wide). The forewards and backwards straps are folded widthwise (2.5 cm wide).

The *IRAD X* saddle bow (**Figure 5**) is supported by two lateral uprights crossing perpendicularily (90°; uprights length = 46 cm); they are made in red or white rectangular slats (3 cm * 6 cm). The uprights form also over the ridge a crosspiece on which are tied up the slowing ropes. The paddings are linked to the lateral small planks by leather laces. The cushions have a trapezoïdal form (Height = 25 cm; main length = 50 cm ; second length = 40 cm), they are filled with cotton fiber and stitched by a spiral needlework. The straps are identical than those of the *IRAD W* model.

Cost Prices of the Saddles

The *IRAD W* model is more expensive (**Table 1**). Its cost price ranges between 29 USD and 33 USD, respectively, for eucalyptus and red rafter options. For the red wood option 48 p.100 of the cost price concern the amount expenses on woodwork (17 p.100); cotton linen for paddings (17 p.100) and red rafter price (14 p.100). Other expenses are marginal. By replacing red wood by eucalyptus blockheads, 4 USD reduction is obtained. It is surely possible to gain 2 USD on the woodworker pay and 2 USD on the cotton linen price. All those savings could lead to the following cost prices : 29 USD for the red wood option and

Table 1. Cost Price of the IRAD W *Saddle (Red Wood Option)*

Material Expenses	USD	Percent of total
Saddle bow		
Red wood rafter (4 × 75 cm × 8 cm × 8 cm)	4,60	14
Red wood rafter (34 cm × 8 cm × 8 cm)	0,53	2
White wood plank (2 × 3 cm × 15 cm × 46 cm)	0,78	2
White wood plank (4 × 3 cm × 7 cm × 46 cm)	0,72	2
White wood plank (4 × 3 cm × 7 cm × 18 cm)	0,25	1
Nails: size 6 (30)	0,12	0
Trcc bolts (4)	1,00	3
Paddings		
Cotton linen (3 × 90 cm × 100 cm)	5,40	17
Cotton fiber (2500 g)	1,33	4
A 5 cm wide Nylon strip (2 × 160 cm)	1,33	4
Abdominal strap		
A 5 cm wide Nylon strip (2 × 80 cm ; 2 × 175 cm)	2,13	6
Smooth concrete iron: diameter 6 (2 × 19 cm)	0,09	0
Forewards and bacwards straps		
A 5 cm wide Nylon strip (2 × 150 cm; 2 × 50 cm)	1,67	5
Rings (4 ; d = 3 cm)	0,08	0
Cotton linen (2 × 25 cm × 40 cm)	0,40	1
Cotton fiber (2 × 100 g)	0,12	0
Hatter		
A 5 cm wide Nylon strip (230 cm)	0,96	3
Rings (3 ; d = 3 cm)	0,07	0
Roping		
Nylon rope (2 × 650 cm)	1,52	5
Sub-total	23,09	71
Labour Cost		
Saddle bow assembling		
Wood work	5,50	17
Paddings assembling		
Cushion sewing	0,50	2
Cushion stiching	0,67	2
Nylon strip sewing	0,27	1
Nylon strip needle work (2)	0,17	1
Abdominal strap assembling		
Nylon strip sewing	0,43	1
Needle works (3)	0,15	0
Rings making (iron bowing and soldering)	0,33	1
Foreward and backward straps assembling		
Nylon strip sewing	0,30	1
Needle works (6)	0,30	1
Small cushion making (2)	0,08	0
Small cushion stiching (2)	0,33	1
Hatter assembling		
Nylon strip sewing	0,19	1
Needle works (8)	0,40	1
Sub-total	9,62	29
Grand Total	32,71	100

25 USD for the eucalyptus option.

The *IRAD X* model is cheaper and easier to make by the wood-maker (**Table 2**). Its cost price goes from 20 USD (white wood option) to 25 USD (red wood option). On this model, about 2 USD savings are surely possible on the wood-worker pay. On the other sources of expense 1 USD can also be saved so that the following cost prices could be obtained: 17 USD and 19 USD for the white wood and red wood options, respectively.

Users' Advice

A real interest has certainly been shown by the farmers in this equipment. Users appreciate it because wounds due to carrying have been avoided and the donkeys are more efficiently used in the dry season. Most of them declared that have discovered a new use of their animals. Women apreciate, in particular, water and firewood transportation facilities. Men are rather interested in cereals, straws and manure carrying. The need for training and popularization of the equipment cleanly appeared from the survey. Some farmers wished to learn manufacturing the saddles.

With regards to handiness the *IRAD W* was prefered. Some farmers load it alone by wedging it with a crutch in one side then the other. On the contrary, the *IRAD X* needs two persons to load. Some farmers suggested to load it on the ground before putting it on the donkey.

Almost no break-in was observed during use for the *IRAD W* model except one lateral stay that broke in a chock against a tree around Mokolo. In fact this model's spread is problematical in the narrow paths of mountainous areas, which is not the case in the plains. For the *IRAD X* model, farmers complained about the nailing of the small planks and the weakness of the saddle bows from which two cracked in use. The problem of the nailing has been solved by a bolting the system (TRCC type bolts).

Farmers estimated that the two models are comfortable and avoid wounds on the donkeys' spinal culumns. Some of them suggested to enlarge the *IRAD W* cushion and to stitch its girths more away from the borders. The two models are well suited to all adult donkeys.

The farmers found the two models a little too expensive. In their majority they wished to get the equipment in a short term credit like the intrant contract of Sodécoton (Société de developpement du coton au Cameroun). In Mokolo users declared to be ready to get it in cash.

The preference of the farmers went clearly to the *IRAD W* model. All users of the *IRAD X* model said

Table 2. Cost Price of the IRAD X *Saddle (Red Wood Option)*

Material Expenses	USD	Percent of total
Saddle bow		
Red wood rafter (92 cm × 8 cm × 8 cm)	1,48	7
Red wood rafter (30 cm × 8 cm × 8 cm)	0,47	2
White wood plank (2 × 43 cm × 14 cm × 20 mm)	0,67	3
Nails: size 6 (20)	0,08	0
Tree bolts (8)	1,67	8
Paddings		
Cotton linen (2 × 2 × 60 cm × 30 cm)	1,43	7
Cotton fiber (2 × 700 g)	0,76	3
Leather laces (2 × 4 × 30 cm × 1 cm)	0,67	3
Abdominal strap		
A 5 cm wide Nylon strip (2 × 80 cm ; 2 × 175 cm)	2,13	10
Smooth concrete iron: diameter 6 (2 × 19 cm)	0,09	0
Forewards and bacwards straps		
A 5 cm wide Nylon strip (2 × 150 cm ; 2 × 50 cm)	1,67	8
Rings (4 ; d = 30 mm)	0,08	0
Cotton linen (2 × 25 cm × 40 cm)	0,00	0
Cotton fiber (2 × 100 g)	0,12	1
Hatter		
A 5 cm wide Nylon strip (230 cm)	0,96	4
Rings (3 ; d = 30 mm)	0,07	0
Roping		
Nylon rope (2 x 6,5 m)	1,52	7
Sub-total	13,84	64
Labour Cost		
Saddle bow assembling		
Wood work	4,06	19
Paddings assembling		
Cushion sewing (2)	0,33	2
Cushion stiching (2)	1,00	5
Abdominal strap assembling		
Nylon strip sewing	0,43	2
Needle works (3)	0,15	1
Rings making (iron bowing and soldering)	0,33	1
Foreward and backward straps assembling		
Nylon strip sewing	0,30	1
Needle works (6)	0,30	1
Small cushion making (2)	0,08	0
Small cushion stiching (2)	0,33	2
Hatter assembling		
Nylon strip sewing	0,19	1
Needle works (8)	0,40	2
Sub-total	7,91	36
Grand Total	21,75	100

that they would prefer to work with the *IRAD W* because they found it easier to load, with a bigger loading capacity, it allows the transportation of any kind of goods and its paddings protect well the donkey's body. No particular preferency appeared between the red rafter and the eucalyptus options. But the woodmaker prefers to work on rafters much more gauged rather than on eucalyptus blockheads which have unsteady diameter on their length. In fact the red rafter saddles have a better finish and are more built because of better given shapes and a more adjusted saddle bow assembly.

Discussion and Conclusion

With reference to this study's specifications, it can be ascertained that the two models could locally be manufactured with materials available in North Cameroon's markets. Their cost prices ranging from 17 USD to 34 USD were adjudged a little too high by the farmers and have to be if possible reduced to 25 and 29 USD for the *IRAD W* model; to 17 and 19 USD for the *IRAD X* model. The two models can be harnessed on any adult donkey of the region. The tripple strapping system (abdominal, backwards and forewards straps) allows a secure set of the saddle on the donkey's back on slopes. In mountainous areas, the *IRAD W* model's spread can cause some problems when skirting obstacles. The two models can carry any goods not exceeding 80 kg (saddles included) but robustness trials have shown that punctually and for a short distance, the total load can go over 80 kg.

Some farmers' advice and suggestions have been taken into consideration in the final manufacturing schemes. The size of the *IRAD W*'s cushion has been lightly enlarged so that when the saddle bow slips, it can not stay on the donkey's rachis. To reinforce the strength of the saddles the lateral small planks will be fixed by bolting rather than nailing in the former specimens.

In the present experience, many farmers said they have discovered a new possible utilisation of their donkey in the dry season as well for domestical purpose (water and firewood carrying) or for production activities (straw, cereals and manure transportation). They were very satisfied and wished to get the equipment without delay. Some of them postulated for a training in manufacturing the saddles.

The farmers preference for the *IRAD W* model is due, according to them, to its better handling, its comfortable use, its multi-purposeness and its bigger loading capacity. The latter remark suggests that for the farmers, loading capacity depends more on the saddles than on the donkey itself. Efforts must be done to sensitize farmers more about such misunderstandings.

Subsequently, it appears to us very important to pursue the popularization of this equipment. Efforts must be focussed on the *IRAD W* model (punctually on the *IRAD X* model in mountainous zones). Wiles are to be found to reduce the cost prices of these equipment. Farmers sensitization has also to be directed on feeding and supplementing donkeys during dry season because transport increases in large scales the expenses of animals (Lawrence and Stibbards, 1990; Dijkman, 1991). Yet, until now, donkeys are abandoned to themselves all along the dry season as their owners do not use them before the return of the rains. Therefore, topics of harvest residues storage and fodder issue must be associated with the use of packing saddles.

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New Co-operating Editor

Benedict Kayombo

Nationality: Tanzania
Birth Date: January 5, 1948
Qualifications:

B.Sc. degree in Agriculture, University of Dar es Salaam, Tanzania, 1974.

M.Sc. degree in Agricultural Engineering (Soil and Water Engineering),Silsoe, Cranfield University, United Kingdom, 1978.

Ph.D degree in Agricultural Engineering, Sokoine University of Agriculture, Morogoro, Tanzania, 1986.

Experience:

1998 - 2001 : Head of Department of Agricultural Engineering and Land Planning, Botswana College of Agriculture, University of Botswana, Gaborone, Botswana.

1997 to Date: Associate Professor of Soil and W ater Engineering,Department of Agricultural Engineering and Land Planning, Botswana College of Agriculture, University of Botswana, Gaborone, Botswana.

1993 - 1997: Associate Professor and Head, Department of Agricultural Engineering and Land Planning, Sokoine University of Agriculture, Morogoro, Tanzania.

1985 - 1993: Senior Lecturer, Department of Agricultural Engineering and Land Planning, Sokoine University of Agriculture, Morogoro, Tanzania.

1982 - 1984: Research Fellow, Resources Management Programme, International Institute of Tropical Agriculture OITA), Ibadan, Nigeria.

1980 - 1985: Lecturer, Department of Agricultural Engineering and Land Planning, University of Dar es Salaam, Morogoro, Tanzania.

1976 - 1980: Assistant Lecturer, Department of Agricultural Engineering and Land Planning, University of Dar es Salaam, Morogoro, Tanzania.

1974 - 1976: Tutorial Assistant, Department of Agricultural Engineering and Land Planning, University ofDar es Salaam, Morogoro, Tanzania.

Current Position:

Associate Professor of Soil and Water Engineering, Department of Agricultural Engineering and Land Planning, Botswana College of Agriculture, University of Botswana, Private Bag 0027, Gaborone, Botswana. Tel: 267-3650125, Fax: 267-328753, E-mail:bkayombo@bca.bw

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Combination Tillage Tool - I (Design and Development of a Combination Tillage Tool)

by

R. Kailappan
Professor and Head
College of Agricultural Engineering
Tamil Nadu Agricultural University
Coimbatore- 641 003
India

R. Manian
College of Agricultural Engineering
Tamil Nadu Agricultural University
Coimbatore- 641 003
India

G. Amuthan
College of Agricultural Engineering
Tamil Nadu Agricultural University
Coimbatore- 641 003
India

N. C. Vijayaraghavan
College of Agricultural Engineering
Tamil Nadu Agricultural University
Coimbatore- 641 003
India

G. Duraisamy
College of Agricultural Engineering
Tamil Nadu Agricultural University
Coimbatore- 641 003
India

Abstract

The design of the combination tillage tool was made taking into account the availability of power in the commercially available tractors, economy in energy spent, adverse field conditions and fabrication capability. The combination tillage tool concept has the salient features of combining sliding actions and rotary motions encountered in primary and secondary tillage operations. A prototype combination tillage tool weighing 405 kg was fabricated which is actuated through a universal joint coupled shaft keyed to the other end to the bevel gear transmission system. The performance of the combination tillage tool under field conditions will be reported subsequently.

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Introduction

Mould board ploughs and disc ploughs having specific design features are conventionally used as primary tillage implements while disc harrows and cultivators are used as secondary tillage implements. As the onset of the monsoon occurs the booming action of seed bed preparation within a stipulated time gives difficulties to farmers and resulted seed bed with clods. Recognising this need, a study for the design and development of a combination tillage tool was undertaken. The combination tillage tool concept has the salient features of combining the sliding actions and rotary motions encountered in primary and secondary tillage operations and designing a new implement to perform both operations simultaneously utilizing the traction power and rotary power available in the tractor wheels and PTO shaft, respectively, in a single pass on the field. If the cutting action of primary tillage operation and pulverizing action of secondary tillage operations are carried out simultaneously in a single pass at "friable soil moisture", a seed bed with "the best tilth" could be produced with minimum energy and less compaction on the sub-soil.

Review of Literature

According to Datt and Mishra (1981) 14 models of tractors are being manufactured in India, having a production capacity of around 150,000 units per annum. The horse power range of these tractors varies from 25 to 50. Most of tractors are of 35 horse power capacity.

Solness (1956) studied an implement to cut and pulverize soil to a pre-determined aggregate size and to deposit the soil in the same place in the continuous operation.

Goryachin (1940) presented an equation relating draft and speed of tillage implements as

$D = Do + EV^2$

Where EF^2 is a dynamic component of the relation.

According to Smith (1965) the unit draft varies with type of soil and he recorded a highest value of 1.05 kgf/cm^2 in soils having heavy clay content. The maximum draft requirement for disc harrowing is 150 kg/meter width (Agrl.Ers.Year book. 1968).

Assumptions

The assumptions made in the design of combination tillage tool are

(a)The maximum unit draft requirement is 1.05 kgf/cm^2 (Smith, 1965).

(b)Maximum power available in most of the commercially available Indian tractor is 35 hp.

(c)Speed of power take off shaft is 540 10 rpm.

(d)Average speed of operation of tractor in the field is 3 kmph.

(e)Coefficient of traction in unploughed soil is 0.85.

(f)The types of stresses encountered in soil-tool system are compression, shear, impact, abrasion and collision.

(g)Maximum draft required for disc harrowing is 150 kg/meter width (Agricultural Engineers Year Book, 1968).

Design of Components

The combination tillage tool consists of the following three major components: frame; cutting blades and rotating blades.

The frame is meant for holding different components of combination tillage tool. It is subjected to bending, tension and vibrations.

The primary tillage operation is achieved by a pair of cutting blades (**Fig. 1**) which penetrate into the soil, failure either in primary, secondary or multiplanes and then elevate, failured soil mass in an inclined plane. The crescent shaped cutting blade's edge has been sharpened for easy penetration and fixed at an angle of inclination of 24 deg to horizontal.

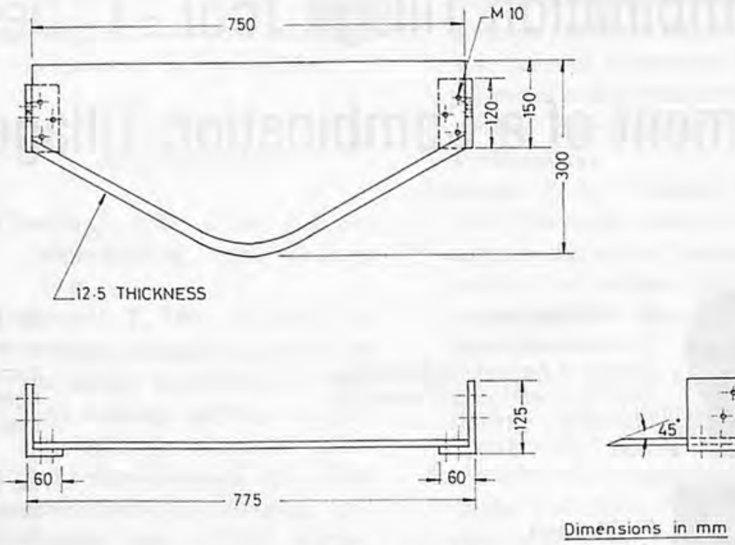

Fig. 1 Cutting blade.

Material= 35 Mn2 Mo 28 alloy steel

Shape = Crescent shape

Length = 750 mm

Maximum width at the centre = 300 mm

Width at the edge= 150 mm

Number of blades= 2

The secondary tillage operation is contemplated through rotating blades by impact, throw and collision operations. The rotating blade assembly (**Fig. 2**) consists of a hollow drum made of carbon steel sheet of 5 mm thick. The length and diameter of the drum are 750 mm and 300 mm, respectively. The drum is fitted to a central shaft and mounted on antifriction bearings horizontally on a suitable frame work. On the periphery of the drum, carbon steel blades of uniformly tapered edges are positioned projecting outwards in an inclined manner such that all the cutting blades are accommodated in 16 rows. The inclination of blades in adjacent rows are opposite in direction.

Blade width = 188 mm

Number of blades = 64

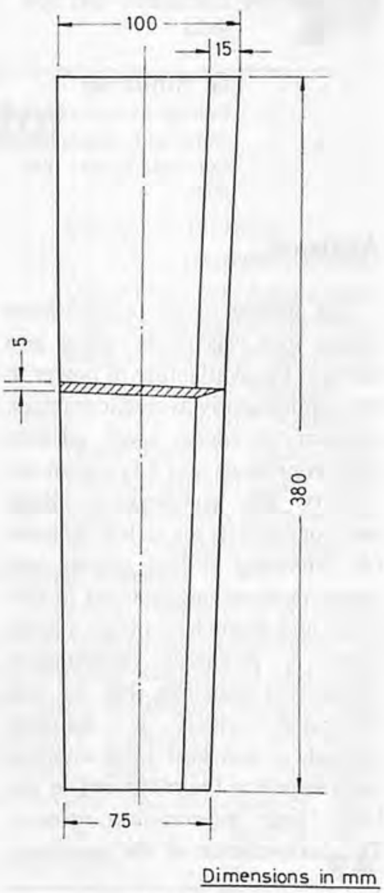

Fig. 2 Rotating blade.

Orientation = 60 deg to axis of the drum

Method of fastening= welding

Mechanical strength of these components to be considered in order to ensure the rigidity of the unit. Hence, the design is divided into the following.

a) Assessment of power required for combination tillage tool
b) Design of cutting blades
c) Design of rotating blades
d) Design of power transmission system and
e) Design of other structural members

Assessment of Power Required

Force required to cut the 15 cm depth soil = $L \times d_1 \times S \times n_1$

$= 75 \times 15 \times 1.05 \times 2$

$= 1921.24$ kgf

Where

L - length of cut, cm
d - depth of cut, cm
S - unit draft required, kg/cm^2
n - number of blades

Horse power required to move the cutting blade at a speed of 3 kmph

= soil resistance × forward speed

$$= \frac{1921.24 \times 3000}{4500 \times 60}$$

$= 21.35$ hp

Rotating blades break the clods which are cut and elevated by the cutting blades. The draft required to break the clods is assumed as twice the force required as in the case of a disc harrow.

Hence, the horse power required for rotating blades at 3 kmph forward speed for pulverizing action

$$= \frac{2 \times 0.75 \times 150 \times 2 \times 3000}{3600 \times 75}$$

$= 5$ hp

∴ Total horse power required for both cutting and breaking the soil clods

$= 21.35 + 5 = 26.35$ hp

Horse power of the prime mover required to operate the implement in unploughed soil

$$= \frac{\text{Total power required}}{\text{Coefficient of friction}}$$

$$= \frac{26.35}{0.85}$$

$= 31$ hp

Hence, this implement can easily be hitched and operated by most of the Indian make tractors of 35 hp capacity (Datt and Misra, 1981).

Design of cutting blades

Maximum force acting on one cutting blade = 1921.24/2 = 960.62 kgf

The cutting blades are fixed to operate at 24 to horizontal to get the best cutting action.

Resolving this force, the normal force acting on the cutting blade on the cutting blade

$$= \frac{960.62}{\cos(90 - 24)}$$

$= 2362.5$ kgf

Assuming trapezoidal soil mass over the blade, the weight of soil standing over the cutting blade vertically, while penetrating full depth

= **Equation 1**.

Resolving this vertical force in a direction normal to the cutting blade, force acting normal to the cutting blade

$= 32.928 / \cos 24$

$= 36.04$ kgf

∴ Total force acting normal to the blade

$= 2362.5 + 36.04$

$= 2398.54$ kgf

Incorporating the correction for speed (Goryachkin, 1940)

The draft at 3 kmph = 2411.4 kgf

Maximum bending moment

$= WL / 24$

$= 2411.4 \times 75 / 24$

$= 7535.6$ kgf.cm

Bending stress, σ_b

$= M_b xy / I$

(Selecting 35 Mn2 Mo 28 hardened and tempered steel for cutting blade, $\sigma_b = 3350$ kgf/cm^2)

$$\therefore 3350 = \frac{7535.6 \times t \times 12 \times 2}{2 \times 30 \times t^3}$$

$\therefore t = 9.5$ mm

Select a 10 mm thick 35 Mn2 Mo 28 hardened and tempered steel for making cutting blade

Design of Rotating Blades

Total area of one blade striking soil

= Inclined length × thickness

$= 17.32 \times 0.5 = 8.66$ cm^2

The maximum soil resistance

$= 8.66 \times 1.05$

$= 9.1$ kgf

Maximum bending moment in the blade, M_b

= Soil resistance × radial distance

$= 9.1 \times 25.5$

$= 232.05$ kgf - cm

$\sigma_b = M_b \times y / I$

$$700 = \frac{232.05 \times 12 \times w \times 2}{2 \times 0.5 \times w^3}$$

$w = 2.83$ cm $= 28.2$ mm

Select a top width of blade

	=	75 mm
Bottom width =		100 mm
Height	=	380 mm

(Soleness, 1956)

Design of Frame

It includes the design of main members, connecting members and attachments for three-point linkage. The forces acting on different members were studied and accordingly the size and material were chosen.

(a) Main member

Force = 1922 kgf

Bending stress = 377 kgf

(b) Connecting member of rotating drum

Maximum bending moment

= 47.116 kgf.cm

(c) Three-point linkage

Force on one lower pin

= 961 kgf

Shear stress = 312 kgf/cm^2

Lower link block edge clearance

= 20 mm

$$\frac{[(1/2 \times 12.2 \times \cos 24 \times 30) + (2.8 \times \cos 24 \times 30)] \times 75 \times 1.8}{1000}$$

$= 32.928$ kgf

Equation 1.

Design of Power Transmission System

Axial load of the gear

$$= \frac{2 \times \tan 20 \times \sin 45 \times M_t}{d_{av}}$$

= 248.8 kgf

(M_t- maximum torque available at pto shaft = 46.42 kgf m

d_{av} - diameter at the centre of the bevel gear = 96 mm)

∴ diameter of the shaft required to transmit power,

$$d^3 = \frac{16 \times 10^3}{\Pi \times \tau} \sqrt{((\alpha wt)/8)^2 + (K_t M_t)^2}$$

∴ d = 29.9 mm

≅30 mm

Compressive strength σ_c=

$$\frac{0.72}{(R-0.56)} \sqrt{\frac{[(i^2 \pm 1)^3]^{1/2} E(M_t)}{ib}}$$

i - transmission ratio = 1

Mt - stress concentration factor × 46.42 = 1.5 × 46.42 kgf - cm

b - face width = 27 mm

Number of teeth = 20

∴ σ_c = 12, 789 kgf/cm^2

Bending strength,

$$\sigma_b = \frac{0.7R\sqrt{(i^2+1)M_t}}{(R-0.56)^2 b Y_n M_n}$$

= 1,242.702 kgf/cm^2

Hence C 45 steel surface hardened and tempered to hardness of HRC 55 was selected for gear material.

Incorporating all the components a prototype combination tillage tool (**Fig.3**) weighing 405kg was fabricated. The performance evaluation of the machine on the fields will be reported subsequently.

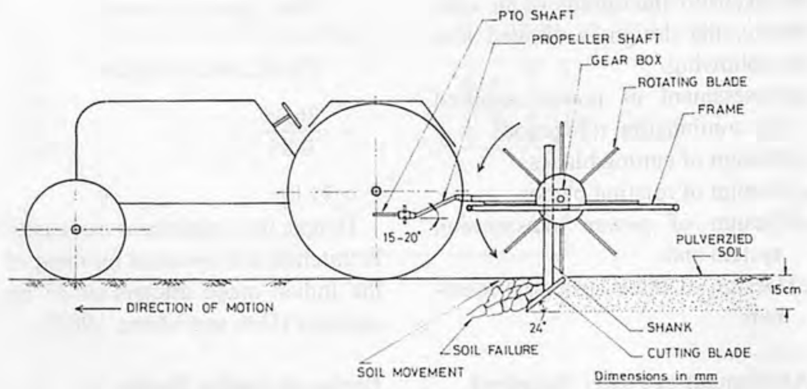

Fig. 3 Schematic diagram of combination tillage tool in operation.

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Effect of Inflation Pressure and Ballasting on the Tractive Performance of a Tractor

by

S. Kumar Lohan
Post Graduate Student
Department of Farm Power & Machinery
Choudhary Charan Singh Haryana
Agriculural University,
Hisar - 125004
India

S. Aggarwal
Professor
Department of Farm Power & Machinery
Choudhary Charan Singh Haryana
Agriculural University,
Hisar - 125004
India

Abstract

The tractive performance of a tractor was measured in ploughed and unploughed soil with different values of ballasting and inflation pressure. The results reveal that as the drawbar load is increased the value of wheel slip increases at all inflation pressures and ballasting conditions both in ploughed and unploughed soil. The results show that in ploughed and unploughed soils the net value of tractive efficiency goes on decreasing as the inflation pressure is increased from 78.5 KPa to 147.1 KPa.

Introduction

The demand placed upon agricultural traction tyres have increased greatly as the tractor power, weight and work rate have risen. The farmer is seeking an increased traction efficiency which is results from the high level of contact pressure and less wheel slip. To optimize the out-put of the tractor performing a draft operation in any soil condition there has to be proper matching of tractor power, weight on traction tyres, tyre design, speed and draft force during operation.

Studies conducted by Zoz (1972) indicate that optimum ballast has to be a function of soil type, tractor power and wheel speed. For high tractive efficiency, the ballast should be increased if the drawbar pull is increased, or wheel speed is decreased.

Gee Clough et al. (1978) used the results from field tests to derive empirical equations from which the tractive performance of tyres in off road conditions can be predicted. The equations were used to predict the field performance of a two wheel drive tractor when ploughing and good agreement was found between measured and predicted results. Using the solution to equations, Gee Clough (1980) drew the curves of the axle load per unit of available power at the axle to ensure operation at maximum efficiency at any forward speed.

Burt and Bailey (1982) reported that the net traction from a single tyre was held constant and combinations of dynamic load and inflation pressure were selected which caused a decrease in travel reduction and an increase in tractive efficiency.

Methodology

Field experiments were conducted to evaluate the tractive performance at different levels of inflation pressure and ballasting conditions in ploughed and unploughed soils at the research area of College of Agricultural Engineering and Technology, CCSHAU, Hisar.

The tractor used to perform the operation was Ford-3600 with average mass of 1850 kg and tyre size of 13.6-28. Three levels of inflation pressure, i.e., 78.5KPa, 112.8 KPa and 147.1 KPa were selected for the study. Similarly, three levels of ballasting conditions were achieved by adding cast iron weights to the rear tyres, i.e., 0 kg, 75 kg and 110 kg per tyres. Four levels of drawbar load on tractor were chosen, i.e., 0 KN, 7.5 KN, 17.5 KN and 27.5 KN. Two types of soil conditions were used, i.e., ploughed and unploughed. **Table 1** shows the different soil parameters observed during the study.

The dependent parameters measured during the experiment were wheel slip, deflection, load on rear tyres and tractive efficiency.

Table 1. Observation of Soil Parameters

	Soil condition-I (ploughed)	Soil condition-II (unploughed)
M.C.	6.60	5.85
B.D.	1.20	1.28
CI	886	1016

M.C. = Moisture Content (%).
B.D. = Bulk Density (g/cm^3).
C.I. = Cone Index Value (Kpa).

Results and Discussion

To compare the tractive performance, namely; drawbar load versus slip, drawbar load versus tractive efficiency at different inflation pressures and ballasting on the rear tyres of the tractor tested were plotted.

Relationship Between Drawbar Load and Wheel Slip.

Fig. 1 shows the maximum slip of 11.64% that occurred at 27.5 KN drawbar load on tractor with 110 kg ballast per tyre. The slip was increased with an increase in drawbar load on tractor at the same inflation pressure and same ballasting conditions.

Fig. 2 shows that the wheel slip increased with an increase in the drawbar load at constant ballast condition. The wheel slip increased with an increase in the ballast condition from 0 kg to 75kg. However, the slip was decreased when the ballast was further increased from 75kg to 110kg.

Fig. 3 presents the wheel slip for each of ballasting condition and drawbar load on tractor at an inflation pressure of 147.1 KPa in ploughed soil. The results reveal that an increase in drawbar load caused an increase in the wheel slip at the same level of ballast condition. Increasing the ballast condition from 0 kg to 75kg slip was increased but decreased at ballast of 110 kg. As shown in **Fig.4** the wheel slip is increased with an increase in drawbar load. The slip increased when the ballast was increased form 0 kg to 75 kg and then decreased at further increase in ballast conditions from 75 kg to 110 kg.

As shown in **Fig. 5** at drawbar load of 0 KN the slip is increased with an increase in ballast from 0 to 75 kg and further decreased with ballast of 110 kg. For the drawbar load of 7.5 KN the slip was slightly increasing with an increase in the ballast condition. At the drawbar level of 17.5 KN and 27.5 KN slip once increased and then decreased with an increase in the ballast condition. **Fig. 6** shows the wheel slip for each ballast and drawbar load on tractor and an inflation pressure of 147.1 KPa on unploughed soil. The wheel slip increased with an increase in drawbar load at constant ballast condition.

It is clear from the graphs that as the drawbar load is increased the value of wheel slip increased at all inflation pressures and ballasting conditions. In such cases, as the inflation pressure was increased there has been nominal decline in the wheel slip. This may be due to the better contact with the soil because of the increased weight on the rear ty-

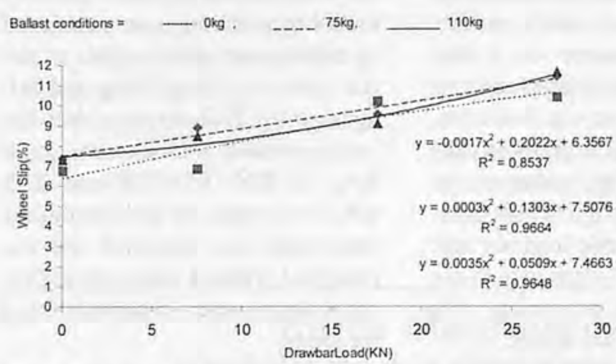

Fig. 1 Relationship between drawbar load and wheel slip at varying ballast conditions with 78.5KPa inflation pressure in soil condition -I (ploughed surface).

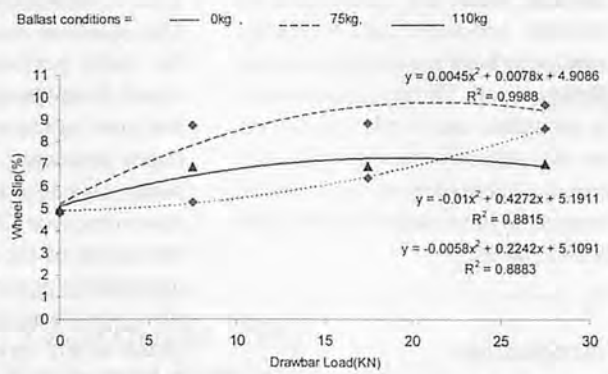

Fig. 2 Relationship between drawbar load and wheel slip at varying ballast conditions with 112.8KPa inflation pressure in soil condition -I (ploughed surface).

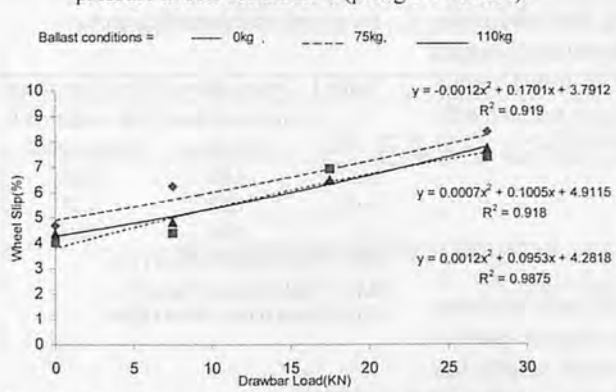

Fig. 3 relationship between drawbar load and wheel slip at varying ballast conditions with 147.1 KPa inflation pressure in soil condition -I (ploughed surface).

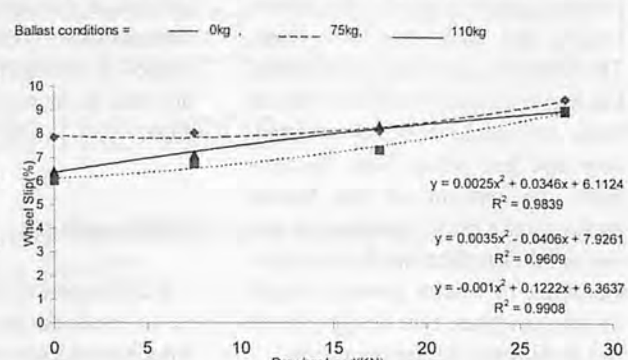

Fig. 4 Relationship between drawbar load and wheel slip at varying ballast conditions with 78.5KPa inflation pressure in soil condition -II (unploughed surface).

res.

Statistical analysis was carried out to determine the effect of inflation pressure, ballasting and drawbar load on wheel slip for each type of soil conditions. The statistical analysis shows that the factors drawbar load, ballasting and inflation pressure on wheel slip for ploughed and unploughed soils differs significantly at 1% level.

Relationship Between Drawbar Load and Tractive Efficiency

Fig. 7 shows that as the drawbar load is increased the tractive efficiency starts decreasing in all the ballast conditions. The tractive efficiency increased with an increase in the ballast conditions from 0 to 75 kg. However, when the ballast condition is increased from 75 kg to 110 kg the tractive efficiency decreased. The maximum tractive efficiency of 75.51% was noted at drawbar load '0' KN and ballast condition of 75 kg. The minimum tractive efficiency was noted at a drawbar load of 27.5 KN and ballast condition of 0 kg.

Fig. 8 shows the effect of drawbar load on tractive efficiency at varying ballasting conditions with 112.8 KPa inflation pressure on ploughed soil. The results show that by increasing the drawbar load the tractive efficiency starts to increasing slightly and then goes on decreasing. The tractive efficiency increased with an increase in ballast condition from 0 kg to 75 kg at drawbar load of 0 KN. When the ballast was further increased from 75kg to 110kg the tractive efficiency decreased.

From **Fig. 9** the results reveal that the tractive efficiency decreased with an increase in the drawbar load. At a constant drawbar load of 0 KN the tractive efficiency decreased with increasing the ballast condition from 0 kg to 75 kg. However, an increase in tractive efficiency was found on further increase in ballast from 75 kg to 110 kg. The decrease in tractive efficiency with an increase in drawbar load was maximum in the ballast condition of 0 kg than the other conditions. This was because of the maximum slip at maximum inflation pressure.

It was clear from **Fig. 10** that the tractive efficiency gradually decreased with an increase in the drawbar load. The maximum tractive efficiency was at ballast of 0 kg, as increasing the ballast conditions from 0 kg to 110 kg, the tractive efficiency decreased at drawbar load of 0 KN and at drawbar load of 27.5 KN. The tractive

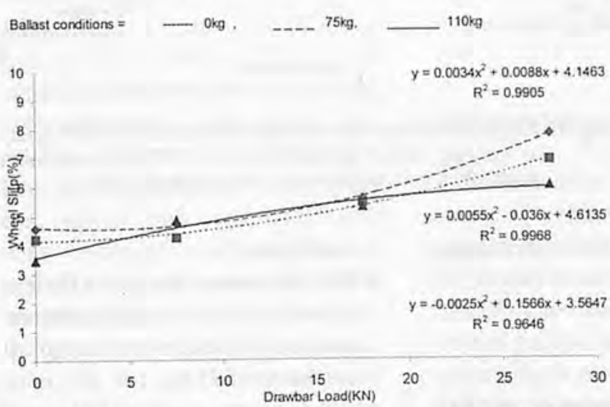

Fig. 5 Relationship between drawbar load and wheel slip at varying ballast conditions with 112.8KPa inflation pressure in soil condition -II (unploughed surface).

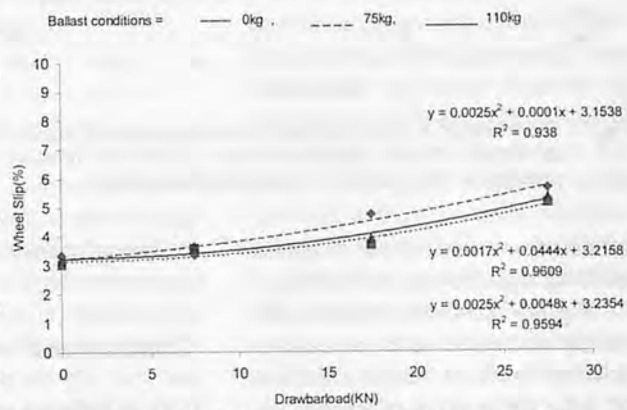

Fig. 6 Relationship between drawbar load and wheel slip at varying ballast conditions with 147.1KPa inflation pressure in soil condition -II (unploughed surface).

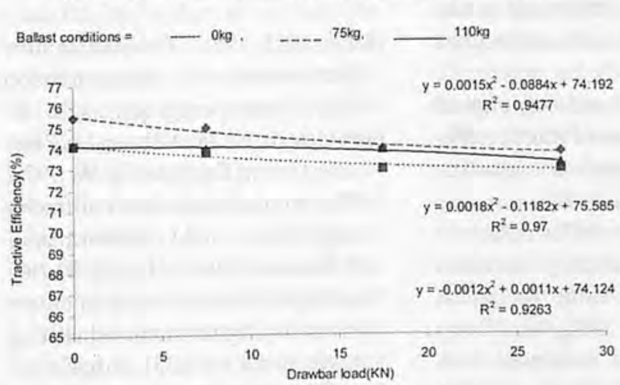

Fig. 7 Relationship between drawbar load and tractive efficiency at varying ballast conditions with 78.5KPa inflation pressure in soil condition -I (ploughed surface).

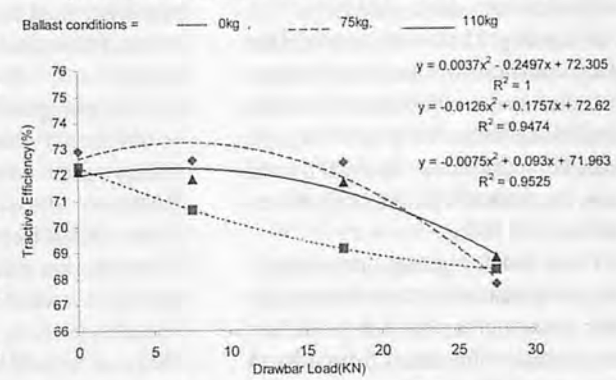

Fig. 8 Relationship between drawbar load and tractive efficiency at varying ballast conditions with 112.8KPa inflation pressure in soil condition -I (ploughed surface).

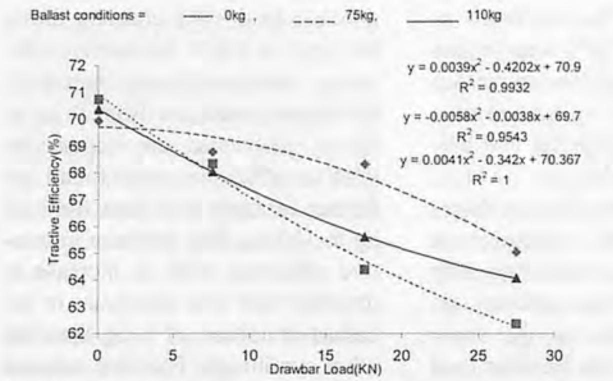

Fig. 9 Relationship between drawbar load and tractive efficiency at varying ballast conditions with 147.1KPa inflation pressure in soil condition -I (ploughed surface).

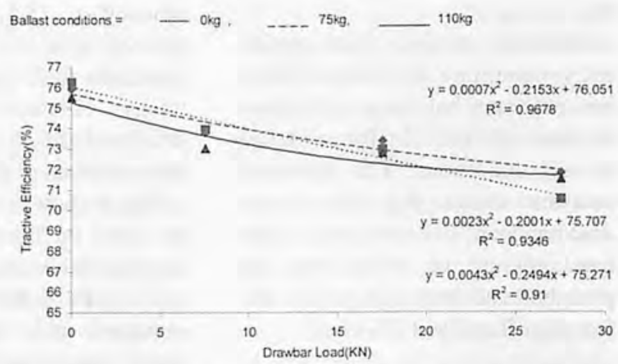

Fig. 10 Relationship between drawbar load and tractive efficiency at varying ballast conditions with 78.5KPa inflation pressure in soil condition -II (unploughed surface).

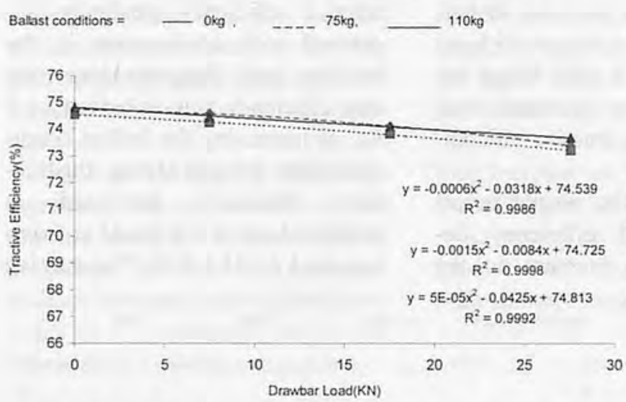

Fig. 11 Relationship between drawbar load and tractive efficiency at varying ballast conditions with 112.8KPa inflation pressure in soil condition -II (unploughed surface).

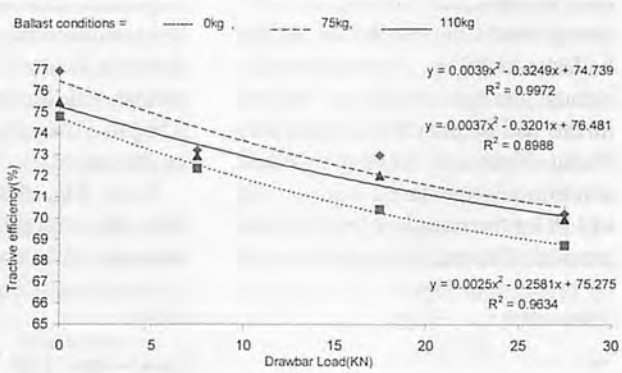

Fig. 12 Relationship between drawbar load and tractive efficiency at varying ballast conditions with 147.1KPa inflation pressure in soil condition -II (unploughed surface).

efficiency was maximum at ballast of 75 kg than the 0 kg and 110 kg.

Fig. 11 shows the tractive efficiency decreased with increase in drawbar load. At ballast condition of 0 kg the tractive efficiency decreased and with an increase in ballast from 0 kg to 110 kg the tractive efficiency increased gradually.

From **Fig. 12** the results reveal the tractive efficiency decreased with an increase in drawbar load. At ballast conditions from 0 kg to 75 kg the tractive efficiency increased and then decreased with the ballast conditions of 110 kg.

From the foregoing discussion it may be pointed out that the tractive efficiency increases when the ballast conditions is increased from 0 kg to 75 kg in all the situations. However, when the ballast conditions increased from 75 kg to 110 kg, the tractive efficiency starts decreasing.

Conclusions

1. At all inflation pressures and ballasting conditions the wheel slip increased with an increase in drawbar load for both soil conditions (ploughed and unploughed soils).
2. In the ploughed and unploughed soils the net value of tractive efficiency goes on decreasing as the inflation pressure is increased from 78.5 KPa to 147.1 KPa.
3. The tractive efficiency increased up to a certain value of ballast conditions (i.e., 0 kg to 75 kg) beyond which it decreased with an increase in ballast condition (i.e., 75 kg to 110 kg) in ploughed and unploughed soil conditions.
4. The maximum tractive efficiency was observed at inflation pressure of 78.5 KPa and a ballast condition of 75 kg.

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Surface Runoff Simulation in Areas Under Conventional Tillage and No-till

by

F. F. Pruski
Professor
Agricultural Engineering Dept.,
Federal University of Viçosa
Fellow of CNPq
36.571-000, Viçosa – MG, Brazil
Tel.: 55-31-8991912
Fax: 55-31-8992735
E-mail:ffpruski@mail.ufv.br.

J. M. A. Silva
M.S. in Agricultural Engineering
Researcher, Water Resources Research Group
Agricultural Engineering Dept.,
Federal University of Viçosa

D. D. Silva
Professor
Agricultural Engineering Dept.,
Federal University of Vicosa
Fellow of CNPq

L. N. Rodrigues
D.S. in Agricultural Engineering
Researcher, Water Resources Research Group
Agricultural Engineering Dept.,
Federal University of Viçosa

Abstract

Soil degradation limits a sustainable agriculture and affects the quality of farmer's life. The problem is more serious in sloping areas, regions with high rainfall and soils with high erodibility. No-till system is an alternative to reduce soil and water loss. The effects of the conventional and no-till systems on the maximum overland flow and surface runoff volume were simulated in the present paper using a model developed to estimate the hydrogram of surface runoff in areas under agricultural conditions. The comparative analysis of the results obtained by two soil tillage systems under the analyzed conditions led to the conclusions that the maximum overland flow obtained for no-till system was 32.6 to 75.5% lower than that obtained for conventional tillage; no-till delayed both the starting time and the peak time of surface runoff; and the surface runoff volumes under no-till were 32.5 to 51.3% less than those found for conventional tillage.

Introduction

Water erosion involves the processes of extraction, transport and deposit of soil particles caused by the impact of rain drops and surface runoff. The intensity depends on several factors such as the precipitation which falls on the soil, soil resistance, water capacity to infiltrate in the soil, soil protection degree against rain action, roughness and slope of the land, slope length and soil use and management. Therefore, a suitable model for the erosive process must take into account the influence of these factors.

Besides soil particles in suspension, surface runoff transports chemical nutrients, organic matter, seeds and agricultural chemicals that cause direct losses to agricultural production as well as pollution of rivers. Thus, the losses through erosion tend to increase production costs and the use of fertilizers as well as to reduce the performance of agricultural machines. Erosion also affects the quality and availability of water, because of pollution and sedimentation in rivers, which favors flooding in the rainy season and increases water shortage in the dry season. The erosive process also causes problems in rivers and reservoirs, reducing the storage capacity, raising water treatment costs, causing imbalance in the dissolved oxygen in the water and increasing costs due to dredging.

Adequate soil management improves its physical characteristics and reduces the risk of erosion. Management practices favorable to erosion control are those that improve the capacity for water infiltration, reduce the destruction of aggregates and rain impact on the soil.

A dense cover on the soil surface ensures protection against rain action and reduces the tendency for erosion. Besides increasing the quantity of water intercepted, the vegetation cushions the impact energy of the raindrops, reducing the aggregate destruction, pore obstruction and surface sealing of the soil. The presence of plants on the soil surface also reduces the velocity of surface runoff due to increase the hydraulic roughness.

Large agricultural production losses caused by erosion and the need to implant soil tillage and management practices which could guarantee environmental protection motivated Pruski et al. (1998) to develop a methodology to estimate the surface runoff hydrogram and determine the maximum overland flow and surface runoff volume for cropped areas. The model developed was used in this study to simulate the influence of conventional and no-till systems on maximum overland flow and surface runoff volume for different locations, slope lengths and slopes.

Materials and Methods

The assumptions made in the model developed by Pruski et al. (1998) to obtain the surface runoff hydrogram were:

a. Precipitation is uniform over the whole area analyzed;
b. At the moment of occurrence of the design rainfall, soil moisture is at field capacity and the infiltration rate close to the constant rate of infiltration after prolonged wetting of the soil (f_c); and
c. The evapotranspiration is zero during the design rainfall.

The initial abstractions (rainfall before surface runoff starts) depend upon the interception, depression storage and infiltration prior to surface runoff. The initial abstraction (Ia) value was calculated, in mm, by the Curve Number method, using the equation recommended by the Soil Conservation Service (SCS-USDA):

$$Ia = 50.8 \times \left(\frac{100}{CN} - 1\right) \qquad (1)$$

where, CN is the curve number, which defines the hydrological soil-vegetation complex, dimensionless.

To determine CN, the criteria of the Soil Conservation Service (SCS-USDA) were used. It was considered that when the rainfall occurs, the soil moisture, as defined by the curve number, was the maximum antecedent moisture condition (AMC III), i.e., the rainfall accumulated during five days prior to the design rainfall was equal to or higher than 52.5 mm.

The time corresponding to the initial abstractions (t_{Ia}) was obtained using the equation

$$\int_0^{t_{Ia}} i_i \, dt = Ia \qquad (2)$$

where, i_i is the instantaneous rainfall intensity, mm h^{-1}.

The instantaneous rainfall intensity was obtained from the equation,

$$i_i = i_m\left(1 - \frac{c\,t}{t+b}\right) \qquad (3)$$

where,

$$i_m = \frac{K\,T^a}{(t+b)^c} \qquad (4)$$

where,

i_m = average maximum rainfall intensity, mm h^{-1};
t = rainfall duration, min;
T = return period, years, and
K, a, b, c,= parameters for a given geographic location.

To obtain the surface runoff hydrogram on a hillslope (which was divided into r lines) it was considered that the overland flow increases up until the contribution from line 1 reaches the considered line. After this time the overland flow decreases with time.

The overland flow value is zero for all the cells until the time t_{Ia}. After this time, the overland flow value for each cell (i) was obtained by summing the overland flow produced in the specific cell and the overland flow produced by cells which contributed with overland flow to the considered cell using the equation

$$q_t[i, t + t_d] = q_t[i-1, t] + \frac{(i_i[i, t + t_d] - f_c)\,L\,c}{3.6 \times 10^6 r} \qquad (5)$$

where,

$q_t[i,t+t_d]$ = overland flow presented by cell i for a time equal to t + td, $m^3 s^{-1}$;
$t_d[i,t]$ = time that the overland flow that occurs in line i-1 in time t takes to reach the line i, min;
$q_t[i-1,t]$ = overland flow presented by cell i-1 for a time t, $m^3 s^{-1}$;
$i_i[i,t+t_d]$ = instantaneous rainfall intensity into line i for a time t + td, mm h^{-1};
f_c = constant rate of infiltration after prolonged wetting of the soil, mm h^{-1};
L = hillslope length, m;
r = number of lines; and
c = column width, m.

The time corresponding to the movement of water on the land surface was calculated using the Manning equation and $t_d[i,t]$ is given by equation,

$$t_d[i,t] = \frac{L\,n_t}{S_t^{1/2}\,y_t[i-1,t]^{2/3}\,60\,r} \qquad (6)$$

where,

n_t = Manning hydraulic roughness coefficient of the soil surface, s $m^{-1/3}$,
S_t = land slope, m m^{-1}; and
$y_t[i-1,t]$ = flow depth under overland flow conditions, for the i-1 line at the time t, m.

The $y_t[i-1,j]$ value was obtained by equation

$$y_t[i-1,t] = \left(\frac{q_t[i-1,t]\,n_t}{S_t^{1/2}}\right)^{3/5} \qquad (7)$$

Silva (1999) developed the "HIDROGRAMA 1.0" software to make the application of the methodology easy. The program allows to obtain the surface runoff hydrogram, the maximum overland flow value and the surface runoff volume. Volume and overland flow maximum behaviors were simulated using the HIDROGRAMA 1.0 software based on the following conditions: a) intensity-duration-frequency rainfall equations for four Brazilian areas: Uberaba (equation 8), determined by Pinto et al. (1996); Cascavel (equation 9), determined by Fendrich (1998); São Carlos (equation 10) and Cruz Alta (equation 11), determined by Denardin and Freitas (1982); b) velocity of infiltration values obtained by Sidiras and Roth (1984) for a Distrophic Dusky-Red Latosol, using a rainfall simulator and corresponding to 45 mm h^{-1} for conventional tillage and 58 mm h^{-1} for no-till; c) Manning hydraulic roughness coefficient of the soil surface proposed by Beasley and Huggins (1981), corresponding to 0.04 for conventional tillage and 0.12 for no-till; d) land slopes of 5 and 15%; and e) slope length of 30 and 150 meters. Simulation was made for both the conventional tillage (CT) and no-till (NT).

$$i_m = \frac{3000T^{0.206}}{(t+37.459)^{0.904}} \quad (8)$$

$$i_m = \frac{1062.92T^{0.141}}{(t+5)^{0.776}} \quad (9)$$

$$i_m = \frac{2081.48T^{0.21}}{(t+23)^{0.88}} \quad (10)$$

$$i_m = \frac{863.25T^{0.14}}{(t+3.6)^{0.70}} \quad (11)$$

A unitary column width, i.e., c = 1m was taken into account in the simulations. Thus, the overland flow obtained was based on meter of width.

Results and Discussion

Figure 1 shows the hydrograms obtained by using the HIDROGRAMA 1.0 software for conventional (CT) and no-till (NT) systems in Cruz Alta, for a 5% hillslope 30 meters long.

The hydrogram for CT had a bigger peak flow (1.77 L s^{-1} m^{-1}) than NT (0.84 L s^{-1} m^{-1}) which caused a reduction of 52.5% in the maximum overland flow. Peak flow time was longer in the area under NT (8.9 min) than in the area with CT (3.7 min), which may be explained by the greater surface roughness found in no-till areas, which reduces runoff velocity. The time to begin surface runoff was longer in the area under NT (1.1min) than in the area under CT (0.4 min). Surface runoff volume was 782 L in the area under CT and 519 L in the area under NT, i.e., there was a reduction of 33.6% in the surface runoff volume with the use of NT.

Figure 2 shows hydrograms for the conventional and no-till systems, for Cruz Alta, considering a slope of 15% and 150 m length. In this case, the hydrogram for CT had the highest value of overland flow, equal to 6.12 L s^{-1} m^{-1}, while for NT the highest value of overland flow was 2.06 L s^{-1} m^{-1}, i.e., 66.3% lower. Peak flow time was 17.9 min for NT and 7.1 min for CT under these conditions. The surface runoff volume was 3904 L in the area with CT and 2408 L in the area with NT, i.e., there was a 38.3% reduction in the volume with the use of no-till.

Table 1 shows the maximum overland flow and the volume of surface runoff for no-till and conventional systems, considering typical rainfall conditions in the four locations analyzed, 5 and 15% slope and 30 and 150 meters of slope length.

From the analysis of the results shown in **Table 1** it can be observed that the overland flow values obtained under NT were from 32.6% (Uberaba, slope length = 30 m and St = 15%) to 75.5% (Cascavel, slope length = 150 m and St = 5%) lower than those obtained with CT. There was a reduction varying from 32.5% (Cruz Alta, slope length = 30 m and St = 15%) to 51.3% (Cascavel, slope length = 150 m and St = 5%) for the surface runoff volume, showing that the use of NT caused more interference in the maximum overland flow than

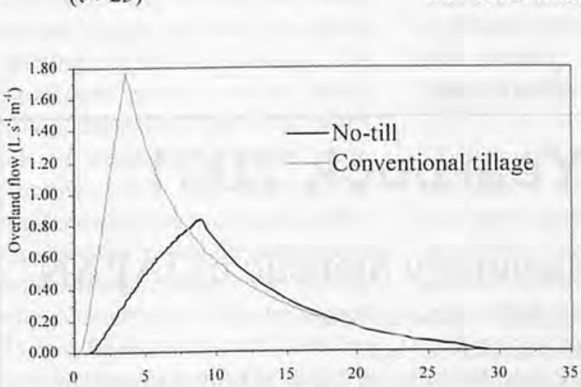

Fig. 1 Hydrograms for the conventional and no-till systems considering typical rainfall conditions in Cruz Alta, 5% and 30 m slope length.

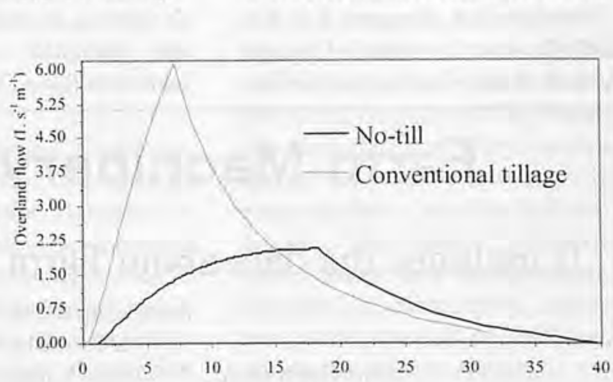

Fig. 2 Hydrograms for conventional and no-till systems under typical rainfall conditions in Cruz Alta, 15% and 150 m slope length.

Table 1. Maximum Overland Flow and Surface Runoff Volume Values for the Typical Rainfall Conditions of Four Locations under Conventional (CT) and No-till (NT) Systems, Two Hillslope Lengths and Two Land Slopes

Tillage system	Location	Overland flow ($L\ s^{-1}\ m^{-1}$)				Volume (L)			
		Length = 30 m		Length = 150 m		Length = 30 m		Length = 150 m	
		S_t = 5%	S_t = 15%	S_t = 5%	S_t = 15%	S_t = 5%	S_t = 15%	S_t = 5%	S_t = 15%
CT	Uberaba	0.90	0.95	3.45	3.89	924	925	4530	4583
	Cascavel	1.59	1.81	4.13	5.45	678	679	3307	3358
	São Carlos	1.02	1.09	3.56	4.19	795	796	3871	3926
	Cruz Alta	1.77	2.03	4.71	6.12	782	782	3890	3904
NT	Uberaba	0.57	0.64	1.33	1.93	575	583	2474	2669
	Cascavel	0.72	0.93	1.01	1.61	433	445	1611	1925
	São Carlos	0.60	0.70	1.10	1.76	495	504	2029	2237
	Cruz Alta	0.84	1.07	1.29	2.06	519	528	2196	2408

in the surface runoff volume.

Conclusions

The comparative analysis of the results obtained by the two tillage systems under the analyzed conditions allows the following conclusions:

1. The maximum overland flow obtained with no-till was 32.6 to 75.5% lower than those obtained with conventional tillage;
2. No-till delayed both the time to start and the time of peak of surface runoff; and
3. The surface runoff volumes in no-till were 32.5 to 51.3% lower than those found under conventional tillage.

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Effect of Tillage Practices on Hydraulic Conductivity, Cone Index, Bulk Density, Infiltration and Rice Yield during Rainy Season in Bangkok Clay Soil

by

M. H. Rahmati
Doctoral student
Agricultural, Aquatic Systems and
Engineering Program
Asian Institute of Technology
Bangkok,
Thailand


V. M. Salokhe
Professor
Agricultural, Aquatic Systems and
Engineering Program
Asian Institute of Technology
Bangkok,
Thailand

Abstract

The effect of different tillage practices on hydraulic conductivity, cone index, infiltration rate, bulk density and rice yield was investigated in Bangkok clay soil during the rainy season. The tillage treatments used were: plowing by moldboard plow, one-time rotary tilling, three -time harrowing, leveling by wooden leveler and followed by transplanting operations (T1), plowing by moldboard plow, three-time harrowing, leveling by wooden leveler and followed by transplanting (T2), plowing by moldboard plow, two-time rotary tilling, three-time harrowing, leveling by wooden leveler and transplanting (T3) and plowing by moldboard plow, two-time harrowing, leveling by wooden leveler and followed by seeding (T4). The results obtained show that treatments T1 and T3 increased rice yield due to reduction of cone index and bulk density in plow layer (0-15 cm). In addition, these treatments decreased hydraulic conductivity and infiltration rate over this depth. The means of hydraulic conductivity and infiltration rate in treatments T2 and T4 were higher than that in treatments T1 and T3, respectively, in plow layer. But treatments T2 and T4 produced lower rice yields than treatments T1 and T3. This study indicated that bulk density and cone index are the two main factors that affect the rice yield in Bangkok clay soil. Also it was revealed that hydraulic conductivity and infiltration rate (percolation rate) played less important role on rice yield during the rainy season.

Introduction

Rice (*Oryza sativa L.*) is the staple food of more than 60 percent of the world population (Jayadeva et al., 1996). Globally, the harvested area of rice can be ranked as second after wheat; but rice provides more calories per hectare than any other cereal crop. The total calorific output of all world food is 3,119 kcal/person per day at the farm gate, with rice accounting for 552 kcal/person per day, or 18% of the total (De Datta, 1981). The most common method of land preparation for wet land rice in South and Southeast Asia is puddling. This method helps weed control, ease of transplanting, water saving and reduction of leaching of plant nutrient (De Datta et al., 1988). On the other hand, puddling operation decreases percolation, but high reduction of percolation causes the increase of toxic organic compounds around roots and prevents root development. As a result, rice yield will be reduced (Yamazaki, 1992). Also, puddling compacts soil and increases soil penetration resistance (cone index) in subsoil. Soil compaction increases the bulk density of soil and reduces water losses. But, desirable growth and penetration of rice roots are encouraged by relatively lower levels of bulk density (Kar and Varade, 1972). The above details show the importance of hydraulic conductivity, infiltration, soil compaction and bulk density on rice growth and yield.

There are various tillage methods used to prepare land for rice cultivation. The effect of these tillage methods on hydraulic conductivity, infiltration rate, bulk density, cone index and rice yield are quite different. The use of suitable tillage practices in each region depend on different factors such as water availability, topography, climate, soil texture, type of rice culture, percolation, depth of water table, soil compaction, aggregation, etc. (De Datta et al., 1988). In order to choose the best tillage method for preparing paddy field in Bangkok clay soil it was necessary that these methods are tested in the field.

The literature reveal that not many researcher studied the effects of tillage practices on hydraulic conductivity, infiltration rate, cone index (soil compaction), bulk density and rice yield during the rainy season in Bangkok clay soil. In this research, the effect of different tillage practices on various parameters listed above was studied in Bangkok clay soil during the rainy season. Other objectives of this research were: determination of tillage treatments which give higher yields; to study the change in hydraulic conductivity; infiltration rate, cone index and bulk density in each tillage treatment, and study the effect of change in hydraulic conductivity, infiltration rate, cone index and bulk density on rice yield.

Literature Review

Sakanoue and Mizunuma (1962) reported that conventional puddling produced significantly higher rice yield than dry-tilled field. This higher yield was attributed to reduction of percolation rate and nitrogen leaching losses by conventional puddling. Koenigs (1967) related high yield of rice from puddled land to less competition from the weeds and the enhanced nutrient availability to rice plants by the increased surface area available for plant roots and by enhanced soil nutrients diffusion. Ghildyal and Naphade (1971) studied the effects of puddling on some physical properties of soil, such as apparent specific volume and hydraulic conductivity in laboratory experiments. They found that puddling significantly decreased hydraulic conductivity and apparent specific volume. This study also shows that the increased intensity of puddling decreased the value of hydraulic conductivity and apparent specific volume. However, in this study the effect of puddling on yield was not investigated.

Paliwal et al. (1974) found that transplanting of paddy seedlings under puddled condition produced high yield through increased number of tillers per hill, panicle length, number of grains per panicle, and grain weight. In Thailand, the effect of puddling on hydraulic conductivity was studied in two different soils, loam and silty clay (Rashid, 1967). Results showed a significant decrease in the hydraulic conductivity of the puddling layer (0-15 cm) and a marginal decrease in the second layer (15-45 cm) of both soils. De Datta and Sharma (1985) reported that puddling reduced bulk density in topsoil (0-15 cm). This reduction provided more desirable conditions for growing rice root and thus increased rice yield. Also, puddling reduced hydraulic conductivity at this depth.

The effect of four tillage treatments in four replications was tested in a Randomized Complete Block Design by De Datta et al. (1988). It was observed that puddling significantly reduced dry bulk density in 0 to 10 cm layer in both soils (clay and clay loam soil). In the clay loam soil, there was no a significant difference between the values of bulk density for minimum tillage and puddling treatments. But the bulk density in minimum tillage was significantly lower than that in zero tillage. In the clay soil, minimum and zero tillage had similar bulk density values. The results show that the soil penetration resistance in 0-15 cm soil depth was significantly low with minimum tillage and puddling than that with zero tillage. Similar effects, but only within the 10 cm depth, were observed for the clay loam soil. In the clay soil, the differences in rice yield between minimum tillage, shallow puddling and puddling were not statistically significant. In the clay loam soil, rice yield from plots with zero and minimum tillage showed similar trends. However, zero tillage produced significantly lower rice yield compared to puddling treatments. There was no significant difference between minimum tillage and puddling treatments in rice yield. The minimum tillage, therefore, had the advantage over puddling in maintaining the physical conditions of the soil and decreasing turn around time.

Materials and Methods

The study was conducted on the research farm of Asian Institute of Technology in Bangkok, Thailand, during the rainy season. The soil was characterized as clay. At 0-15 cm depth range, the soil contained 23% silt, 11% sand and 66% clay; 15-30 cm depth range contained 21% silt, 2% sand and 77% clay and at 30-50 cm depth range it contained 22% silt, 3% sand and 75% clay.

The details of tillage treatments used are given in **Table 1**. As it is

Table 1. Details of Tillage Treatments

Treatments	Details					
	Plow (MB)	Rotary tiller	Harrow	Leveler	Transplanting	Seeding
T1	1	1	3	1	1	-
T2	1	-	3	1	1	-
T3	1	2	3	1	1	-
T4	1	-	2	1	-	1

observed in this table, besides four tillage treatments two methods of rice culture (seeding and transplanting) were used in this research. The experimental design was Randomized Complete Block Design (RCBD) with four replications (4 treatments, 4 blocks and 16 plots). The plot size was 10 m × 22 m.

In order to measure soil penetration resistance (cone index) before and after tillage, five locations were chosen at random in each experimental plot. Then the values of cone index at these locations were measured by a cone penetrometer over 0 to 50 cm soil depth.

The values of saturated hydraulic conductivity and bulk density were measured twice, firstly, before performing the tillage practices in plots and secondly, 40 days after transplanting. To measure saturated hydraulic conductivity and bulk density, two locations were selected at random in each plot. Core samples at soil depths of 0-15, 15-30 and 30-40 cm were obtained by a core sampler. The hydraulic conductivity of these samples was measured by a falling head method in laboratory and the bulk density of samples was estimated by standard method.

The infiltration rate was measured twice, firstly, before the tillage in plots and secondly, 25 days after transplanting. To measure infiltration rates, two locations were chosen in each plot and measurements were done by using a double-ring infiltrometer.

All tillage treatments were performed two days before seeding and transplanting of paddy seedlings. Transplanting carried out by a paddy transplanter and seeding was done manually. Seven days after transplanting and seeding operations, ammonium phosphate fertilizer was applied in all plots. N-P-K and rate of this fertilizer were 16-20-0 and 4.5 kg/plot, respectively.

Another fertilizer that was applied in the experimental plots was nitrogen with ratio of N-P-K: 26-0-0 at a rate of 4 kg/plot. To control pest and snail that is the major problem in primary stage of seedlings growth, insecticide at a rate of 10 g/plot and copper sulfate at a rate of 260 g/plot were used. Before harvesting operation, the average number of panicles and tillers in each hill were determined and the average height of plant was measured as well in all plots.

After ripening, 20 m^2 area from each plot was selected at random to assess crop yield. The crop was harvested manually and threshed by using a mechanical thresher. The dry weight of straw (straw yield) was calculated by considering moisture content of the harvested samples in each plot.

To measure 100-grain weight, 20 samples were taken from the harvested samples (area of 20 m^2). The values of 100-grain weight that were measured in these 20 samples were used to calculate the average of 100-grain weight in each plot. The final harvesting operations were done by a rice combine harvester. The grain yield from each plot was weighed and at the same time its moisture contents was measured by a grain moisture tester and grain yield was calculated at 14% moisture basis.

All data were statistically analyzed by using analysis of variance (ANOVA) and the differences between the treatment means were compared by LSD test at 5% level of significance. The statistical software MSTAT was used to perform the analysis of variance and LSD test.

Results and Discussion

Tillage Effects on Cone Index

As it is shown in **Fig. 1**, conventional puddling + one time rotary tiller (T1) and conventional puddling + two times rotary tiller (T3) significantly decreased cone index compared to conventional puddling (T2) and conventional puddling + seeding (T4) at 0-15 cm soil depth. At this depth, treatments T3 and T4 indicated the lowest and highest cone index, respectively. At increased depth, cone index increased in all tillage treatments. Treatments T3 and T1 increased cone index higher than treatments T2 and T4 at 15-30 and 30-50 cm soil depths (**Fig. 1**). At these two depths, the highest and lowest cone indices were recorded by treatments T3 and T4, respectively. However, the statistical analysis did not confirm any significant difference between the means of treatments at these two depths. The maximum cone index in all tillage treatments was recorded at about 40 cm soil depth.

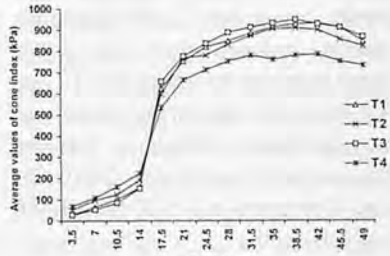

Fig. 1 Cone index vs. depth after tillage treatments.

A comparison of the cone index before and after treatment T1 shows that this treatment reduced cone index by 82.2% in plow layer (0-15 cm). But at higher depth, the treatment T1 did not change cone index considerably (**Fig. 2**). Cone index vs. depth, after and before treatment T2, indicated 75% decrease in cone index for 0-15 cm soil depth. But the treatment T2 was not effective in changing the cone index below this depth (subsoil). Also, treatment T3 reduced the mean of cone index by 82.6% in plow layer (**Fig. 2**). On the other hand, treatments T1 and T3 reduced the cone index more than treatments T2 and T4 in plow layer. In addition, treatment T3 increased the cone index slightly in depths of 15-30 and 30-50 cm. However, considerable difference was not found between the means of the cone index before and after treatment T3 at these depths.

The influence of treatment T4 on cone index in plow layer (surface soil) was almost similar to the other treatments (**Fig. 2**). However, it reduced the cone index in plow layer less than the other tillage treatments (66%). Also, this treatment did not affect the cone index at 15-30 and 30 -50 cm soil depths. After treatments T1, T2, T3 and T4, the values of cone index for 0-15 cm soil depth were 86, 120, 79 and 140 kPa, respectively. The statistical analysis indicated that there were significant differences between the cone index means of treatments T1 and T3 with T2 and T4. In other words, treatments T1 and T3 significantly reduced the cone index more than that by treatments T2 and T4 over this depth. But there was no significant difference between the means of cone index for all tillage treatments at 15-30 and 30-50 cm soil depths.

Tillage Effects on Bulk Density

The average bulk density for treatments T1, T2, T3 and T4 were 1.16, 1.20, 1.17 and 1.20 g/cm^3, respectively, at 0-15 cm soil depth. As observed at this depth range, the bulk density of plots with treatments T1 and T3 were lower than that of treatments T2 and T4 (**Fig. 3**). Over 15-30 cm soil depth, the bulk density of plot with treatment T3 was higher than that of plots with treatments T1, T2 and T4. The differences between the bulk density for all tillage treatments were negligible at 30- 40 cm soil depth.

Treatment T3 reduced the bulk density by 6% over 0-15 cm soil depth. However, the statistical analysis did not show any significant difference between the bulk density by tillage treatments at different soil depths.

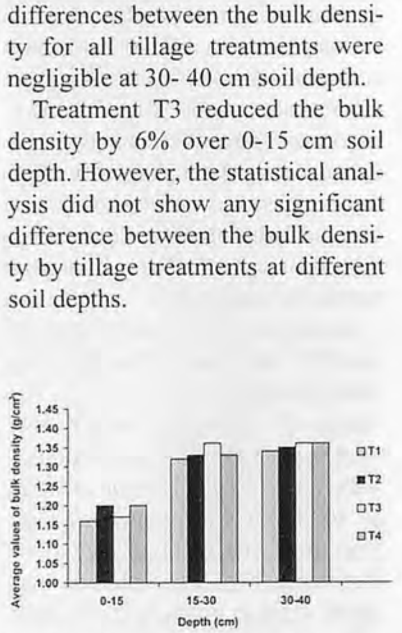

Fig. 3 Effect of tillage treatments on bulk density at different depths.

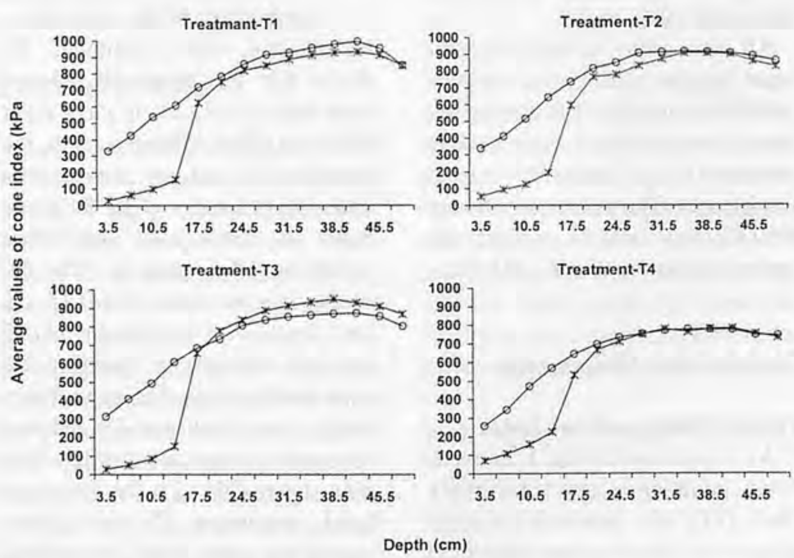

Fig. 2 Effect of tillage treatments on cone index; before tillage treatment:—o— , after tillage treatment:—*—

Tillage Effects on Hydraulic Conductivity

The average hydraulic conductivity values for different treatments and depths are presented in **Fig. 4**. For 0-15 cm soil depth, the hydraulic conductivity for treatments T1 and T3 was less than that of treatments T2 and T4. The lowest average hydraulic conductivity was obtained for treatment T3 (**Fig. 4**). The average hydraulic conductivity for all tillage treatments was almost the same at 15-30 and 30-40 cm soil depths. Treatments T1 and T3 reduced the hydraulic conductivity by 7.8% and 10% over 0-15 cm soil depth whereas treatments T2 and T4 reduced it only by 2.5% and 3%, respectively, at the same depth. Since for treatments T1 and T3, besides moldboard plow and harrow, rotary tiller was used for puddling. Therefore, treatments T1 and T3 destroyed soil aggregates and eliminated non-capillary pores more than by treatments T2 and T4. As a consequence, water passed through non-capillary pores slowly. At 0-15 cm soil depth range, the average hydraulic conductivity for treatments T1, T2, T3 and T4 were 3.91, 4.45, 3.71 and 4.38 mm/day, respectively. But the only significant difference was found between the means of hydraulic conductivity for treatment T3 and the other treatments. This treatment reduced hydraulic conductivity more than the other tillage treatments over 0-15 cm soil depth.

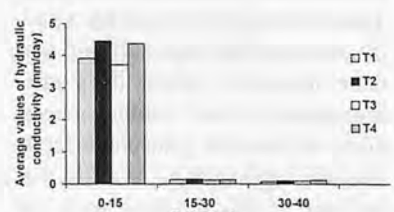

Fig. 4 Effect of tillage treatments on hydraulic conductivity at different soil depth.

Tillage Effects on Infiltration Rate

Another parameter that was measured before and after the performance of the tillage treatments was infiltration rate. The results of this measurement after tillage practices shows that all tillage treatments reduced the infiltration rate. But for treatments T1 and T3 the reduction was significantly higher than for treatments T2 and T4 (**Fig. 5**). The average infiltration rates after treatments T1, T2, T3 and T4 were 2.5, 3.25, 2.5 and 3.40 mm/day, respectively. The infiltration rates for treatments T1 and T3 were the same. Moreover, a significant difference in the infiltration rate was not observed between treatments T2 and T4. The infiltration rates measured before the treatments T1, T2, T3 and T4 were 3.10, 3.50, 3.20 and 3.60 mm/day, respectively (**Fig. 5**).

The comparison of infiltration rates before and the after-tillage practices indicates that treatments T1 and T3 reduced the infiltration rates by 19.5% and 22.5%. But, treatments T2 and T4 reduced it only by 7.1% and 6.1% (**Fig. 5**).

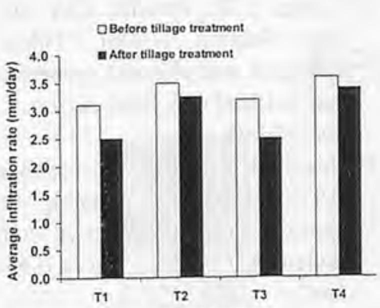

Fig. 5 Comparison of infiltration rates beforeandaftertillagetreatments.

Tillage Effects on Yield

The yield analysis indicates that treatments T1 and T3 produced a higher number of panicles and tillers than treatments T2 and T4 (**Table 2**). As a result, the rice yield of treatments T1 and T3 (4.27 and 4.03 t/ha) was found higher than that of treatments T2 and T4 (3.44 and 3.34 t/ha). A statistically significant difference in rice yield was not found for plots with treatments of T1 and T3. But, there was a statistical significant yield difference between treatment T1 compared to treatments T2 and T4. Treatment T1 produced higher rice yield than treatment T3. However, a significant difference in yield between treatments T1 and T3 was not observed. No significant difference in 100-grain weight was recorded among the means of treatments (**Table 2**). The number of grains per panicle in treatments T4 and T2 were higher than the other treatments not effective in increasing the rice yield because these treatments produced a number of panicles and tillers less than treatments T1 and T3. Also, a significant difference in the height of plants was not observed among treatments T1, T2 and T3. However, it was found that there was a significant difference between treatment T4 and the other treatments (**Table 2**). The lowest plant height was obtained for treatment T4 (105.3 cm). However, treatment T4 produced the maximum straw yield among all tillage treatments. The lowest straw yield was produced by treatment T2.

Discussion

Treatments T1 and T3 significantly reduced the hydraulic conductivity and infiltration rate higher than conventional puddling (T2) and conventional puddling + seeding (T4). Because in first two treatments puddling was performed by a rotary tiller. On the other hand, in treatments T1 and T3 puddling was done more intensively compared to treatments T2 and T4. So, treatments T1 and T3 destroyed soil aggregates and eliminated non-capillary pores more than in treatments T2 and T4. As a result, water passed through non-capillary pores slowly (Ghildal and Naphade, 1971; Wickham and Singh, 1978; De Datta et al., 1988).

Treatments T1 and T3 reduced the values of the cone index and bulk density considerably more than that by treatments T2 and T4 due to the use of a rotary tiller in these treatments. In other words, intensive puddling in treatments T1 and T3 reduced the bulk density and cone index in plow layer. Awadhwal and Singh (1992) indicated that the value of cone index in plow layer was reduced with increasing puddlings. De Datta et al. (1988) also found that in clay soil with increasing intensity of tillage the values of bulk density and cone index decreased in plow layer.

Studies on the role of percolation rates in lowland rice production resulted in diverse conclusions. Some results showed that percolation is needed to remove toxic substances beyond the root zone. In Malaysia, Sugimoto (1969) obtained higher rice with 10 mm/day hydraulic conductivity than no percolation. Ghildyal and Patel (1980) found

Table 2. Effects of Different Tillage Treatmentson Grain, Panicles and Yield in the Rainy Season

Treatments	Grains (no./panicle)	Panicles (no./hill)	Tillers (no./hill)	100-grain weight (g)	Grain yield (t/ha)	Plant height (cm)	Straw yield (t/ha)
T1	123.5 bc	22.8 a	25.8 a	2.55 a	4.27 a	112.0 ab	4.98 ab
T2	123.9 ab	16.3 ab	18.5 b	2.53 a	3.44 b	116.8 a	4.17 b
T3	122.1 c	22.8 a	26.3 a	2.53 a	4.03 ab	113.0 a	4.43 ab
T4	125.1 a	15.8 b	17.3 b	2.56 a	3.34 b	105.3 b	5.34 a

(Note: Any two means in the same column not sharing the same letter differ significantly at 5% level.)

the highest yield with 18 mm/day hydraulic conductivity compared with no percolation. However, in some other studies higher hydraulic conductivity (percolation) increased leaching losses of nutrients and reduced grain yields (De Datta and Karim, 1974; Shoji et al., 1974). Many researchers reported that the reduction in cone index and bulk density in topsoil increased root growth and yield. Gupta and Jaggi (1979) observed a decline in rice yield due to the higher cone index and bulk density of surface soil. Huang (1982) obtained a negative correlation between bulk density of surface soil and rice yield. On the other hand, decrease of the bulk density in topsoil resulted increase in rice yield. Also, in a green house experiment, reduction in the root length density from 0.3 to 0.1 cm/cm^3 when cone index in topsoil increased from 0.35 to 1.05 MPa was observed (De Datta and Sharma, 1985).

The effect of various tillage methods was investigated on soil and rice yield by De Datta et al. (1988). The results of this investigation indicates that intense puddling reduced bulk density and cone index in topsoil in comparison with the other tillage treatments thereby, it increased the root growth and rice yield. As observed, there are some contradictions in the results obtained by researchers as studies were done in different soils with different characteristics in depth of water table, rainfall, mineralogy, soil texture and aggregation, etc. (De Datta et al., 1988).

In this study, it was found that hydraulic conductivity and infiltration rate in treatments T2 and T4 (conventional puddling) were higher than in treatments T1 and T3 (conventional puddling + one or two times rotary tiller) in plow layer. But treatments T1 and T4 produced lower rice yield than treatments T1 and T3. In other words, the higher percolation in treatments T2 and T4 might not have reduced toxic compounds around rice roots. Also it could not create better conditions for desirable growth of the rice roots.

Treatments T1 and T3 reduced infiltration and hydraulic conductivity more than treatments T2 and T4 in plow layer. However, in spite of this high reduction, treatments T1 and T3 produced higher rice yield than treatments T2 and T4. The main reason for this increase in yield could not be due to a reduction in percolation rate and leaching of nutrients by treatments T1 and T3. Because the values of hydraulic conductivity and infiltration rate (percolation) are very low in Bangkok clay soil. So, leaching of soil nutrients is negligible and it could not be an effective factor in changing the rice yield.

The results obtained from this study indicates that reduction of bulk density and cone index in plow layer by treatments T1 and T3 provided fine soil and suitable conditions for growing the rice root. As a result, these treatments produced higher rice yield than treatments T2 and T4 (conventional puddling).

Conclusions

The results of this study indicates that treatments T1 and T3 (puddling by rotary tiller) reduced bulk density and cone index in topsoil and provided favorable soil conditions for root growth of rice. As a result, these treatments produced higher rice yield than the conventional puddling (T2) and conventional puddling + seeding (T4). Treatment T1 produced higher rice yield than treatment T3. However, statistical analysis did not show any significant difference in the rice yield for these two treatments during the rainy season. It was found that hydraulic conductivity and infiltration rate were not effective factors in changing the rice yield in Bangkok clay soil during the rainy season. Tillage treatments did not show significant effect on the hydraulic conductivity, cone index and bulk density in subsoil. In this study, two methods of seeding and transplanting were used in rice cultivation. The statistical results indicate that transplanting produced higher rice yield than seeding does.

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New Co-operating Editor

Suraweth Krishnasreni

Nationality: Thai
Birth Date: July 4, 1946
Qualifications:
B.S. Mechanical Engineering, Feati University, Philippines, 1971.
M.S.A. Agricultural Engineering (Meritus), Araneta University, Philippines 1973.

Experience:
1984-1992:Head of Agricultural Machinery Research Group Agricultural Engineering Division, Department of Agriculture.
1992-1996:Expert in Agricultural Engineering Agricultural Engineering Division, Department of Agriculture.
1997-2000:Director of Agricultural Engineering Division, Department of Agriculture.
2000-Present:Senior Expert in Agricultural Engineering, Department of Agriculture.

Current Position:
President of TSAE (Thai Society of Agricultural Engineering)
Senior Expert in Agricultural Engineering, Department of Agriculture, Chatuchak, Bangkok 10900, Thailand. Tel. 5792153, 5794497, 5798520 Ext. 124. Fax:9405791, E-mail:Suraweth@doa.go.th

Soil Compaction Potential of Tractors and Other Heavy Agricultural Machines Used in Chile*

by
Edmundo J. Hetz
Professor
Faculty of Agricultural Engineering
University of Concepcion
P O Box 537, Chillan, Chile.
E-mail:ehetz@udec.cl

Abstract

The objective of this research work was to estimate the potential to cause superficial and deep soil compaction of tractors, conventional and zero tillage grain drills, high volume foggers, grain harvesters, and transport wagons. A cadastre was carried out in order to establish the national offer of tractors and machines under study, collecting the specifications and data about makes, models, power, weights, ballast and tire dimensions. The largest weights acquired by the machines in the field, including tare, inputs, products harvested, ballast and operator(s) were used to calculate the pressures generated at the soil/tire interface and the weights carried by the axles; soil/tire contact areas were calculated using known equations.

The results show that almost all models of tractors and machines generate pressures above the limits recommended as maximum to avoid superficial soil compaction. There are models equipped with tires much larger (better) than other models of equal weight and/or power. A very high percentage of models carry on their heavier axle weights greater than the limits recommended as maximum to avoid cumulative deep soil compaction.

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Introduction

Modern agriculture would be unthinkable without the utilization of tractors and machines; the farmers use them, essentially, to increase their work capacity and the productivity of the land and labor. However, their power and weight have increased considerably in the last 20 years; in 1975 two wheel drive (2WD) tractors weighed about 45 kN (4,587 kg), in 1995 front wheel assist (FWA) tractors weighed some 70 kN (7,136 kg), and now large four wheel drive tractors are weighing 200 kN (20,387 kg) and more (Renius, 1999; Witney, 1995; Sanchez-Giron, 1996). This weight increment, quite larger than the increment in tire sizes, is causing severe soil compaction and degradation problems, with worrying economic consequences in several countries with intensive agriculture (Schaefer et, 1992; Wood et al, 1993; Renius, 1999; Smith Dickson, 1990; Botta et al, 1998; Sanchez-Giron, 1996; Voorhees, 1991; Oskoui and Voorhees, 1991).

Soil compaction is, basically, a cumulative process of increment in the bulk density due to a reduction in macroporosity which causes negative effects upon root development, decreased biological activity and insufficient supply of oxygen due to bad soil ventilation; the infiltration decreases and the fields suffer erosion or remain flooded for long periods (Taylor and Gill, 1984; Wood et al, 1993; Sanchez-Giron, 1996; Jorajuria et al, 1997; Froelich and Ellwein, 1990; Schaefer et al, 1992).

A distinction should be made between superficial and subsuperficial or deep soil compaction. The first one occurs in the top 30 cm of the soil profile and is produced by the pressures generated at the soil/tire interface. Some authors (Taylor and Gill, 1984; Sanchez-Giron, 1996; Smith and Dickson, 1990) limit these pressures to 100 kPa for conditions and soils easily compactible and to 200 kPa for soils more resistant to compaction; this kind of compaction can be eliminated through the yearly primary tillage.

Subsuperficial compaction occurs deeper than the first 30 cm of the soil profile; it is cumulative and is the product of the weight that the tractors and machines carry on their axles. Botta et al (1998), Voorhees (1986; 1991) and Sanchez-Giron (1996; Smith and Dickson, 1990) have proposed to limit these weights to 25 kN and 35 kN per axle for soils that are susceptible and resistant to compaction, respectively. The elimination of subsuperficial soil compaction requires deep subsoiling which can be a very slow and expensive operation.

Given the intensive use of tractors and machines in Chilean agriculture the objective of this research work was to establish the potential to cause superficial and deep soil compaction of tractors, conventional and no-till seeders, high volume foggers, grain harvesters and transport wagons.

Methodology

The work was carried out between October 1997 and March 1999 in the Department of Mechanization and Energy of the Faculty of Agricultural Engineering of the University of Concepcion, Chillan, Chile.

A national cadastre was carried out in order to establish the offer of agricultural tractors, conventional and zero tillage grain seeders, high volume foggers (>1000 L), self-propelled grain harvesters, and transport wagons. From the manufacturer's literature data was obtained relating to makes, models, power, weight and its distribution by axle, ballast and tire sizes. The largest weights acquired by the machines in the field, including tare, full deposits with inputs or produce harvested, ballast for heavy draft operations and 70 kg operator (s) were used, obtaining in this way the most adverse condition in relation to soil compaction. In the case of tractors, weight addition and transfer by the implements (plows) was accounted for in the following way: the weight distribution of two wheel drive (2WD) upon the front and rear axle was 20% and 100% of static weight; in front wheel assist tractors (FWA) the distribution was 30% and 70% of static weight, augmented in 20%, in the front and rear axle, respectively (Balbuena and Mendivil, 1996; Witney, 1995; Renius, 1999).

The weight distribution in the front and rear axle of the machines was the following: 10% and 90% in foggers and seeders (the front axle here being the tractor drawbar); 50% in each axle in transport wagons; 70% and 30% in grain harvesters.

The area of the ellipse of soil/tire contact was calculated using equation 1 (Schwanghart, 1990, 1991) and the proposals of Bolling (1986), Wood and Burt (1987), Burt et al (1992), Way et al (1997), Adam and Erbach (1995), Upadhyaya and Wulfsohn (1990):

$A = 0.78 * W * L$ Equation 1

where

A = soil/tire contact area
W = tire width
L = length of soil/tire contact area

The tire width was obtained from the tire dimensions given by tire manufacturers; the length of the contact area was calculated using equation 2 (Schwanghart, 1990, 1991):

$L = (R^2 (R - Z)^2)^{0.5}$ Equation 2

where

L = length of soil/tire contact area
R = tire radius
Z = tire sinkage in the soil

The tire radius was calculated using equation 3 (FAO, 1993):

$R = D/2 + (H/B) * W$ Equation 3

where

R = tire radius
D = tire rim diameter
H/B = tire aspect ratio; height/width

In relation to average sinkage of the tire in the soil three typical rolling surfaces in agricultural work were considered (Adam and Erbach, 1986; Way et al, 1997; Wood and Burt 1987):

- firm soil, not disturbed, prairie: 2 cm
- traditional seedbed: 5 cm
- recently plowed with moldboard or disks: 9 cm

The equations assume that the tire is rigid and does not deflect; given that reality is different, a 20% increment in contact area was used, for normal tire inflation pressures, according to what has been found by Upadhyaya and Wulfsohn (1990), Adam and Erbach (1986), FAO (1993), Wood and Burt (1987) and Bolling (1986).

Results and Discussion

Agricultural tractors

Table 1 shows that 14 makes with 127 models of tractors are offered to the farmers in Chile; 54 models (42.5%) have 2WD and 73 (57.5%) have FWA. Their weights go from 1,390 to 6,120 kg with 23.5 to 59.5 kg/HP in 2WD, and from 1,670 to 9,330 kg with 27.8 to 68.1 kg/HP in FWA. The power

Table 1. General Characteristics of the Agricultural Tractors Used in Chile

Characteristics	Magnitude
Total makes and models offered	14 and 127
2WD and FWA models offered	54 and 73
Weight range in 2WD, kg	1390-6120
Weight range in FWA, kg	1670-9330
Models with >25 kN on rear axle, 2WD and FWA, %	78 and 74
Models with >35 kN on rear axle, 2WD and FWA, %	31 and 41
Weight range per unit power in 2WD, kg/HP	23.5-59.4
Weight range per unit power in FWA, kg/HP	27.8-68.1
Power range in 2WD and FWA, HP	50-107 and 50-137
Concentration of 2WD supply, HP range and %	66-95 and 59
Concentration of FWA supply, HP range and %	66-95 and 49

2WD = two-wheel drive; FWA = front wheel assist.

ranges go from 50 to 107 HP in 2WD and from 50 to 137 HP in FWA, with 49 to 59% of the offer concentrated in the 65-95 HP range.

A high percentage of the models (74-78%) carry on their heavier axle weights greater than 25 kN and a smaller percentage (31-41%) carry weights greater than 35 kN; the numbers in **Table 1** show that FWA tractors are heavier than 2WD models and, therefore, more likely to cause deep soil compaction problems (Voorhees, 1986; Smith and Dickinson, 1990; Jorajuria et al, 1997)

Table 2, on the other hand, shows that all pressure values at the soil/tire interface, except two, are greater than the 100 kPa set as the limit to avoid superficial compaction in susceptible soils. It is also possible to see that a large number of the pressures exceed the 200 kPa limit of soils resistant to compaction, pointing out the bad treatment that the soils are receiving (Taylor and Gill, 1984; Sanchez-Giron, 1996). **Table 2** also shows the large increment in the pressures as the tractor weights increase, and the reduction of the pressures as the tires sink more in the soil. It is important to notice that 2WD tractors generate larger pressures than FWA tractors of equal weight, and consequently are more prone to cause superficial compaction problems. This can be explained by the larger size of the front tires and the better weight distribution of FWA tractor models (Renius, 1999; Witney, 1995).

Table 2. Pressures Generated at the Soil/Tire Interface by Agricultural Tractors Used in Chile, by Weight Ranges (kPa)

Weight (Ton)	No. of Models		Tire sinkage in the soil (cm) 2	5	9
		Two-Wheel Drive Tractors			
<2.5	11		209	134	102
2.5-3.0	16		230	147	112
3.0-3.5	8		235	150	114
3.5-4.0	8		250	160	121
4.0-4.5	5		267	170	129
4.5-5.0	4		307	196	148
5.0-5.5	0				
>5.5	2		365	233	176
Total	54	Mean	244	156	118
		Front-Wheel Assist Tractors			
<2.5	8		167	107	81
2.5-3.0	10		196	126	95
3.0-3.5	11		222	142	107
3.5-4.0	8		211	135	102
4.0-4.5	10		247	158	119
4.5-5.0	5		255	163	123
5.0-5.5	11		283	180	136
5.5-6.0	1		296	189	143
6.0-6.5	4		321	205	155
6.5-7.0	3		328	210	158
>7.0	2		446	284	215
Total	73	Mean	243	155	117

Table 3. Tare, Payload and Total Weight Ranges of Heavy Agricultural Machines Used in Chile

Machines	Makes	Models	Tare (kg)	Payload (kg)	Total weight (kg)
Transport Wagons	6	17	380-1500	2000-8000	2500-9500
No-till seeders	4	18	1030-3330	460-1611	1490-4941
Conventional seeders	8	37	440-2988	384-1026	824-4014
Foggers	6	24	290-860	1000-2000	1290-2860
Grain harvesters	4	11	6165-9460	1725-4620	7890-13310
Total	28	107			

Table 4. Number and Percentage of Machines with Weights Larger than 25 kN and 35 kN on Heavier Axle

Machines	Makes	Models	Machines >25 kN No.	(%)	Machines >35 kN No.	(%)
Transport Wagons	6	17	17	100.0	9	52.9
No-till seeders	4	18	9	50.0	4	22.2
Conventional seeders	8	37	4	10.8	1	2.7
Foggers	6	24	8	33.3	0	0.0
Grain harvesters	4	11	11	100.0	11	100.0

Heavy Agricultural Machines

Table 3 shows the general characteristics of the 5 types of machines analyzed, with a total of 28 makes and 107 models. It is clear that grain harvesters and transport wagons carry the heaviest weights associated with deep soil compaction (Voorhees, 1986; 1991; Sanchez-Giron, 1996). **Table 4** shows the number and percentage of machines that carry weights larger than 25 kN and 35 kN on the heavier axle, associated with deep compaction of susceptible and resistant soils, respectively (Botta et al, 1998; Sanchez-Giron, 1996; Voorhees, 1986, 1991). **Table 4** shows that 100% of grain harvesters carry weights that can generate important deep soil compaction problems, with transport wagons also showing a similar behavior. No-till seeders present sizable percentages (22-50%) of models with weights leading to deep soil compaction problems. On the other hand, foggers and conventional seeders present very small percentages of models carrying weights above the values proposed to avoid deep soil compaction (Wood et al, 1993; Sanchez-Giron, 1996; Botta et al, 1998; Jorajuria et al, 1997;

In relation to the pressures generated at the soil/tire interface, **Table 5** shows that all values greatly exceed the limits proposed as maximum to avoid compaction of susceptible and resistant soils, 100 and 200 kPa, respectively (Sanchez-Giron, 1996; Taylor and Gill, 1984; Froelich and Ellwein, 1990; Adam and Erbach, 1995; Smith and Dickson, 1990). The values ranged from a minimum of 187 kPa in a conventional seeder with 5 cm tire sinkage in the soil, to a maximum of 891 kPa in a transport wagon with 2 cm tire sinkage. The average values ranged from 346 kPa in conventional seeders with 5 cm sinkage, to 654 kPa in transport wagons with 2 cm sinkage.

The big pressure values at the soil/tire interface established for the 5 machines analyzed in this work could be explained by the large (maximum) weight utilized to calculate the pressure. It should be pointed out that during long periods of time the machine will not carry the full load, since it is unloading inputs or loading produce harvested. However, the very large magnitude of the pressure values, two and three times above the limits recommended to avoid soil compaction, demonstrates that these machines are not equipped appropiatedly for the large loads that they have to transport in the field (Way et al, 1997; Wood et al, 1993).

On the other hand, the solution to the problem using larger tire sizes has a high cost. **Table 6** shows the pressure reduction at the soil/tire interface and the increment of the costs as a transport wagon is equipped with larger tires. It can be seen there that in order to reduce the pressure to adequate levels it is necessary to duplicate the cost of the standard tires.

Table 5. Pressures Generated at the Soil/Tire Interface by Heavy Agricultural Machines Used in Chile (kPa) (1)

Machines	Makes	Models	Sinkage 2 cm Range	Sinkage 2 cm Mean	Sinkage 5 cm Range	Sinkage 5 cm Mean
Transport Wagons	6	17	417-891	654	269-574	422
No-till seeders	4	18	357-868	613	230-560	395
Conventional seeders	8	37	289-783*	536	187-505	346
Foggers	6	24	249-695	474	**	
Grain harvesters	4	11	351-527	439	**	

(1) 100 kPa = 1 bar = 1 atmosphere = 1 kg/cm^2 aproximatedly.
* One model generated 961 kPa.
** Not calculated; not a condition found in the field.

Table 6. Pressures (kPa) Generated at the Soil/Tire Interface and Costs Increments (%) Associated to Different Tire Numbers and Sizes in a Coloso T-40 Transport Wagon, with 4 Ton Load Capacity

Tire number and sizes	Tire sinkage in the soil 2 cm	Tire sinkage in the soil 5 cm	Price increment %
750 × 16* (1)	632	498	0
750 × 16 (2)	316	204	30
1000 × 20 (1)	416	267	70
1000 × 20 (2)	208	134	123

* Standard equipment.
(1) single wheels.
(2) dual wheels.

Conclusions

The great majority of agricultural tractors used in Chile generate pressures at the soil/tire interface that exceed the limits proposed as maximum to avoid superficial soil compaction.

There are tractor models equipped with larger (better) tires than other models of equal weight and/or power.

A high percentage of tractor models carry on their heavier axle weights that exceed the limits proposed as maximum to avoid cumulative deep soil compaction.

Two-wheel drive tractor models are more likely to cause superficial soil compaction problems and front wheel assist models are more likely to cause deep soil compaction.

All the machines analyzed, except a conventional seeder, generate pressures at the soil/tire interface bigger than the values proposed as maximum to avoid superficial soil compaction. The reduction of pressure using more tires and/or larger sizes has a high cost.

All the grain harvesters and transport wagons used in Chile carry on their heavier axle weights that exceed the limits proposed as maximum to avoid cumulative deep soil compaction. No-till seeders show a slightly smaller problem.

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Comparative Study on Different Peanut Digging Blades

by
Elnougomi A. Gadir Omer
Dept. of Agric. Engg.
Faculty of Agricultural Sciences
Dongola University
Dongola
Sudan

Dr. Desa Ahmad
Assoc. Prof.
Dept. of Bio. and Agric.Engg.
Faculty of Engineering
UPM
Malaysia

Abstract

The performance of four types of peanut digging blades, namely; flat-type, curved type, V-shaped type and double discs were evaluated. The results show that there was a difference in the degree of soil disturbed by the diggers. The percentage of soil disturbed decreased according to the shape of diggers used, namely; V-shaped, flat, curved and double discs, respectively.

The results show that the V-shaped type had lower average draft force for increasing digging depths at both inclined angles of 0° and 40° compared to other digger types.

For design of simplicity the V-shaped digger type was the best, and should be used as a digging blade in peanut harvesting machine.

Introduction

Peanut (*Arachis hypogaea*) is a major oilseed crop produced in commercial scale in India, China, France, Nigeria, and USA. In 1991 the total annual production of peanut of the world was 17.3 million tonnes, with growing area over the world about 18.9 million hectares. (Babu 1992).

The current digger types have many blades, each with some advantages and disadvantages, depending on blade type, working situation and conditions. According to Shepped (1963), the windrow combine method consisted of digging, shaking and windrowing. The half sweeps operated just below the nut zone. They should cut the roots without dragging the plants and should loosen the soil sufficient to permit lifting of the vine with a minimum number of pods becoming detached. Awadhwal, *et al.* (1995), reported that a chisel digger was designed and developed at ICRISAT Asia Center, for harvesting groundnut crop. The digger had two shares inclined at 120° to each other and contained chisel points for increased penetration into the soil. Gupta and Parmar. (1991), stated that a new groundnut harvester blade was developed and tested. It cut deeper leaving a minimum number of pods in the soil and reduced harvesting losses by approximately 47%. Self-propelled peanut harvester with a pair of digger screw for digging the soil was designed to harvest peanuts in sandy soil. (Busono, *et al.* 1992).

In spite of the stress on the importance of the blade type in the digging operation, the amount of losses, draft and degree of soil penetration and disturbance, no comparative study has been done to investigate a suitable blade which is more reliable. Thus the objective of this study was to investigate and select the most efficient blade design for digging peanuts.

Materials and Methods

The experiments were conducted on UPM farm. Four peanut digging blades (as shown in **Figs. 1** to **4**), were evaluated, namely; flat, V-shaped, double discs and curved type respectively.

The digger's main frame was made from hollow tubes and T-steel to hold up the dynamometer and different digger blade types. Provision was also made for the blades to be attached at two inclined angles with the horizontal soil surface. The peanut seeds of Spanish variety was sown in Mun-

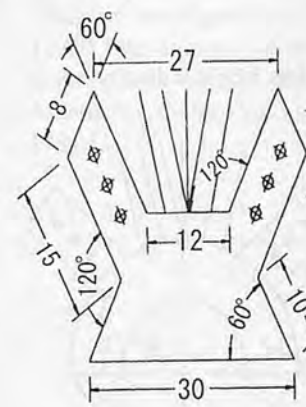

Fig. 1 Flat blade type.

chong Series Soils. A soil moisture Meter was used to measure soil moisture content at different depths and different days from last irrigation. The digger frame was attached to the tractor, three hitching points. Three forward speeds were tested varying from 1.4 to 2.2 km/h, to select the suitable forward speed.

An extended octagonal ring transducer consisting of a machined block aluminum was used. Twelve strain gauges were mounted at strain nodes, and were arranged to form three separate bridge circuits.

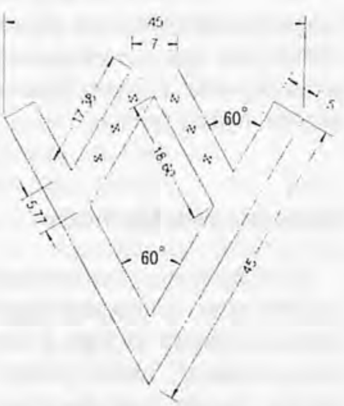

Fig. 2 V-shaped blade type.

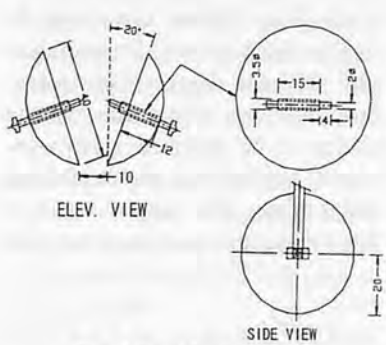

Fig. 3 Double discs type.

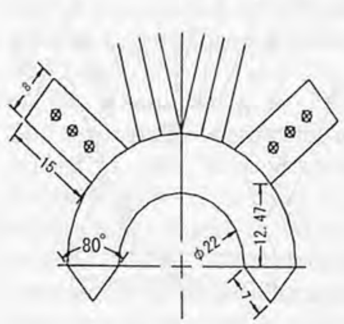

Fig. 4 Curved type.

A lead wire consisting of 12 single wires attached together were used to connect the three channels from datataker and the dynamometer. The datataker is an instrument used to log on, save and read out the data. The datataker would be programmed through a computer to read the force as voltage from strain gauges and record them.

The dynamometer calibration was carried out to determine the response of dynamometer to the load applied. This is important in demonstrating its linearity of response. The datataker, loads ranging from 10kg to 100kg, a computer and a dynamometer were used as instrumentation for calibration. The calibrations were carried out for three channels from datataker for different loads. The output voltages (millivolts) were recorded and a linear relationship was obtained with (R^2 =0.9997), as shown in **Fig. 5**. Based on optimum harvesting date (95days from emergence), the plots were dug out, at the soil moisture content of about 35% (d. b.). Calculations were done to determine the digging losses (pods left in the soil after digging operation). Percent digging losses = (Digging Losses/ Total Yield) × 100%. The soil disturbance was observed between different blades.

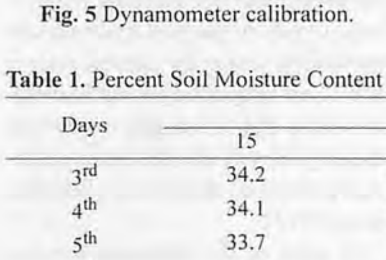

Fig. 5 Dynamometer calibration.

Results and Discussions

Data collected in this experiment was processed and the analysis of variance and LSD were performed.

The results of moisture content values are tabulated in **Table 1**. The results show that values flocculate between 29.8% and 38.5% (d.b). This is due to the Munchong series soils properties, which maintain the moisture for a long time. The peanut digging operation was done at moisture content ranging between 29.8 and 35.0% (d.b), for different depths.

The effect of using different forward speeds on soil disturbance, digging losses and draft forces are shown in Figures 6,7 and 8, respectively.

Figure 6 shows that the soil disturbance at 2.2 km/h was higher than 1.4 km/h, but the difference was not significant between 1.8 km/h and 2.2 km/h, and the V-shape digger blade in all cases showed higher soil disturbance compared to other blades. The degree of soil disturbance for flat and curved blades was similar, This was due to similarity between their shapes.From **Figure 7** the results obtained show that at 1.4 km/h for-

Table 1. Percent Soil Moisture Content Values

Days	Depth (cm)			
	15	20	25	30
3rd	34.2	35.3	36.6	38.5
4th	34.1	35.3	36.4	38.5
5th	33.7	34.7	36.4	35.5
6th	33.7	34.5	35.7	35.3
7th	32.6	33.5	35.5	35.1
8th	31.9	31.8	35.0	35.1
9th	31.9	31.5	33.4	35.0
10th	29.9	30.5	32.1	34.9

* Measuring by soil moisture meter for varying depths and days from last irrigation.

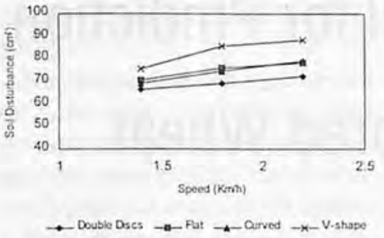

Fig. 6 Effect of forward speed on soil disturbance for different digger blades.

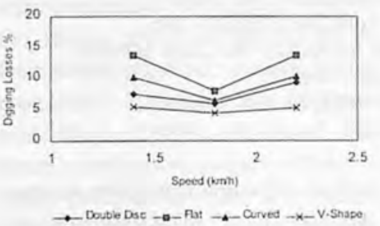

Fig. 7 Effect of forward speed on digger losses for different digger blades.

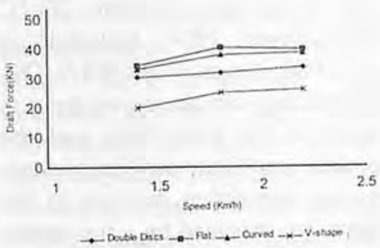

Fig. 8 Effect of forward speed on draft force at different digger blades.

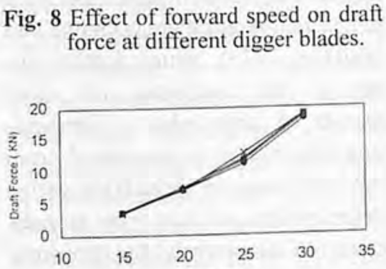

Fig. 9(a) Draft force for different digger blades, against different depth for 0° inclined angle.

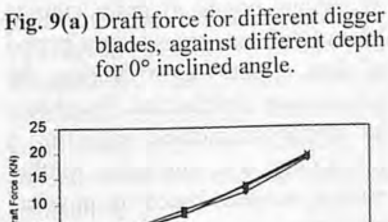

Fig. 9(b) Draft force for different digger blades, against different depth for 40° inclined angle.

ward speed the digging loss was higher when compared with 1.8 km/h, which was found similar to 2.2 km/h. These variations were due to the fact that at lower forward speed most pods would still be stacked in soil. At medium speed of (1.8 km/h), it was noticed that the values of losses were less for all digger blade types. This was due to the fact that this speed will permit all pods to be free from soil as a result of blade motion inside the soil. On the other hand it was found that at 2.2 km/h higher digging losses occur for all digging blades, since the quick motion of blades inside soil will release pods from plants, resulting in the digging losses. Comparing the over-all performance of the different blade sections at different forward speeds, it may pointed out that the flat blade appeared to show the maximum unit draft followed by the curved, double discs and v-shape blade sections, as shown in **Figures 8** and **9**. Previously Yadav (1984), found that the draft required for v-shaped and convex blade types were observed to be smaller than other blade types. This may due to the fact that the soil scouring was better in case of v-shape and double discs blades. Moreover, the flat and curved blades had the tendency to gather the soil. The better performance shown by v-shape blade may also be due to the fact that it had lower resistance due to its shape which permits gradual penetration into the soil.

Conclusion

The V-shaped digging blade caused high soil disturbance, less digging losses with minimum draft. Angle of inclination had significant affects on the draft force values for different digging blades. In terms of efficiency in soil disturbance, digging losses and draft force values, the first choice would be V-shaped digging blade, followed by double discs, curved and flat type, respectively.

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Application of Heat Transfer Model for Prediction of Temperature Distribution in Stored Wheat

by
Sirelkhatim K. Abbouda
Associate Professor
Dept. of Agricultural Engineering
Faculty of Agriculture and Food Sciences,
King Faisal University
P. O. Box 4421, Al-Ahsa 31982
Saudi Arabia

Ali M. S. Al-Amri
Associate Professor and Head
Dept. of Agricultural Engineering
Faculty of Agriculture and Food Sciences,
King Faisal University
P. O. Box 4421, Al-Ahsa 31982
Saudi Arabia

Abstract

The combined convective and conductive heat transfer model previously developed by Abbouda *et al.* (1992) was applied in this study to simulate the temperatures of wheat during storage using input data of initial grain temperatures, ambient air temperatures, wind speeds and thermal properties of grain, bin structure and soil. The local weather data used in the model were obtained from the meteorological station of King Faisal University at Al-Ahsa Province of Saudi Arabia. Experimental data show that bin size and initial moisture content affected the grain temperature differences between the top surface and the bottom of the bin. The average grain temperature followed the trend of the ambient air temperature with a time delay. Predicted and measured grain temperatures were in close agreement for a test period of one year. Results indicated that the model and the parameter values used in the model are applicable for predicting temperature of stored wheat under static storage conditions.

Introduction

To maintain the grain at a temperature and moisture below the level at which rapid deterioration occurs, is one of the main objectives in the design and operation of grain storage system. But because of weather changes, both temperature and moisture are changing in both time and space within a storage bin. The criteria for safe storage are, therefore, dependent upon the local climatic conditions. Study of the effects due to naturally occurring variations in weather is necessary, in order to provide a rational basis for safe storage design (Lo *et al.*, 1975).

Temperature of grain in storage is one of the three main biotic factors, besides the intergranular gas composition and the grain moisture content, that determine the keeping quality and control measures used to protect grain from insects, mites and damaging microflora (Oxley, 1948; Muir, 1980; Longstaff and Banks, 1987). Temperature changes in the stored grain are caused by both internal and external sources of heat. Internal sources are heat of respiration of grain, microorganisms, insects, and mites. External sources include the changes in the ambient air temperature, solar radiation, and wind velocity which varies with location of the storage structure (Converse *et.al*, 1973). Rates of respiration and multiplication of insects, mites and fungi, and respiration of the grain itself are largely dependent on grain temperature (Oxley, 1948). Grain-infesting insects multiply slowly or not at all at temperatures below 15 °C, generally can not survive above 40 °C, and thrive best at about 30 °C (Christensen, 1974; Mckenzie *et al.*, 1980; Noyes *et al.*, 1987). Difference between the center temperature of the grain bulk and the outside ambient air temperature causes convection currents in the grain accompanied by a movement of moisture from high temperature to low temperature areas (Sinha and Wallace, 1977), which further enhances the outbreak of mold growth. A knowledge of temperature distribution in the stored grain not only helps in identifying active deterioration, but also gives an indication of the potential for deterioration.

Collecting the temperature data at various points in grain storage bins of different sizes over a period of time is one way of finding the temperature distribution. But this is an inefficient method, requiring a lot of time, cost, and labor. Mathematical models, based on physical principles can potentially predict with accuracy the temperature distribution in a grain storage bin. Further, using the mathematical models, the effect of bin size, bin wall material, location, etc., on the temperature distribution can be studied (Alagusundaram *et al.*, 1990).

Numerical methods have served as useful tools for predicting temperature distribution in grain storage bins. Muir (1970), Yaciuk *et al.* (1975), and Lo *et al.* (1975) applied a finite-difference method to predict temperatures in the radial direction in the bin. Muir et al.(1980) refined their model to simulate temperatures of stored grain in both the radial and axial directions in free-standing cylindrical bins under controlled atmosphere. Metzger and Muir (1983) combined the force convection model (Thompson, 1972) and the conduction model (Muir et al., 1980) into one model to predict temperatures, moisture contents, and deterioration of wheat in circular steel bins with and without ventilation. Alagusundaram *et al.* (1990) developed a three dimensional finite element model for predicting grain temperatures in a storage of any shape and size. Chang *et al.* (1993) developed a heat transfer model, which accounts for periodic aeration and daily variations in soil temperature, ambient weather, and solar radiation, for accurate prediction of grain temperatures. In another study, Abbouda *et al.* (1992) employed the equivalent coefficient of thermal conductivity, which defined as the sum of the heat transfer coefficients for the conduction and natural convection, in the conduction equations to predict temperatures of grain sorghum in small cylindrical steel bins (0.76 and 1.42 m diameter). Their results show an improved accuracy for temperature predictions with the inclusion of natural convection and internal heat generation.

The objectives of this study were to: (1) test the applicability of the mathematical model developed by Abbouda *et al.* (1992) under the weather conditions of the Eastern Province of Saudi Arabia; and (2) observe the temperature changes of wheat stored in cylindrical steel bins as the ambient air temperature, initial moisture content, and bin size varied.

Mathematical Model

The combined convective and conductive heat transfer model previously developed by Abbouda *et al.* (1992) was applied in this study. The finite-difference model developed by Muir *et al.* (1980) was used by Abbouda *et al.* (1992) as a basis in their study. The original model was capable of simulating conductive heat transfer in both the radial and axial directions. The free convection was incorporated by Abbouda *et al.* (1992) into the original model by using an equivalent thermal conductivity coefficient (k_{eq}) which was defined by Lykov (1966) as:

$$k_{eq} = k + hL$$

where

k = thermal conductivity (W/m.K)

h = convective heat transfer coefficient (W/m^2.K)

L = characteristic dimension (m)

The combined convective and conductive heat transfer model was run on a digital computer to simulate the temperatures of wheat during storage using input data of initial grain temperatures, ambient air temperatures, wind speeds and thermal properties of the grain, bin structure and soil. The local weather data were obtained from the meteorological station of King Faisal University at Al-Ahsa-Eastern Province of Saudi Arabia. The thermal conductivity and specific heat of wheat were estimated at 0.19 W/m.K and 2kj/kg.K, respectively (Chang, 1986). The average bulk density of stored wheat was estimated to be 790 kg/m^3 (Chang *et al.*, 1993).

Materials and Methods

Four cylindrical, leak-proof steel bins of the same height (128 cm), but of two different diameters, were constructed and placed outdoors on concrete floor from 10 October 1997 to 30 October 1998 in the Rýýýesearch Station at King Faisal University, Eastern Province, Saudi Arabia. The diameters of the two bins were 142 cm and 76 cm.

Newly harvested wheat supplied by the Saudi Siloe Cooperation was divided into two lots. Lot 1 was originally with 7.00% moisture content and 35 °C temperature. Lot 2 was conditioned to 8.00% moisture content and 35 °C temperature. Two bins (a large one and a small one) were loaded with wheat from lot 1. The other two bins were filled with grains from lot 2. All bins were filled to 112 cm high.

Temperature measurements were taken hourly at three cross-section of the cylindrical bins. They were 8, 61 and 112 cm above the bottom of the bin, respectively. As shown in **Fig. 1**, five points were selected for the large bins along each axis beginning at 8 cm form the wall and 31.5 cm apart. For the smaller bins, four points were selected along each axis beginning at 8 cm from the wall and 20 cm apart. Thus, temperatures were measured at a grid of 39 points (13 × 3) for the large bins and 36 points (12 × 3) for the small bins. In each bin, thermocouple sensors were installed in the specified points to measure the temperatures of grain at different depths and different radial distances from the bin center. The sensors (accuracy 0.2 ± °C) were connected to a data-logger system to test, display and record the data throughout the experimental work.

Results and Discussion

Measured Temperatures in Experimental Bins

Figure 2 shows the variation of measured temperatures as ambient temperature changes. The data shown are the average of 13 radial temperatures over time at different vertical depths in one of the large bins.

Figure 3 shows the changes of average axial grain temperature at different radius as the ambient temperature changes. Each point on **Fig. 3** is an average of 18 points (6 radial × 3 axial ones). The data for the center position are the average of 3 axial points.

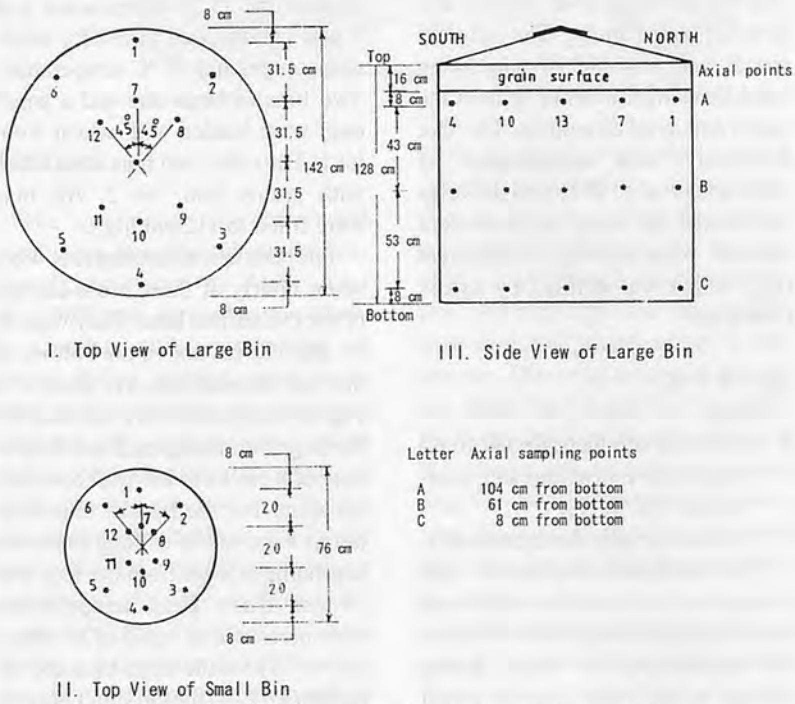

Fig. 1 Location of measured points in the experimental bins.

In general, the temperature of the stored grain followed the trend of changes in air temperature. It reached 19.42 °C during the winter and 40.62 °C during the hot summer whereas the lowest air temperature was 13.6 °C and the highest was 38.2 °C. It took 10 days for the grain temperature to respond to the cold temperatures and approximately five days to respond to the hot temperatures. This time lag was observed to be the same for all measuring points considered as shown by the parallelism of the temperature graphs in **Figures 2** and **3**.

As expected the grain at the surface and near the bin wall had higher temperatures than that in other parts during prolonged heating period from 120 to 300 days storage. The average grain temperature at the top surface was about 0.44 - 4.80 °C higher than that at the bottom bin. The average temperature near the bin wall was approximately 0.34 - 6.51 °C higher than that at the center. An opposite trend existed during the cooling period from 0 - 120 days; the grain at the center was generally 2.13 °C to 7.53 °C higher than that near the wall.

The average temperature at each layer in the small bin is shown in **Fig. 4**. A similar trend found in **Fig. 2** is observed here. The highest grain temperature in the hot summer was not as high as that observed in the large bin. The difference between the top and the bottom surface during the prolonged heating period (between 120 to 300 days storage) was between 0.16 to 3.92 as compared to 0.44 to 4.80 °C that occurred for the large bin.

Figure 5 is presented to show the

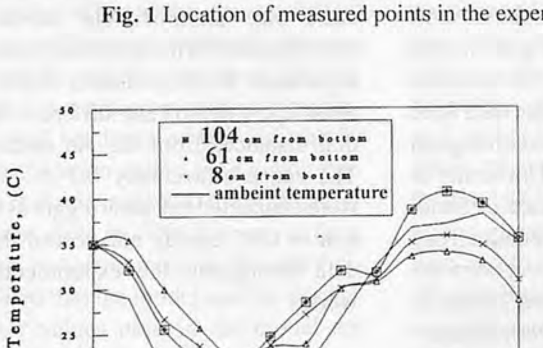

Fig. 2 Measured daily grain temperature variation at different depths inside the 142 cm diameter bin containing wheat at 8.0% IMC.

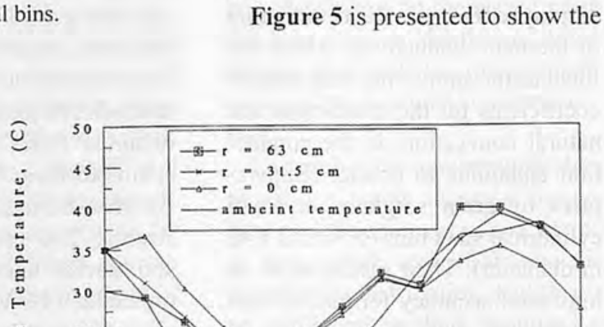

Fig. 3 Measured daily grain temperature variation at different radii inside the 142 cm diameter bin containing wheat at 8.0% IMC.

effect of initial moisture content (IMC) on storage temperature. The data in **Fig. 6** were from a small size bin. The bin was filled with wheat at 7.0% IMC as compared with 8.0% in **Fig. 4**. Examining the heating period between 120 to 300 days storage, one will notice that the highest grain temperature in **Fig. 5** (7.0%) was lower than that in **Fig. 4** (8.0%). The temperature difference between top surface and bottom bin was approximately 0.01 to 2.30 °C for 7.0% IMC, as compared with 0.16 to 3.92 for 8.0% IMC.

It is known that the amount of dry matter loss is a function of grain moisture content. Lower moisture content results in a smaller amount of dry matter loss. As a result, the heat generated from respiration will be small. Comparing **Fig. 5** and **Fig.4**, it is reasonable to say that lower initial moisture content results in less heating of grain.

Comparison of Measured and Predicted Temperature

Predicted and measured grain temperatures at 104 cm from the bottom and at the center of bin are plotted in **Figs. 6** and **7** for a large size bin containing wheat at 7.0% IMC. The predicted temperatures were from the combined convective and conductive heat transfer model developed by Abbouda *et al.* (1992). The standard error of estimate was 0.32 for grain at 104 cm from the bottom and 0.28 for the grain at the center of the bin. Close agreement between measured and predicted grain temperatures indicated that the model and the parameter values used in the model are applicable for predicting temperature of stored grain under the local climatic conditions of Al-Ahsa Province of Saudi Arabia.

Conclusions

The average grain temperature

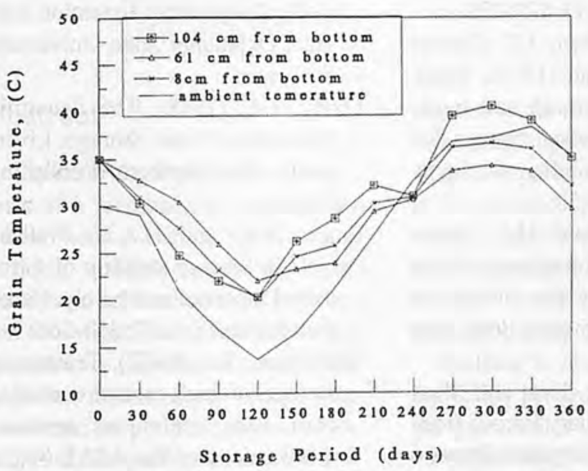

Fig. 4 Measured daily grain temperature variation at different depths inside the 76 cm diameter bin containing wheat at 8.0% IMC.

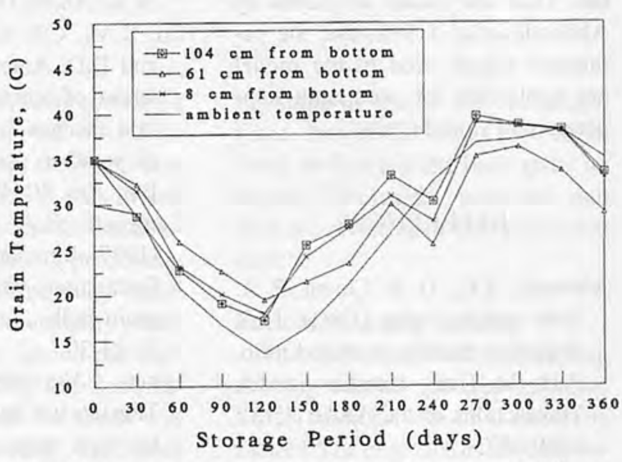

Fig. 5 Measured daily grain temperature variation at different depths inside the 76 cm diameter bin containing wheat at 7.0% IMC.

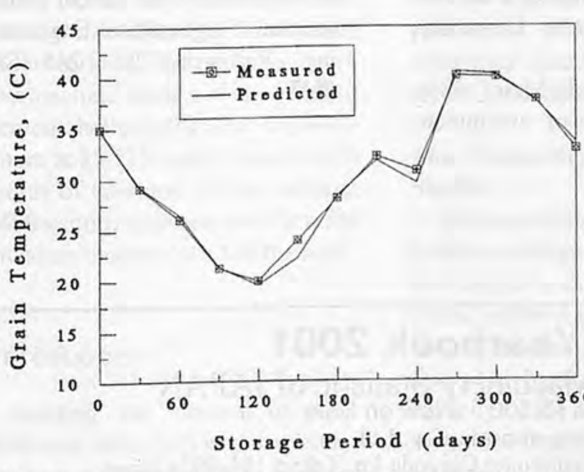

Fig. 6 Comparison between measured temperature and temperature predicted by the model at 104 cm from bottom of a 142 cm diameter bin.

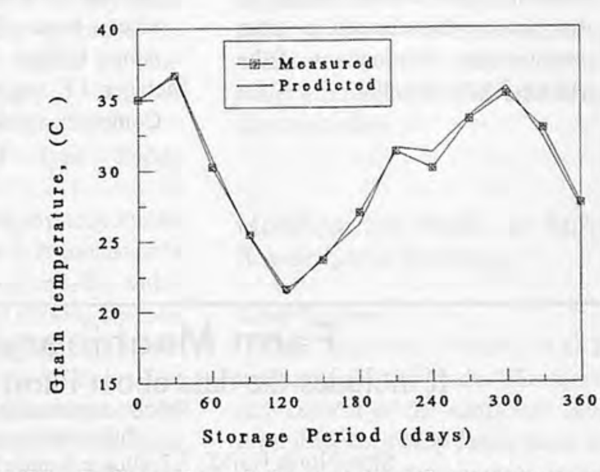

Fig. 7 Comparison between measured temperature and temperature predicted by the model at the center of 142 cm diameter bin.

followed the trend of ambient air temperature after 10 days of storage. The time lag between a change in ambient air temperature and a change in grain temperature was approximately 5 to 10 days.

The bin size and the initial moisture content of wheat had some influence in grain temperature during storage. In general, lower initial moisture content resulted in lower storage temperature. The temperature difference in small bins is smaller than that in large bins.

The grain temperature predicted by the combined model, including conduction and free convection agreed very well with measured temperature in the experimental bin. Thus, the model developed by Abbouda *et al.* (1992) and the parameter values used in the model are applicable for predicting temperature of stored grain.

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Modifications Made on Centrifugal Paddy Sheller for Sunflower Seed Shelling

by
G. Amuthan
Senior Research Fellow
College of Agricultural Engineering
Tamil Nadu Agricultural University
Coimbatore,
641 003, India
E-mail: gamuthan(rediff.com

P. Subramanian
Assistant Professor
Department of Bioenergy
College of Agricultural Engineering
Tamil Nadu Agricultural University
Coimbatore,
641 003, India

P. T. Palaniswamy
Associate Professor
Rice Research Station,
Thirur, Tamil Nadu
602 025, India

Abstract

The centrifugal paddy sheller consists of a feed hopper, rotating impeller with 3 vanes, rubber lined striking surface, outlets for husk, paddy and brown rice and a 2 hp motor. Modifications were made on the impeller viz., number of vanes in the impeller, radius of curvature of the vanes and the peripheral speed of the impeller. The performance of the machine was tested after modifications for sunflower seed shelling. It was observed that centrifugal sheller for paddy can be very well utilized for sunflower seed shelling with suitable modifications. The performance of the machine measured in terms of percent shelling efficiency was maximum at 87.72% with 4 vanes, 8 cm radius of curvature of the vanes at 2600 m/min peripheral speed at 6.5% moisture content (w.b.) of the seed.

Introduction

Shelling, the removal of outer seed coat called hull is an important process in the sunflower processing. Sunflower seeds contain about 30 percent hulls, which contains 50 percent crude fiber. Hull contains a very small quantity of oil (18%) when compared with the oil present in the kernel (50.3%). Also, hull creates more wear in the machinery. Its presence during processing reduces the plant capacity apart from producing a low quality meal.

Shelling is also carried out during paddy processing. The centrifugal type sheller used for paddy was modified for shelling sunflower seed. The shelling in a centrifugal dehusker is done through impact. It is affected by many parameters. An attempt was made to modify these parameters suitably to make the centrifugal paddy sheller for sunflower seed shelling.

The Centrifugal Type Paddy Sheller

The centrifugal type paddy sheller is shown in **Figure 1**. It consists of a feed hopper, rotating impeller with 3 vanes, rubber lined striking surface, outlets for husk, paddy and brown rice, a blower and a 2-hp motor. The capacity of the machine is about 80 kg/hr. The feed rate can be regulated by adjusting the slide gate in the feed hopper. When the paddy flows through the feed hopper to the rotating impeller due to the centrifugal force, the paddy strikes the rubber lined surface and the husk splits on impact. The paddy brown rice and husk are collected in their respective outlets.

Factors Affecting Shelling

The important factors affecting shelling can be grouped into two viz., (1) crop factors and (2) machine factors. The crop factors are crop variety and moisture content of the seed. The important machine factors are feed rate, peripheral speed of the impeller, number of vanes in the impeller, width of the impeller, radius of curvature of the vanes in the impeller and hardness of material striking the surface.

Modifications Made for Sunflower Seed Shelling

Crop Factors

The sunflower variety, CO-2, was used for the study. The moisture content of the sunflower seed is an important crop factor since an increase in moisture content makes cushioning effect while striking the hard surface resulting in poor shell-

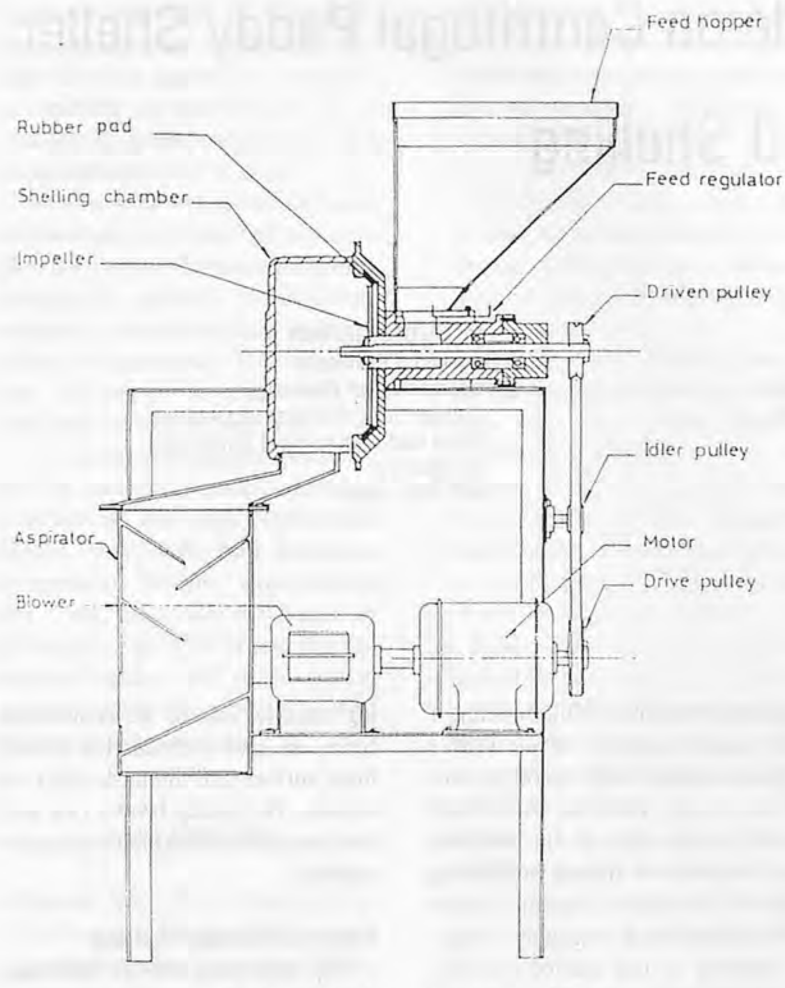

Fig. 1 Centrifugal dehusker-sectional view.

ing efficiency. Hence, the moisture content of the seeds was varied at 6.5, 9.0, 12.0 and 15.0 per cent (w.b.).

Machine Factors

The feed rate of the machine was kept unchanged throughout the study at about 60 kg/hr by adjusting the slide gate in the feed hopper. If the feed rate is greater than optimum then there is a possibility of blocking in the impeller resulting in more unshelled seeds. The width of the vane in the impeller was kept at 1.6 cm to enable the seeds to flow freely in the impeller. The material of the striking surface (rubber lining) was also not changed during the study.

The peripheral speed of the impeller is an important factor as great speed will affect the efficiency with more brokens and vice versa. The actual speed was varied using a variable speed motor at 1700, 2000, 2300 and 2600 m/min.

The radius of curvature of the vanes and number of vanes affect the shelling by varying the distribution of seeds that fall from the feed hopper to the striking material. The radius curvature of the machine was taken at 6,8,10 and 12 cm and the number of vanes was 3,4 and 5.

Performance Evaluation

The performance evaluation of the modified machine was done by calculating the shelling efficiency and percent seed damage. After shelling the sunflower seeds they were used for oil expression, the importance being given to shelling efficiency. During evaluation of the machine the percent seed damage was restricted to less than 20% since excessive seed damage results in chocking of the oil expeller.

It was observed from the study that 6.5% (w.b.) moisture content was optimum for shelling sunflower seeds in the centrifugal sheller. The increase in the peripheral speed of the impeller improved the shelling efficiency and increasing the speed beyond 2600 m/min causes greater damage and hence, it was restricted to 2600 m/min. The reason for the improvement of the shelling efficiency in increased peripheral speed of the impeller is that the impact force required for shelling is also increased by the speed. The maximum shelling efficiency was 87.72% with four vanes, 8 cm radius of curvature of vanes at 2600 m/min peripheral speed where the seed damage was 17.55 percent. The same shelling efficiency was obtained when the number of vanes was changed from 4 to 5 and the radius of curvature from 8 to 12 cm (**Figures 2** and **3**).

Hence, the centrifugal type paddy sheller can be used for sunflower seed shelling by modifying the number of vanes to 4 and radius of curvature at 8 cm at 2600 m/min peripheral speed of the impeller.

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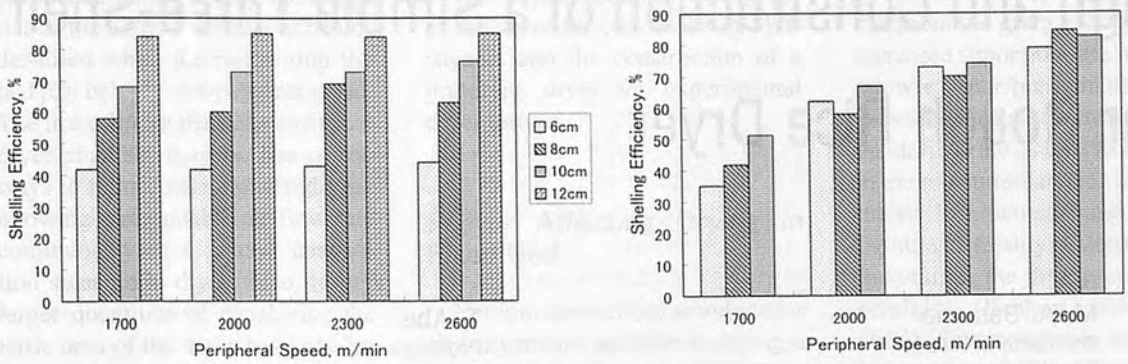

Fig. 2 Shelling efficiency at 6.5% moisture content.

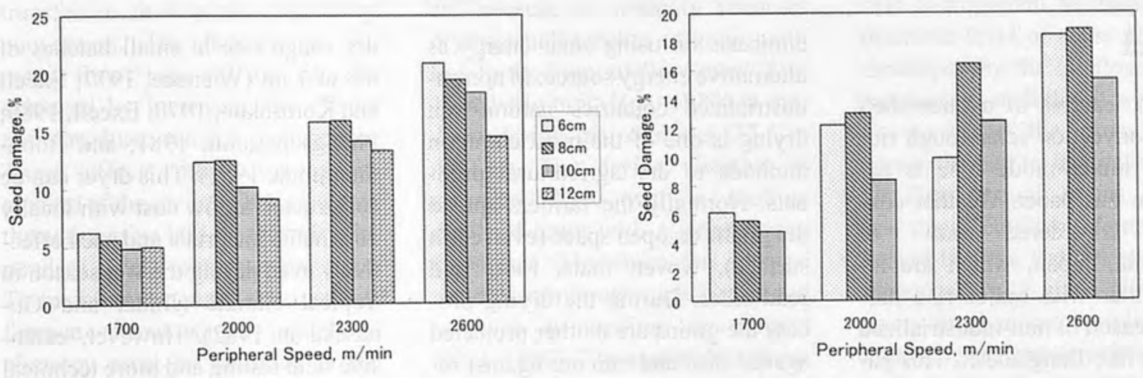

Fig. 3 Per cent seed damage at 6.5% moisture content.

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■■

Design and Construction of a Simple Three-Shelf Solar Rough Rice Dryer

by
M. A. Basunia
Postdoctoral Fellow
Department of Biomechanical Systems,
Ehime University,
Matsuyama 790-8566,
Japan.

T. Abe
Professor
Department of Biomechanical Systems,
Ehime University,
Matsuyama 790-8566,
Japan.

Abstract

Design features of a three-shelf natural convection solar rough rice dryer of mixed-mode type is described in this paper. Weather conditions considered are of Matsuyama, Japan, which are almost similar with major rice harvesting season of non-industrialized countries like Bangladesh. This paper deals with design considerations and presents the results of calculations of design parameters. A minimum of 17.4 m^2 solar collector area is required to dry a batch of 600 kg of rough rice in 17 h (two days drying period). The initial and final moisture contents considered were 25% and 15% wet basis, respectively. The average ambient conditions are 20^{0}C air temperature and 70% relative humidity with daily global solar radiation incident on a horizontal surface of 14MJ/m^2. A prototype of the dryer is so designed and constructed that it has a minimum collector area of 1.74 m^2. This prototype of dryer will be used in experimental drying tests under various loading conditions of the three shelves.

Introduction

Drying of grains is an energy-intensive operation. High prices and shortages in fossil fuels increase the emphasis on using solar energy as alternative energy source. In non-industrialized countries natural sun drying is one of the most common methods to dry agricultural products. Normally the farmers spread the grains on open space (even earth surface), woven mats, roofs and road sides. During the drying process the grains are neither protected against dust and rain nor against rodents, birds and insects. Poor quality due to contamination with dusts and other foreign materials and high losses caused by incomplete drying are the results of natural sun drying. An economical use of oil or gas-heated dryers as common in industrialized countries is restricted to non-industrialized countries because of the high initial costs and the need for expensive fossil energy. Mulbauer et al., (1993) stated that in developing countries, the use of solar energy technologies in agriculture are most economically viable compared in industrialized countries. Solar drying system seems to be a most promising alternative in reducing post-harvest losses of rough rice or paddy.

Review of Literature

Simple solar dryers in which heated air rises by natural convection through the grains have been proposed for use in rural areas to dry rough rice in small batches of 0.5 to 1 mt (Wieneke, 1977; Excell and Kornsakoo, 1978; Excell, 1980; Phongsupasamit, 1981; and Boonthumjinda, 1981). This dryer can be constructed at low cost with locally obtainable materials and used effectively even during the wet season in tropical climate (Jindal and Gunasekaran 1982). However, extensive field testing and more technical data on the construction, operation and economic aspects of the solar drying systems using natural convection of warm air are needed to harness their full potential and to popularize them.

Solar drying systems must be properly designed in order to meet particular drying requirements of specific crops and to give satisfactory performance with respect to energy requirements (Steinfeld and Segal, 1986). Ampratwum (1998) described the design procedure for a cabinet type solar dryer for drying dates. Ibrahim and Hansen (1984) and Bala (1994) presented the simulation model for theoretical analysis of the performance of the natural convection solar rough rice dryer. Akhtaruzzaman and Bala (1989) reported that the use of solar dryers reduce the drying time and improve the quality of dried products.

Excell (1980) reported the importance of proper design of simple solar rice dryer of a single layer. He also reported that if the bed is left untouched during drying the rough rice at the bottom is liable to be under-dried while the rice within the bed just below the top is over-dried. The use of more than one shelf in a dryer chamber may be one of the ways to reduce such uneven drying allowing a reasonable air flow rate continuously in a natural convection solar grain dryer. Also, to dry larger quantities of rough rice the basic area of the dryer has to be increased. Hence, it is preferable to place the grain in several independent layers. The necessary heat transfer is thus accomplished by convection. The increase in the mass flow rate of air can be achieved by increasing the effects that produce natural convection. These effects must also be increased if the air is to be circulated through grains laid in several independent layers, one over the other. To maintain a natural pressure difference without using a ventilator, a chimney must be included in the structure to discharge the air from an elevated location.

In Matsuyama, Japan the typical 14 MJ/m^2 of solar radiation upon a horizontal surface per day takes place during October and November. This can be used to provide the supplemental heat required to heat up the air in low temperature grain drying. In Bangladesh, an almost similar solar radiation period of the year is available during major rice harvesting season in December and January (Bala, 1994).

The present study was conducted in Matsuyama, Japan with the hope that this dryer could be utilized in other developing counties like Bangladesh where climate conditions are at par with those in Matsuyama, Japan.

The specific objectives of this study are:

(1)to design a three-shelf natural convection solar dryer of mixed-mode type; and

(2)to construct a prototype of the dryer for drying rough rice.

This paper reports on the design of the dryer for conditions in Matsuyama and the construction of a prototype dryer for experimental dryer tests.

Factor Affecting Drying in Fixed Bed

Natural convection, simple solar rice dryers are suitable in drying a fixed flat-bed for grains. The fixed flat-bed method drying is most suitable for use of small capacity dryers because it normally involves drying small batches of grain, with low to medium air flow rates (8 to 16 $m^3/min.m^2$) (Hall, 1980) at medium drying temperatures (37.8 to 48.9^{0}C). The drying chamber is normally filled with a shallow depth of grain with a large drying floor area. Moreover, this method requires minimum supervision and involves a medium investment (Hall, 1980). The major drying parameters pertinent to a fixed-bed batch drying method are the temperature and relative humidity of the drying air, its air flow rate and the grain bed depth (Brooker et al., 1974). A lower relative humidity provides a better drying potential causing more water to evaporate from the grain.

The increased temperatures of the drying air by heating results a reduction of its relative humidity and increases its moisture-carrying capacity. This is important, particularly in locations with high ambient air relative humidity. The increased air temperatures increase the grain temperature that causes the vapor pressure within the grains to increase without any change in vapor pressure of the drying air. This gives rise to a higher vapor pressure differential thus improving the drying potential (Brooker et al., op. cit.).

The air flow rate is also an important factor in a successful drying process. The absolute humidity of the air increases as it picks up the moisture from the grain giving rise to an increased vapor pressure resulting in a lower vapor pressure differential. This would cause a slowing down of the drying rate as well as a decrease in the moisture-carrying capacity of the air. It is then essential to replace the air with freshly heated air in order to continue the drying process successfully (Ibrahim and Hansen, 1984). This reasonable air flow rate has to be established since it determines the rates of the corresponding drying time.

It is important to ensure that a desirable level of static pressure is developed by the air flow delivery mechanism such that it is sufficient to overcome the pressure drop across the bad to facilitate a proper air flow through grain. A proper bed depth could be determined to ensure that the static pressure head developed by a given air flow delivery mechanism, is able to overcome the resistance offered by the grain bed so that enough air flow could occur. This is extremely important in the natural convection drying system since no external air flow delivery mechanism is involved (Ibrahim and Hansen, 1984). This will help induce air flow. Establishing necessary air flow rate in a natural convection drying system is difficult because it has to be self-induced by and within the drying system itself. Inducing and establishing the necessary air flow rate will be one of the main tasks in a natural convection drying system (Ibrahim and Hansen, op. cit.). This depends on the thermodynamics conditions of the drying air coupled with the physical characteristics of the system. One of the solutions to this problem is to use more than one shelf in the drying chamber: built one above other like a battery style. Each shelf will be filled with shallow depth grain bed keeping the grains with free space in each shelf along their length. The free space can be alternately positioned back and front ends or front and back ends of the shelves starting from the bottom shelf. A chimney ventilation system at the elevated location also helps to induce air flow.

The Design Concept

In the mixed mode type of dryer, the heated air from a separate air heater is passed through a grain bed and at the same time the top surface of the bed absorbs solar energy directly through a transparent cover. The essential components of the system are the inlet, heating chamber, drying chamber and chimney discharging at an upper elevation. When ambient air enters the heating chamber, in this case the solar collector, the heated air expands and becomes relatively light. This lighter air is then impelled upwards by a bouncy force which is equal to the weight of the ambient air displaced by the expansion of the lighter inside air. The collector is mounted facing south and is tilted at an optimum angle for the area and the particular season of the year. Additional heating is obtained from the solar radiation transmitted through transparent sheets covering the drying chamber. Grain is dried simultaneously by both convection and conduction principle.

The design and construction a three-shelf natural convection solar grain drying system is shown in **Fig. 1**. This system was chosen because it was found to be superior to either open floor or cabinet type dryers (Zaman and Bala, 1989). It represents the general design of a limited number of systems that are currently under study or in use at several different locations that would fit the application of natural convection air flow theory. This system is considered to have a potential for adoption and application by small farmers in developing countries. It is small in capacity, simple in operation and independent of auxiliary source of power.

Design and Construction of the System

The following points were considered in the design of the natural convection solar drying systems:

(a) *Amount of moisture to be removed from a given quantity of wet rough rice to bring the moisture content to a safe storage level in a specified time-* The amount of moisture to be removed from the product, W_w, in kg is estimated from the following expression:

$$W_w = \frac{W_g\left(M_i - M_f\right)}{100 - M_f} \qquad (1)$$

where W_g is the initial mass of wet rough rice to be dried, kg; M_i is the initial moisture content,% wet basis and M_f is the final moisture content,% wet basis.

(b) *Harvesting period during which drying is needed-* The harvesting period will indicate the ambient temperature and relative humidity conditions. The rice harvesting period in Matsuyama usually lasts for approximately one month starting from mid-October to mid-November. In comparison, the major rice harvesting season in Bangladesh is lasts from mid-December to mid-January.

(c) *The daily sunshine hours for the selection of the total drying time during which drying will take place-* The useful sunshine hour may be considered as 8:00 AM to 4:30 PM. It is considered that 17 hours (two days) would be required to reduce the moisture content to safe storage level. Average drying rate, W_{dr}, kg/h, is determined from mass of moisture to be removed by solar heat and drying time by the following expression

$$W_{dr} = \frac{W_w}{t_d} \qquad (2)$$

where t_d is the total drying time required to remove W_w kg of water from the wet rough rice, h.

(d) *The quantity of air needed for drying-* The quantity of air needed for drying may be estimated from the energy balance equations or from the psychometric chart. Both methods are used to determine the amount of air needed to dry a particular quantity of rough rice. The basic energy balance equation for the drying process is:

$$W_w\ L = W_a\ c_a \rho_a \left(T_i - T_f\right) \qquad (3)$$

or

$$W_a = \frac{W_w L}{c_a \rho_a \left(T_i - T_f\right)} \qquad (4)$$

where W_a is the quantity of air needed to absorb W_w kg of water, m^3; L is the specific latent heat of vaporization of water from rough rice, 2620 kJ/kg (Basunia and Abe, 1996); c_a is the specific heat capacity of the air at constant pressure, kJ/(kg.^{0}C); ρ_a is the density of drying air, kg/m^3; and T_i and T_f are the initial and final temperatures of the drying air, ^{0}C, respectively. The problem in designing a solar dryer is to determine a suitable initial temperature T_i, temperature of the drying air before passing through the grain bed, and the correct quantity of air W_a necessary to remove a specified amount W_w of moisture from the rough rice. It is considered that L, c_a and ρ_a are known, and the T_f can be found from the final humidity ratio and enthalpy with the help of a psychometric chart. The volume flow rate of air Q_a, m^3/h, can be determined by dividing W_a by the total drying time as follows:

$$Q_a = \frac{W_a}{t_d} \qquad (5)$$

Volume flow rate of air required, Q_a, m^3/h, can also be calculated from the following expression (Sodha et al., 1987):

$$Q_a = \frac{W_{dr}}{\rho_a \left(H_f - H_i\right)} \qquad (6)$$

where W_{dr} is the average drying rate, kg water/h; H_i is the initial humidity ratio, kg water/kg dry air and H_f is the final humidity ratio, kg/kg dry air. Equation (6) was also used by Ampratwum (1998) in designing a cabinet type solar dryer for dates.

(e) *Daily solar radiation to determine energy received by the dryer per day and area of the solar collector*- When compared to other orientations, a south-facing tilled collector gives maximum daily solar energy collection (Arinze et al., 1998). For a given collector tilt angle and latitude of a location, the solar energy collected on a tiled surface is obtained by multiplying the horizontal solar radiation with a factor R_b, the ratio of solar radiation on a tilled surface to that on horizontal. In order to optimize solar energy collection during the harvesting months from mid-October to mid-November, the optimum tilt angle was considered equal to the latitude and that the corresponding monthly average R_b factors ranged from 1.30 in October to 1.5 in November (Duffie and Becman, 1991).

From the total useful heat energy required to evaporate moisture and the net radiation received by the tilled collector, the solar drying system collector area A_c, in m^2 can be calculated from the following relationships:

$$A_c\ I\ R_b\ \eta = E_u = Q_a\ \rho_a\ c_a \left(T - T_f\right) t_d \quad (7)$$

Therefore, area of the solar collector is:

$$A_c = \frac{E_u}{I\ R_b\ \eta} \quad (8)$$

where E_u is the total useful energy received by the drying air, kj; I is total global radiation on the horizontal surface during the drying period, kj/m^2; and t_d is the drying time, h; η is the collector efficiency, 30 to 50% (Sodha et al., 1987).

(f) *Dryer area and dimensions*- In the design of natural convection, the solar dryer depth of grain bed is a most important dimension. It must be so chosen that the pressure difference across the bed causes the right amount of air to flow through. Also, over-drying and under-drying depend on the depth of the grain bed. In order to maintain a continuous air flow, 3-shelves with shallow depth of grain bed in each shelf is considered. Approximately 5% area of each shelf will be left as grain free along the length alternately front and back or back and front of the shelves starting from the bottom shelf. However the width of the dryer should not be more than 90 cm so that an operator can easily load and unload the shelves at uniform depth with his hands and he, standing on the ground behind the dryer. The length of the dryer can be chosen according to the need of the system. The depth of grain bed is considered 5 cm in each layer, instead of using a single layer dryer of 15 cm depth of grain bed. The length of the grain bed in each layer can be calculated from the following expression:

$$L_g = \frac{W_p}{3\rho_g\ b_g\ d_g} \quad (9)$$

where L_g, b_g and d_g, respectively, length, width and depth of grain bed in each layer, m; and ρ_g is the density of the wet grain, kg/m^3.

(g) *Wind speed (V_w) for the calculation of air vent dimensions*- The air vent area is calculated by dividing the volumetric airflow rate by wind speed as:

$$A_v = \frac{Q_a}{V_w} \quad (10)$$

where A_v is the area of the air vent, m^2; V_w wind speed, m/h. The length of the air vent, L_v, m, will be equal to the length of the dryer. The width of the air vent is given by:

$$B_v = \frac{A_v}{L_v} \quad (11)$$

where B_v is the width of the air vent, m.

(h) *Air pressure head*- The pressure difference across the grain bed will be solely due to the density difference between the hot air inside the dryer and the ambient air. The relationship for the determination of air pressure is (Jindal and Gunasekaran, 1982):

$$P = 0.00308\ g\left(T_i - T_{am}\right) H \quad (12)$$

where H is the pressure head (height of the hot air column from the base of the dryer to the point of air discharge from the dryer), m; P is the air pressure, Pa; g is the acceleration due to gravity, 9.81 m/s^2; T_{am} is the ambient temperature, ^0C. A number of chimney can be employed to the dryer.

The conditions and assumptions made for the estimations of different parameters of the dryer are summarized in **Table 1**. The values of the different parameters of the designed dryer are calculated from different relationships and also obtained from the psychometric chart for different conditions and assumptions made. The values of the designed parameters are summarized in **Table 2**

Construction of Prototype Dryer

The schematic diagram of the prototype dryer constructed for experimental tests is shown in **Fig. 1**. The dimensions of the dryer are shown in **Fig. 2**. A prototype of the 3-shelf dryer is so sized that it has a 90 × 90 cm in cross-section area of each shelf. The vertical distance between two adjacent shelves is 15 cm. Approximately 5% area of each shelf will be left as grain free along the length for easy air movement (**Fig. 3**). A space for air movement can be left alternatively back and front ends of the shelves, starting from the bottom shelf

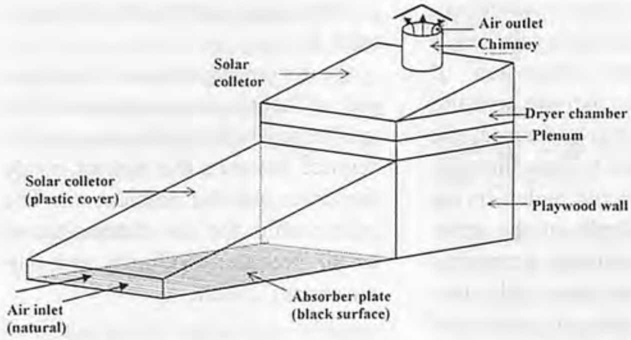

Fig. 1 Schematic diagram of mixed-mode type of natural convention solar grain dryer.

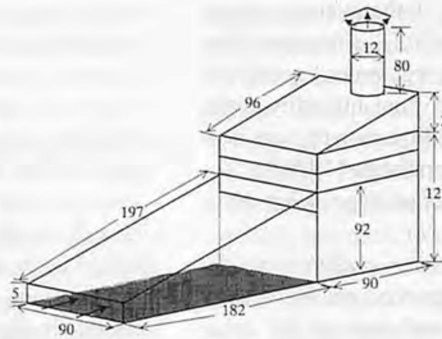

Fig. 2 Schematic diagram of the different parts of the dryer and dimensions (all dimensions in cm).

(Figs. 3 and 4). These arrangement will provide better air movement for drying of grain as it is a natural convection solar dryer. A part of the heated air will pass directly through the grain bed and the remaining hot air will pass along the bottom of each layer. This heated air will absorb moisture from the wet grain while it is passing through and along the bottom of the grain beds of independent layers.

Finally the air will be discharged from the dryer unit through the chimney at an elevated location. The wall of the solar drying system is made of plywood. The shelves were made with wire mesh net supported by steel rod net. The heights of the shelves were selected in such a way that a man can easily load and unload the independent layers from the ground. A door is provided behind the dryer for loading and unloading the dryer. One of the main advantages of shelf-type dryer is that it can be operated as single layer or more layers without changing the arrangement. The bottom solar collector area is 1.74 m^2 (88 × 197cm) and its upper side is 0.92 m from the ground. The upper solar collector is 0.81 m^2 (90 × 90cm) which is considered as an auxiliary collector. The effect of auxiliary collector was not considered in the calculation. The major part of the energy collected will pass through the chimney without passing through the grain bed. The main solar collector area is calculated on the basis of loading rate of 60 kg per batch in 2 days. The transparent thick plastic sheets were used as collectors. The hard black plastic sheet was used as an absorber plate, placed over the wooden base of the main collector. The chimney is 0.12 m in diameter and 1 m in length, made of light sheet metal. The overall dimensions of the unit is 90 × 272 × 225 cm.

Table 1. List of Design Conditions and Assumptions Made

Items	Condition or assumption
Location	Matsuyama, Japan
Crop	Rough rice
Drying period	Mid-October-mid-November
Harvesting days	30 days
Quantity of crop to be dried per season	9 ton (1 ton =1000 kg)
Drying per batch (2 days/batch), W_g	600 kg
Depth of grain bed in each shelf, d_g	5 cm
Number of shelf	3
Vertical distance between two adjacent shelves	15 cm
Density of wet grain, ρ_g	600 kg/m^3
Initial temperature of the drying air before passing through the grain bed, T_i	35^{0}C
Initial moisture content at harvesting, M_i	25% w.b.
Final moisture content for storage, M_f	15% w.b.
Drying time (h), t_d	17 h (8.5 h/day)
Ambient air temperature, T_{am}	20^{0}C (Average of October and November)
Ambient relative humidity, R_H	70%
Incident solar radiation, I	14 (Mj/m^2.day)
Collector efficiency, η	30%
Wind speed, V_w	0.75 m/s

Table 2. Lists of the Design Parameters

Parameters	Value	Data or equation used
Initial humidity ratio H_i	0.0103 kg water/kg, dry air	T_{am}, R_H
Equilibrium relative humidity, R_{Hf}, 15% moisture content w.b.	80%	M_e isotherm
Final operating temperature, T_f	23.5^{0}C	T_{am}, R_H, T_i, R_{Hf}
Final humidity ratio, H_f	0.0148 kg/kg, dry air	T_f, R_{Hf}
Mass of water to be evaporated, W_w	80 kg	(1)
Average drying rate, W_{dr}	4.71 kg/h	(2)
Volumetric air flow rate, Q_a	912 m^3/h	(5)
Volumetric air flow rate, Q_a	910 m^3/hr	(6)
Total energy required in drying, E_u	208.7 MJ	(7)
Solar collector area, A_c	17.4 m^2	(8)
Length of grain bed, L_g	7.4 m	(9)
Vent area, A_v	0.337m^2	(10)
Vent length, L_v	7.4 m	(9)
Vent height, B_v	0.455m	(11)
Air pressure head, P	1.02 P_a	(12)

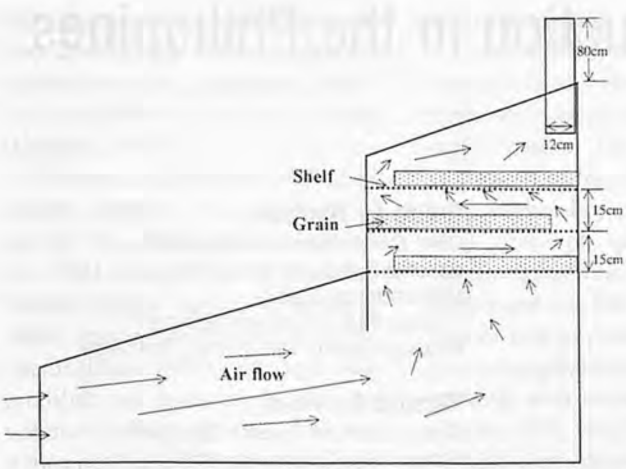

Fig. 3 Direction of air flow inside the drying chamber with opening area starting from the front end of the bottom layer.

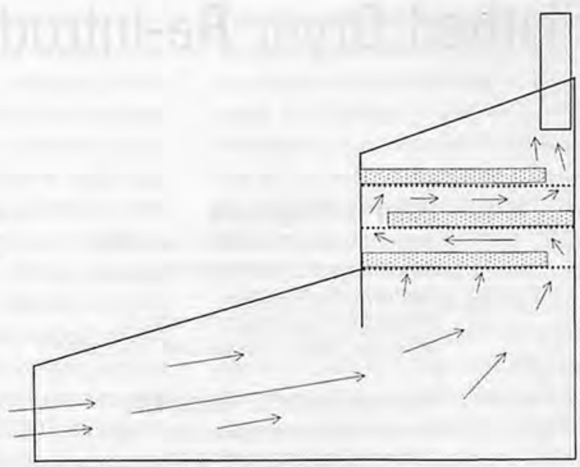

Fig. 4 Direction of air flow inside the drying chamber with opening area starting from the back end of the bottom layer.

Discussion

Drying the batch of 600 kg of paddy in 3 shelves was estimated by considering a medium scale farmer who harvests 9 mt of rough rice during harvesting season. The drying period is considered 30 days, starting from mid-October to mid-November. In Bangladesh, farmers usually dry a batch of approximately 600 kg of rough rice in 2-3 days to bring the moisture to a safe storage level. The utilization of solar dryer will considerably reduce the drying time and the quality of the dried grain will also be improved. The equilibrium moisture value used is reported by Excell (1980).

The prototype dryer is a scale down size (one-tenth) of the designed dryer to be used in the experimental drying tests before constructing the full scale dryer. Ampratwum (1998) also used a similar size prototype in designing a cabinet type solar dryer for dates.

Conclusions

A 3-shelf mixed mode type natural convection solar dryer was designed for drying of rough rice under protected conditions. The designed dryer with a collector area of 17.4 m^2 is expected to dry 600 kg of rough rice in two days. Drying time was considered 8.5 h per day staring from 8:30 AM to 4:00 PM. The initial and final moisture contents were considered as 25% and 15% wet basis. The Matsuyama, Japan ambient conditions during harvesting period from mid-October to mid- November were the setting of study. A prototype of the dryer with 1.74 m^2 solar collector area was constructed to dry 60 kg of rough rice in 2 days. This prototype will be tested for different loading conditions of the 3 shelves. This dryer can also be used for drying other crops and vegetables besides rough rice.

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Flatbed Dryer Re-introduction in the Philippines

by
Eden C. Gagelonia
Senior Science Research Specialist
National Rice Engineering and
Mechanization Center
Philippine Rice Research Institute,
Maligaya, Muñoz, Nueva Ecija, Philippine

Eulito U. Bautista
Chief Science Research Specialist
National Rice Engineering and
Mechanization Center
Philippine Rice Research Institute,
Maligaya, Muñoz, Nueva Ecija, Philippine

Manuel Jose C. Regalado
Supervising Science Research Specialist
National Rice Engineering and
Mechanization Center
Philippine Rice Research Institute,
Maligaya, Muñoz, Nueva Ecija, Philippine

Rizaldo E. Aldas
Senior Science Research Specialist
National Rice Engineering and
Mechanization Center
Philippine Rice Research Institute,
Maligaya, Muñoz, Nueva Ecija, Philippine

Abstract

A high-capacity flatbed dryer developed in Vietnam using rice hull for fuel was adopted, modified and evaluated under Philippine condition. This dryer has three main parts, namely; the drying bin, blower and rice hull furnace. It was modified to suit the farmers' need of farmer cooperatives in the Philippines. This modified design was named PhilRice-UAF flatbed dryer.

Some 113 units of PhilRice-UAF flatbed dryer were assembled and are now operational in the different regions in the country. Private entrepreneurs, local government units and cooperatives financed the construction of the dryers. The Philippine Rice Research Institute (PhilRice) provided technical assistance during installation of the dryer. The operators were also trained on the proper operation of the dryer.

The PhilRice-UAF flatbed dryer solved the farmers' problem in paddy drying. The dryer was found to have lower drying cost compared to existing dryers. This was mainly due to the use of rice hull as fuel, low labor requirement and cost, low repair/maintenance cost, and higher drying capacity compared to similarly priced dryers.

The dryers are successfully being utilized in a commercial scale by the adopters. Aside from paddy it is also used to dry corn, soybean, coffee and banana chips. According to one adopter in Solano, Nueva Vizcaya, operation of this dryer gained more profit in coffee and corn drying. The investment cost can be recovered in less than a year if the dryer is used for coffee drying. For this condition, the annual use is 30 tons per year with 20.53% internal rate of return. Likewise, one adopter in Muñoz, Nueva Ecija had a net income of $1,000 from custom drying during 1998 DS harvest period, which is 1/3 of his investment cost in putting up the dryer.

Based on the adopters' experiences, critical issues that should be considered in the promotion of the dryer are management capability of the adopter, location of the installation with respect to the rest of the community, and training/skills of the operator.

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Introduction

Paddy drying is one of the most critical operations in the post harvest process. This is also a problem due to humid conditions at harvest time, particularly during the wet season and in areas with Types II and IV climate.

In the Philippines, moisture content of the grain is commonly lowered by sundrying. This is still the predominant practice even if mechanical dryers are available because sundrying is cheaper, the milling quality of sundried paddy is believed to be better, and mechanical dryers have limited capacity (Andales, 1995). With the double-cropping system in most rice production regions and with one harvest season coinciding with the rainy period in most rice areas, mechanical dryers can maximize the value of the wet season harvest.

So far, the simplest mechanical dryer developed for Philippine conditions is the flatbed dryer. Originating from the University of the Philippines at Los Banos (UPLB) and developed further by the International Rice Research Institute (IRRI), the flatbed dryer was introduced in late 1970's to early 1980's to rice farmers. This technology, however, was not widely adopted due to several constraints which are mainly socio-economic, rather than technical (Sison et. al., 1983). Reasons mentioned were the dryer's high fuel cost/high operating cost, poor quality of processed paddy, inconvenient drying operation, limited capacity and short time of use (Cardino, 1985).

Vietnam's experience on flatbed dryers, however, was opposite to that of the Philippines. Based on the IRRI design, locally modified flatbed dryers along the Mekong Delta region were reported to be useful (Hien, 1995). The dryer was modified to accommodate larger volume of rice to dry (2, 3, 4, 6, and 8 tons per batch). To reduce operating cost, all modified dryers use rice hull waste for heating the air. Local materials were also used in its construction to reduce investment cost. Now, these dryers are used intensively in the region for custom drying (Hien, 1991).

Objectives

1. To assess the adaptability and acceptability of the Vietnam-designed dryer in the Philippines;
2. To accelerate the adoption of mechanical rice dryers in the Philippines;
3. To create awareness among seed growers, farmer-cooperatives, private entrepreneurs, and other financing institutions on the technology and its benefits; and
4. To ensure the quality and viability of rice harvest through proper and timely drying.

Methodology

Review of the previous studies on the development and promotion of flatbed dryer-Data and information from previous studies on the development and promotion of flatbed dryer were gathered. We analyzed and determined the causes of low adoption and failure in the promotion of the flatbed dryer.

Based on previous studies, the constraints to wide adoption were more socio-economic than technical in nature. The foremost constraints were the dryer's high fuel cost, high labor requirement, and slow rate of drying (Cardino, 1985). Also, one of the reasons mentioned by the users was the lack of skill in proper operation and the incompatibility of the drying capacity with the total requirement (Sison, 1983; NAPHIRE, 1990).

With these findings, the design criteria of the dryer suitable at farm level could be simple, low cost, and capacity within the average production of a farmer, which is around 120 *cavans (or about 5.4mt) for the average landholding of around 2 ha/farmer.

Adaptation of flatbed dryer suitable to the farmers' need-Existing flatbed dryers were studied and evaluated to select a simple design that could be improved and made appropriate at the farm level.

Simple designs of flatbed dryers were those introduced by UPLB and IRRI. These dryers were introduced during the late 1970s to early 1980s. These flatbed dryers had a capacity of 1-2 tons per batch and a kerosene burner as heat source. Also, a rice hull furnace developed by IRRI was used as an alternative heat source. This furnace was equipped with a vibrating ash grate and an inclined step feeder. However, these designs did not gain wide acceptance due to high drying cost and their small capacities. Thus, a higher capacity and low drying cost that utilize biomass fuel is needed to fit the farmers' requirement. In Vietnam, 5 models of flatbed dryers were developed. Of these the SHT-6 was selected since the capacity (6 tons/batch) is suited to the farmers' average production. This dryer has similar design as the 2-ton flatbed dryer of UPLB and IRRI.

In 1992, the Philippine Rice Research Institute setup a 6-ton per batch dryer based on the Vietnam design to evaluate its suitability to Philippine condition (Gagelonia, 1994).

Modifications were made, particularly in the bin, by using hollow blocks and cement instead of firebricks as in the original design. The IRRI rice hull furnace was adapted to the dryer as heat source. However, it was observed that the vibrating ash grate was worn-out after one season. This was replaced because it can no longer be moved and resulted to accumulation of ashes in the grate. The material could be replaced by cast iron but it is expensive. Similarly, due to high temperature in the combustion area, the top portion of the furnace frame expanded. This caused the breakage of the firebrick wall.

The furnace design was improved to make it durable and to lessen the repair and maintenance cost. A stationary inclined step grate was adopted and an arched design in place of the flat top surface of the furnace was made. With this improved design (**Fig. 1**), the grate lasted longer and it could be

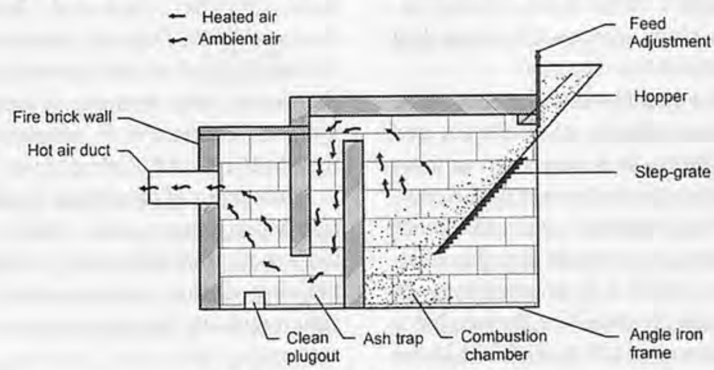

Fig. 1 Modified rice hull furnace.

* 1 cavan = 50 kg paddy (freshly harvested); 45 kg if dried

used even when deformed. The breakage of firebrick wall on top was likewise minimized.

The PhilRice-UAF flatbed dryer (**Fig. 2**) has the following parts:

Fig. 2 The PhilRice-UAF flatbed dryer.

Drying bin-The drying bin was constructed from reinforced hollow blocks (4 × 6 × 8 in) and cement. It has a dimension of 702 × 402 × 130 cm with maximum grain depth of 52 cm (the distance of the false floor from the top). It has several windows for grain unloading. The perforated false floor is made of gauge 22 perforated sheets with 2.44 mm diameter holes and is supported by 4 × 8 cm wooden frames. The plenum has two openings, one at rear, which is bolted with 2 mm G.I. sheets for cleaning purposes and the other in front wherein the blower is connected for entry of air.

Blower-The blower has a diameter of 75 cm consisting of 10 vane axial type blades. It runs at 1600 rpm to deliver around 0.83 m^3/s-ton of paddy at 30 mm water static pressure and a power requirement of 9 kw or 12 hp. The output of the blower is channeled to the plenum through a round metal opening using a cloth canvass transition duct to prevent fan vibration.

Rice hull furnace-The step grate furnace is made of firebricks and steel frame. It is composed of three sections, the first serves as the combustion chamber while the other two serve to trap ash from the heated air before it is diverted into the duct and plenum. The furnace has a dimension of 110 × 89.5 × 121 cm and is designed to consume 30-50 kg/h rice hull.

Evaluation of the improved flatbed dryer-Performance evaluation on the improved dryer was conducted to determine its drying performance and economic feasibility.

Seven runs were conducted. The first was a preliminary run for familiarization. The succeeding runs were used to obtain comprehensive data for the evaluation of the dryer. Initial weight of samples before and after loading was determined. Moisture content of samples at the top, middle and bottom layer was monitored every hour during the drying process. Relative humidity was also monitored during the drying process. Also, rice hull consumption was determined after drying.

Promotion of the PhilRice-UAF flatbed dryer-Lessons and experiences on the promotion of flatbed dryer were studied to serve as guide in the successful adoption of the technology.

Bulletins on PhilRice-UAF flatbed dryer were disseminated to farmers and visitors coming to PhilRice. Mass media was even used in the promotion of the dryer; this was featured in *Agrisyete* and *Agri-Link* TV programs of Channel 7 (GMA) and 5 (ABC), respectively. It was a collaborative effort of the Technology and Livelihood Resource Center and PhilRice. Also, it was featured in *Philippine Panorama* and *MARID Digest*. Corollary to this, several inquiries coming from different regions were received. Technology demonstration was also conducted during Farmers' Field Days for farmers to be familiarized on the operation of the dryer. Also, training of operators was conducted to adopters of the PhilRice-UAF flatbed dryer.

Monitoring of the dryers' utilization-Monitoring and follow-up were made through actual visits to the sites and/or regular communication with the dryer adopter or operators.

Training of manufacturers in the fabrication and assembly of dryer parts. Prospective farm machinery manufacturers in Luzon, Visayas, and Mindanao were identified. Manufacturers who underwent the training and produced their first units satisfactorily (i.e., blower units and furnace frames pass quality inspection and tests satisfactorily) were given certificate of accreditation by PhilRice. However, the accreditation was subjected to revalidation after a certain period of time.

Results and Discussion

Technical Findings

The drying tests showed (**Table 1**) that around 5 tons of paddy at initial moisture content of 22- 26% could be dried to 14% in 4 - 6 h at drying air temperature of 43-49°C. The moisture removed ranged from 285.5-502.5 kg, corresponding to mean drying rate of 1.5-2.1% MC/h. The MC difference between the top and bottom layer ranged from 0.5-2.1%, which is almost 2% of the preferred value. The furnace had a rice hull consumption rate of 27.4-44.5 kg/h and was capable of maintaining the drying air temperature at 41-50°C.

Data on average milling quality of paddy are shown in **Table 2**. The highest milling recovery was 65.60% and the lowest was 57.14%. Milling recovery of paddy dried in the dryer was comparable with that of the control (paddy dried under a shade). The head rice recovery (HRR) was reduced at high drying air temperature. Thus, the drying air temperature had an effect on the HRR.

The average paddy germination data at different drying air temperature are presented in **Table 3**. The relationship of the drying air temperatures to germination was significant such that overexposure of paddy to high air temperature resulted to low germination. Wimberly (1983) had proven that at drying

Table 1. Results of Drying Tests at Different Grain Depths, Fan Speed and Drying Air Temperature for the PhilRice-UAF Flatbed Dryer. Philrice 1994

Item	1	2	3	4	5	6	7
CROP CONDITION:							
Initial MC, %	24.0	23.2	22.5	22.9	22.7	26.0	30.0
Final MC, %	15.3	14.0	14.1	13.4	13.8	14.0	14.1
Initial wt.,t	4.7	3.5	2.9	4.8	4.8	5.8	5.0
Final wt., t	4.3	3.2	2.6	4.3	4.3	5.1	4.4
Grain depth, cm	27.0	24.3	19.9	29.8	29.6	35.0	31.3
AMBIENT CONDITIONS:							
Temperature, oC	31.0	33.5	32.0	31.0	33.0	31.0	30.0
Relative Humidity, %	75	64	67	75	60	72	85
DRYING RESULT:							
Drying air temp., oC	43	43	41	43	51	49	43
Drying time, h	5.5	5.0	5.3	5.0	4.0	6.0	10.0
Drying Cap., kg/h	1149	1053	479	853	1076	895	1250
Top&Bot.,MC.Diff, %	2.1	1.8	0.5	2.0	1.8	2.0	2.1
Moisture removed, kg	443	346.5	285.5	525.5	495.6	502.6	572.8
Drying rate, % MC/h	1.6	1.8	1.5	1.9	2.2	2.0	1.6
% MC reduction	8.7	9.2	8.4	9.5	8.9	12.0	15.9
Rice hull consumption	145	105	137	160	130	180	300
Feeding rate, kg/h	26.4	21.0	25.8	32.0	32.5	30	30.0
FAN OPERATION							
Static Press., mm water	19	16	15	17	20	22	22
Airflow rate, $m^3/s\text{-}m^2$	0.22	0.19	0.19	0.19	0.21	0.22	0.22
Airflow m^3/s	6.2	5.3	5.5	5.5	6.2	6.2	6.2
RPM	1750	1500	1450	1630	1620	1700	1750

Table 2. Average Milling Quality of Paddy at different Grain Depths and Drying Air Temperature. PhilRice, 1994

Grain Depth (cm)	Air Temp. (°C)	Milling Recovery (%)	Headrice Recovery (%)	Broken Rice (%)
19.9	41	58.66	87.62	12.10
24.3	43	61.74	88.20	11.57
27.0	43	65.60	88.50	11.23
29.6	51	57.14	82.34	17.21
29.8	43	61.05	88.23	11.46
31.3	43	63.50	88.10	11.88
35.0	49	64.20	84.20	15.76
F Values		1.72 ns	31.64 **	26.69**
R^2		0.51	0.95	0.94

ns - not significant. **Significant at 1% level.

Table 3. Average Percentage Germination of Paddy at Different Grain Depths and Drying Air Temperature. PhilRice, 1994

Grain Depth (cm)	Drying Air Temp. (°C)	Germination (%)
19.9	41	90.30
24.3	43	91.80
27.0	43	85.66
29.6	51	72.30
29.8	43	92.50
31.3	43	91.60
35.0	49	75.80
F Value		27.93 **
r^2		0.94

**Significant at 1% level.

air temperature of 45°C, paddy could withstand the heat for 75 min without affecting the viability. On the other hand, the Philippine Council for Research and Resources Development recommended a drying air temperature of 43.3°C for seed purposes.

Other Observations

Drying cost per cavan for the dryer is competitive with sundrying. The cost per cavan, relative to the volume of paddy dried per year, ranges from 2-4% of the paddy value, similar to sundrying. The dryer also has a low investment cost, since some parts, i.e., engine, shed and concrete flooring may already be available and need not be purchased or put up.

The dryer is simple to operate and maintain. Since the dryer has few moving parts, it requires simple maintenance. The perforated flooring may have to be replaced from time to time due to wear. The dryer is also very simple to operate since paddy mixing at the drying bin is not required. The only part that needs attention during operation is the feeding of rice hull and the scraping of ash in the furnace. However, operations like loading, unloading, rice hull feeding and ash removal are still manually done.

Controlling rice hull feed rate can easily regulate drying air temperature. In most rice hull furnace the temperature of drying air is difficult to control. However, the design of the dryer furnace does not have any moving part but provides adjustment of the drying air temperature to allow drying of paddy for seeds (at 43°C) or for commercial purposes.

The dryer facilitates complete drying (down to 13-14% MC). It allows the reduction of moisture of paddy in one operation down to the desired moisture level of 13-14%, with no adverse effect on the paddy.

Paddy output is suitable for both seed and commercial purposes, depending on the drying air temperature used.

Economic Analysis

The cost involved in the construction of the dryer, the assumptions in the computation, and the cost analysis are presented in **Table 4**. The data and assumptions made are based on actual operations in Gapan, Nueva Ecija.

The use and operating conditions of the dryer were varied to determine the break-even point. Based

Table 4. Economics of Using PhilRice-UAF Flatbed Dryer Based on Actual Drying Operation in Gapan, Nueva Ecija. PhilRice 1995 WS

GENERAL ASSUMPTION/ACTUAL CONDITION:					
Dryer investment cost, (IC)		$6,000	Interest on investment, %		20
Estimated useful life (yrs)		5	Tax and insurance (% of I.C.)		2
Salvage value		0	Drying time/batch, h		5
Repair and Maintenance (% I.C)		10	Diesel cost ($/li)		0.29
Payment of operator, $		6			
SPECIFIC CONDITIONS:					
Annual use (tons/yr)	50	100	150	200	300
Operating days/yr w/ 5t/day cap.	12	20	30	40	60
% Paddy recovery (by weight) after drying	90	90	90	90	90
Benefit from drying ($/kg)	0.04	0.04	0.04	0.04	0.04
Fuel requirement, li/h	1.8	1.8	1.8	1.8	1.8
Loading/unloading labor wage ($/t)	3.2	3.2	3.2	3.2	3.2
Drying Cost, ($/45kg)	1.2	0.8	0.6	0.5	0.4
Drying Cost, ($/kg)	0.027	0.018	0.014	0.012	0.009
Drying Cost, % Paddy Value	8.41	5.66	4.29	3.60	2.91
Disc. Net Present Value	-4232	-172	4902	9978	200128
Disc. Benefit-Cost Ratio	0.63	0.99	1.38	1.73	2.32
Internal Rate of Return, %	-94.77	14.63	36.78	44.83	51.59
Return on Investment, %	8.9	29.6	55.5	81.3	132.9
Payback period, yr	11.12	3.37	1.80	1.23	0.75

US$1 = P25.

on the prevailing prices during wet season in the area, a $0.04 per kg price difference between wet and dry paddy was adopted. A 5t/batch of drying was adopted in the analysis based on the optimum condition (this is equivalent to 5h/batch -operation for 24 to 14% moisture reduction.).

The cost of drying per cavan (50 kg if fresh paddy) ranged from $0.4-1.2 depending on annual use or volume of paddy dried in the dryer per year. This represented a drying cost of 2.9-8.4% of the paddy value. At $0.04/kg price difference between wet and dry paddy, the dryer starts to become profitable at an annual use of 120 tons/yr. However, if the dryer is operated with the paddy output as seeds (with a price difference of $0.2/kg), the dryer only needs at least 24 tons per year for the operation to become profitable.

Moreover, for coffee drying, the investment cost can be recovered in less than a year at annual use of 30 tons per year with 20.53% internal rate of return. At this condition the drying cost is $0.065/kg (**Table 5**).

On-Site Utilization of the PhilRice-UAF Flatbed Dryer

At present there are 113 units of PhilRice-UAF flatbed dryer installed in different areas of the Philippines. Private entrepreneurs, local government units and cooperatives financed the construction of these dryers. The dryers were used for their own harvest, custom hiring and service to members of cooperatives. PhilRice provided technical assistance during the construction of the dryer.

PhilRice made the blower and furnace of the dryer. This is to ensure quality and correct specification of the design. Upon completion of the installation, the owner was briefed on the operation and their operator trained on the proper operation of the dryer. The utilization of these installed dryers was monitored every season. The owner and operator of the dryers on the sites were interviewed regarding utilization and problems encountered during operation. So far, no problem has been encountered. Continuous dissemination is needed in the successful adoption of the technology.

In Muñoz and Gapan, Nueva Ecija, the dryer was mainly used in drying paddy seeds. The owners also accepted custom drying from neighbors after drying their harvests. The drying fee charged by the owners was $0.38/cavan or $0.5/cavan, respectively. This includes the loading and unloading of the paddy in the drying bin.

As regards another dryer in Aurora, Isabela, it is being hired in drying commercial paddy and corn. According to the owner, mixing of paddy was done during the drying process to lessen the drying time and to accommodate 2-3 batches of drying per day (including night). With the continuous use of the dryer, the furnace collapsed after drying 20,000 cavans. In spite of this, the investment was recovered in just 2 seasons and $25 was spent for the repair of the furnace.

Generally, these established dryers were successfully utilized in a commercial scale by the adopters. However, according to one of the adopters in Solano, Nueva Vizcaya, this dryer gained more profit in coffee and corn drying. Likewise, one

Table 5. Economics of Operating the PhilRice Flatbed Dryer for Drying Coffee in Nueva Vizcaya in 1997 (the Case of Mr. Casumpang)

GENERAL ASSUMPTION/ACTUAL CONDITION:				
Dryer investment cost (IC)		$4,000	Interest on investment	24
Estimated useful life (yrs)		5	Tax and insurance(% IC)	2
Salvage value ($)		0	Drying time/batch	36
Repair and maintenance (% I.C)		30	Electricity cost, $/kw-h	0.11
Payment of operator ($/8-h working day)		2.8	Cost of labor for loading and unloading, $/60 kg	0.06
SPECIFIC CONDITION				
Annual use (tons/yr)	30	60	90	120
Operating days/yr	15	30	45	60
% Coffee recovery (by wt.) after drying	22	22	22	22
Benefit from drying ($/kg)*	1.57	1.57	1.57	1.57
Electricity requirement (kw-h/h)	7	7	7	7
Loading/unload labor wage, $/t	0.95	0.95	0.95	0.95
Transport cost, $/kg	0.02	0.02	0.02	0.02
Drying Cost, $/60 kg include. transport	3.92	2.66	2.24	2.03
Drying Cost, $/kg include. transport	0.065	0.044	0.037	0.033
Drying Cost, $/batch include transport	392	266	224	203
Disc. Net Present Value	21598	49504	77411	105318
Disc. Benefit-Cost Ratio	4.17	7.76	10.89	13.62
Internal Rate of Return, %	20.53	21.48	22.95	25.48
Payback Period, yr	0.32	0.15	0.10	0.07
Return on investment, %	311.65	667.30	1022.96	1378.6

*Benefit = Price of dried milled coffee ($1.8/kg) - Cost of fresh coffee ($0.23/kg) - Cost of milling ($0.03/kg).
US$1 = P35.

of the adopters in Muñoz, Nueva Ecija had a net income of $1,000 from custom drying during 1998 DS harvest, which is 1/3 of his investment cost in putting up the dryer.

The introduction of the PhilRice-UAF flatbed dryer solved the farmers' problem in paddy drying. Based on actual drying operations by the adopters of the PhilRice-UAF flatbed dryer, it was found to have a lower drying cost compared to other existing dryers. This was mainly due to the following: 1) use of rice hull as fuel; 2) low labor requirement and cost; 3) low repair/maintenance cost; and 4) drying capacity is higher compared to similarly priced dryers.

During on-site evaluation of the dryer, it was observed that the following contributed significantly to the successful operation of the dryer.

Management capability-For the technology to be effective and efficient, the adopter must have the capability to operate and manage the drying operation and other activities.

Location of the dryer with respect to the rest of the community-The dryer must be installed in place where the drying activities are not hampered i.e., during the night or far from the neighborhood and the dryer to be fully utilized not only by the adopter but also by the rest of the community.

Training of operator-The skills of the operator are very important in the adoption of this technology. The operator must know how to control the temperature and to feed the rice hull. The operator must also have a basic knowledge on the drying process.

Conclusion and Recommendation

Based on tests and actual operation, the PhilRice-UAF flatbed dryer was found to have a lower drying cost compared to existing dryers due to the use of rice hull as heat source. It is simple and easy to operate; it has low maintenance cost; it can dry grains completely to 13%; it has low investment cost compared to other dryers with the same capacity; the drying air can be regulated; and it can dry seed and paddy for commercial purposes. However, its operation is still manual and the ash should be removed from the dryer at regular time intervals.

The adoption of the PhilRice-UAF flatbed dryer solved the farmers' problem on drying paddy. The flatbed dryer can be an alternative method for drying paddy and other grains during wet season. With the increasing number of adopters, it can be inferred that the dryer is socially acceptable. Moreover, the year round use of the dryer even for other crops also increases its profitability. It is recommended for use by traders, farmer cooperatives or seed growers.

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Effect of Globalization on the Agricultural Machinery Industry in Brazil[1]

by
J.P. Molin
Professor
University of São Paulo - ESALQ
Av. Padua Dias, 11
13418-900, Piracocaba, SP, Brazil
E-mail:jpmolin@carpa.ciagri.usp.br

M. Milan
Professor
University of São Paulo - ESALQ
Av. Padua Dias, 11
13418-900, Piracicaba, SP, Brazil
E-mail: marmilan@carpa.ciagri.usp.br

Abstract

Novelties in the agricultural business are drastically changing the agricultural mechanization scenario in developing countries. In Brazil, facts like the expansion of no-till area and the imminent introduction of precision agriculture technology, are forcing new trends in the agricultural mechanization industry. Associated with that, the recent government change through a less controlled economy has allowed the globalization to play its role and the results are just starting to be seen. The local tractor industry is being influenced by the world major manufacturers as never before and the implements' industry is being forced to search for partnerships with external companies. Farmers not engaged in this new trend will lose competitiveness and that will result in an even stronger correction for the next few years.

Introduction

Two centuries ago, when the farming activity was still totally based on human and animal power, agriculture differences among countries existed only because of environment and natural resources distinctiveness. However, even then, some large farms already contrasted the ordinary style of farming using slave labor. Crops like tobacco, cotton, sugar cane, and coffee, were associated with slavery until the 19th Century in several parts of the world, specially in the American Continent.

With slave labor or not, agriculture was limited by its power units. The Industrial Revolution transformed the world, taking people out of agriculture and concentrating them in cities. That reduced agricultural labor force and increased the demand for food. As the Industrial Revolution was supported by power plants and machines, the ingenious of humankind transferred it back to the agricultural field giving a start to the agricultural revolution.

Nowadays, we deal with three different worlds. The rich countries are leading in technology, industry and agriculture. There are several countries on their way to development. Finally, several regions in the world are far away from the agricultural and technological revolution.

The new trend that is spread all over the world is including towards globalized economical activities. This process has been made possible after the boom of computers and efficient worldwide communication systems. A new model is being imposed by actions of any sort. Nevertheless, adjustment problems may be predicted after these actions.

In the agricultural environment, the self-sufficient small farmer is being pushed out to a more productive activity or out of the business. The huge economical and cultural differences among countries or regions are causing a fast rupture with the traditional. We are witnessing a process of mergers in the agricultural supplier industry as never before. Similar technological packages are being proposed and the new law is worldwide and no more neighborhood competitiveness.

The Brazilian Case

The continental proportions of the Brazilian territory shows some discrepancies. As reported by the Agrianual (1998), the total area comprises 850 million hectares and that is more than 32 European countries put together. Brazil has 550 million hectares of potential agricultural area. Today 27% of its area is occupied with agriculture and grazing. From that total, 19% is pasture, 1% in permanent crops and only 7% of the total land (60 million hectares) are being farmed annually. The total area for grains is 36 million hectares. The major

[1] Mention of trade and company names are for the reader and do not infer endorsement or preferential treatment of the products by the University of São Paulo.

grains are soybeans and corn and their geographical distribution is shown on **Figure 1**.

Brazil today is the first world producer of coffee, orange juice, sugar cane, and tropical fruits. It ranks the second in soybeans and cattle, and the third in corn, chicken and tobacco. Some major agricultural products are presented on **Table 1**. Those numbers show very poor yields compared with the best of the world. Nevertheless, regionally it is possible to find very good averages with crops like irrigated rice that represents 60% of the total Brazilian rice production and gets an average yield of 5.0 mt/ha. Corn is another good example where the national statistics do not represent the regional reality. Corn grown with some differential technology represents more than half the national production and its average yield is more than 5.0 mt/ha, still not enough for competing in the international market.

The urban population comprises 68% of the total. From a labor force of 57 million people, 42% are in services, 33% in industry and 25% are in agriculture. Brazil is the 10^{th} agriculture labor force in the world with 13.5 million agricultural workers. Those numbers are from 1993, and an accelerated process of urbanization is still in action (IBGE, 1995).

Table 1. Some of the Most Important Brazilian Crops and their Performance in 1996

Crop	Area (ha × 1000)	Production (tons × 1000)	Yield (Kg/ha)
Beans	4,945	2,821	570
Corn	13,401	32,002	2,388
Coffee	1,990	2,670	1,342
Cotton	807	1,015	1,258
Oranges	972	108,977	112,014
Rice	3,928	10,003	2,547
Soybean	10,737	23,205	2,162
Sugar Cane	4,826	324,562	67,241
Wheat	1,832	3,293	1,797

Source: FAO (1997).

Agricultural land is widely distributed in unit area. Several factors like occupation policies (European immigration in the 19^{th} and early 20^{th} century), soil fertility, geographical location, major crops/ market in each area, labor, etc., dictated that. However, today the pressure is more than ever about ending the small agricultural business, at least in some areas of transition between "modern" and "old fashion" agriculture.

The conflict between the old and the modern is evident in some crops or activities. A small farmer (up to 50 ha) farming corn and dry beans, only viable in a mechanized system, hardly survives in an economy in transition to the "first world". A crop like soybeans is not competitive at all without mechanization, at least for the harvesting operation. Some projects have been tried to adjust a mechanized system for small soybean growers, but not one succeeded.

Several regions in the country, most in the South and Southeast, occupied by European immigrants as family units, still survive in hilly and stony soils. They farm corn, dry beans and other crops and use almost only human and animal labor. Farmers in their small communities still maintain several cultural aspects that their ancestors brought from countries like Italy and Germany. They are efficiently transforming corn to meat, by growing pigs and chickens. Technically, this is the farthest they can go, but it does not provide enough income with dignity for a family in the 21^{st} Century. This kind of farming activity is condemned to disappear soon.

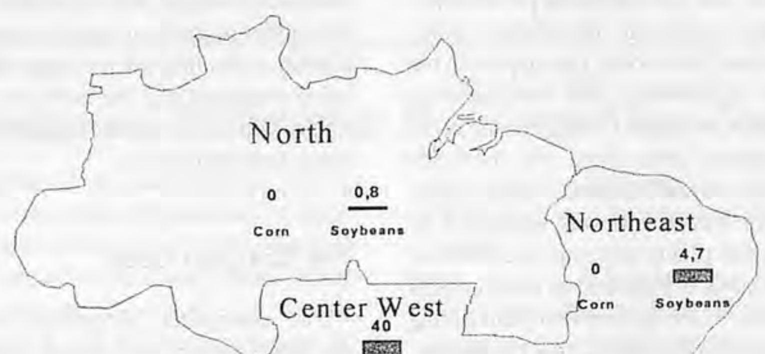

Fig. 1 Geographical distribution of the major crops in Brazil, in% of the total yield (Agrianual, 1997).

The march that is dictating the process of elimination of farming units is proportional to the industrial and urban expansion. The urban employment is the factor that has to regulate that. Sometimes the process is not properly managed by policies and politicians, so crisis and social conflicts are unavoidable.

In other areas where crops like sugar cane dominate, the small farm units are already gone or rented. If there is no capital available for investing in machinery, it is impossible to stay in the business, and that has already caused a process of land concentration

For crops like coffee, mechanization has not been the factor that dictated land distribution changes, yet. Nevertheless, the harvesting technology for both, sugar cane and coffee is in its process of big booming. It means that a large amount of human labor being used in the field will be dismissed soon. The environmental appeal is dictating the end of sugar cane burning before harvesting and the only option is replacing all the human sugar cane harvesting by machines. Even adjustments on land use will come because of the topographical limitations for sugar cane harvesters.

One of the most classical examples the history gives us is the cotton harvesting mechanization in the South and Southeast of USA. Masses of people were affected and big social transformations that happened when cotton pickers were introduced in the area. That is about to occur in several countries at any moment and for several crops or farming activities, especially in these days, when globalization is the order. The market and modern communication systems are forcing the expansion of technological frontiers, regardless of cultural and social consequences.

In some sectors, countries like Brazil and others already changed or adapted themselves to a modern farming style. The success with oranges is a local example of very recent and advanced technology. Soybean is another example where the country is trying to compete with the USA. Subsidy cuts and the lack of money for investment have resulted in some hard days for lots of farmers in the last three years. That is the price for trying to adjust and being able to compete with the rest of the world. It also shows that the agricultural mechanization is being forced to be more efficient.

Agricultural Machinery Market and its Trends

In 1958 the total available working tractors in the Brazilian agriculture were approximately 50,000 imported tractors and up to 140 brands could be found. The Brazilian tractor industry started in 1960, after a Government plan of actions. Since then the market has been characterized by "ups" and "downs" due to several factors related to political and economical instability. **Figure 2** represents those numbers.

These have been the worst years for the agricultural machinery industry. In 1996, Brazilian farmers bought 16% of the number of tractors that they bought in 1976. Partial data from 1997 show a tendency of improvement on internal sales (45% higher than in 1996).

The number of available tractors is about 500,000 and it is decreasing since the early 80s. On the other hand, the yearly grain production jumped from 50 to 80 million mt.

After the first cycle of depression in 1977 the local industry started an aggressive exporting campaign, trying to compensate the internal losses. Then the industrial capacity was at its high limit, around 70,000 wheel tractor units a year.

It was in 1986 that the combine's industry reached the production pick, already in a strong exporting program. Some good results came from that exporting effort, as shown on **Figure 3**. **Figures 4** and **5** present the data related to the countries that are buying tractors and combines from the Brazilian

Fig. 2 Brazilian market of wheel and track tractors, combines and tillers since the beginning of the local industry (ANFAVEA, 1997).

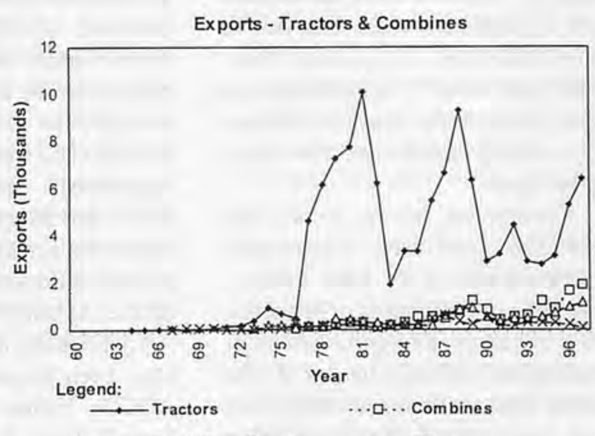

Fig. 3 Wheel and track tractors and combines exported by the Brazilian industry since its beginning (ANFAVEA, 1997).

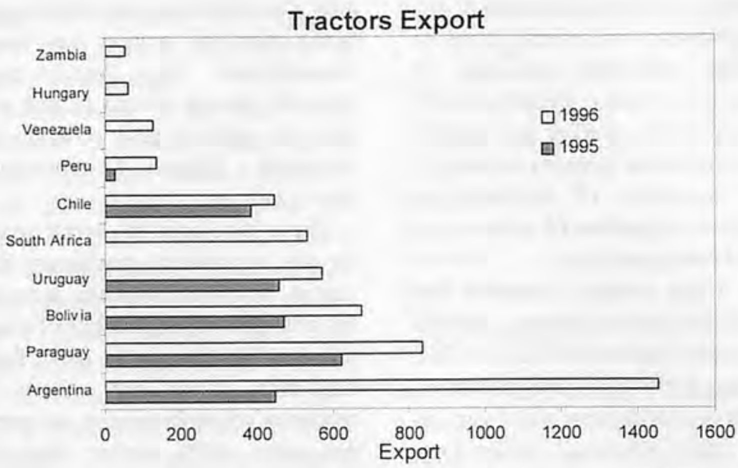

Fig. 4 Countries of major export of tractors from Brazilian industry (ANFAVEA, 1997).

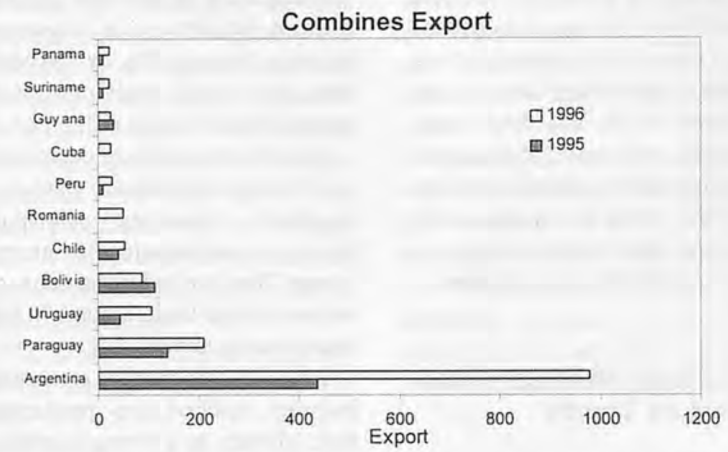

Fig. 5 Countries of major export of combines from Brazilian industry (ANFAVEA, 1997).

industry. The area of influence has traditionally been Latin America. The major buyer countries are Argentina, Paraguay, Uruguay and Bolivia. The first three are exactly the countries that today take part in the MERCOSUR (Common Market) with Brazil. Argentina has its own agricultural machinery industry already established for many years now.

Government actions during the last few years have significantly turned the economy more flexible. Brazil is in the process of privatization of energy, transport, communications and mining industry. At the same time the international market has been opened. As in any other area, the agricultural machinery industry is being affected by those changes.

Contradicting the low market conditions, some radical changes have been seen between 1996 and 1997. Almost at the same time and by different approaches John Deere, Case and AGCO got into the Brazilian market. All those companies have plans for the regional market, primarily the Mercosul, with plants in Brazil and some association with Argentinean factories. It clearly shows that this market is promising a new era for agricultural machinery manufacturers, despite the tendencies of last two or three years.

Traditionally the dominant brands have been Massey Ferguson (now AGCO), Valmet (now Valtra) and New Holland. For years the local products have not shown important technological changes. Unpublished numbers tell us that between 1996 and 1997 more than 500 tractors have been imported. More than 400 of those had between 37 and 67 kW (50 and 90 hp), and from just one manufacturer. It means that they are competing with the local traditional products and are characterized by being very simple and inexpensive tractors. The other imported ones are the more sophisticated, high-powered tractors which come from the headquarters of the major manufacturers.

Other Factors

More recently the no-till technology has brought a new reality to the agricultural machinery industry. The same has been observed in other countries, but particularly in Brazil the growth rate is even stronger. The area covered with no-till annual crops and its growth is shown on **Figure 6**. Those 6 million hectares of no-till estimated for 1997 represent about 17% of the grain area. In USA, as reported by the Conservation Technology Information Center (1995), conservation tillage represented 35.5% of the total annual crop area in 1995 (14.7% in no-till, 1.2% in ridge-till and 19.6% in mulch-till). USA is well known as one of the proponents of this technology and its commercial adoption started there in the late 70s. The major factor that implemented the expansion was the economics of reduced soil tillage. The same is happening in Brazil.

As Brazilian climatic conditions dictate, the major problem with the system is to manage the residue from the previous crops. The major soybean area, where no-till is expanding, has a dry and mild winter and the soil coverage decomposes fast.

The crisis observed on tractors' market during the last few years also affected the implements' industry. Lately this industry has been involved in a direction change

Fig. 6 No-till area of annual crops in Brazil and its annual growth (Saturnino and Landers, 1997).

through no-till planters production and that is strongly pushing up the market of those who have a good no-till planter to offer. A good product has been associated with air seed meters and that has been possible by promoting partnerships with external companies that provide this technology. Excellent exporting businesses have been observed because of that. Countries like Argentina, Paraguay and Bolivia are intensely buying no-till planters from Brazilian companies.

Precision agriculture is another technological change right now being announced to the local farmers. As it is new even for the more advanced countries, it is not known how the adopting march will be and its economical consequences. Site specific application is relatively well fitted to systems already in use, for example in USA. Fertilizer and chemical dealers are costum applicators and liquid fertilizers have been used for years, based on a network already in place.

In Brazil farmers have been using mainly dry fertilizers applied with the planter. Introduction of new ideas, like costum application of products which come with new machines, imply a totally new market where all hardware is going to be imported. This new system is already starting, opening the new marked of costum applicators. Consultants will be demanded to fill the lack of knowledge that farmers have for data acquisition, analysis and decision making, based on spatial variability of their lands.

One evidence about precision agriculture being globalized is that undeveloped and under development countries will be even more dependable. This new wave has a strong technological background on it. Those countries must buy equipment and technology to compete with those who sell it. For the farmer it seems that it is steering the agricultural business again to the dilemma of continuing or not in the business. If site-specific applications can result in profits for those who are going to use it, what may happen to those who are not ready for such a challenge? The competition is already tighter than ever and the "losers" will have to give up their positions to those more prepared or bigger in the business.

Conclusions

Countries like Brazil are witnessing drastic changes in the agricultural mechanization scenario. The agricultural machinery industry is adapting itself to a new era where a less controlled economy has allowed the globalization to play its role. In the same way, with the success of MERCOSUR (Common Market) the major manufacturers are establishing new strategies to dispute the regional market.

Significant expansion of no-till areas, especially with soybeans and corn, is dictating some changes also in the implements' industry, traditionally an industry with local capital. In the same way, the imminent introduction of precision agriculture technology is forcing new trends in the agricultural mechanization industry and in the agribusiness.

A critical and dangerous transition is just starting, forced by the necessity of local farmers to adapt to a worldwide technological competition in agriculture. Farmers not engaged in this new trend are losing competitiveness.

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Table 2. Number of Figs 2 and 3

Year	Brazilian Market - Tractors and Combines (Fig.2)				Exports - Tractors and Combines (Fig.3)			
	Tractors	Combines	Track-Type Tractors	Tillers	Tractors	Combines	Track-Type Tractors	Tillers
60	0.037	-	-	-	-	-	-	-
61	1.679	-	-	0.751	-	-	-	-
62	7.586	-	-	1.240	-	-	-	-
63	9.908	-	-	1.110	-	-	-	-
64	11.535	-	-	1.765	0.002	-	-	-
65	8.401	-	-	2.403	0.000	-	-	-
66	9.543	-	-	3.120	0.006	-	-	-
67	6.506	-	0.072	1.971	0.031	-	-	0.010
68	9.376	-	0.104	2.535	0.007	-	-	0.089
69	9.982	-	0.054	2.081	0.007	-	-	0.050
70	14.740	-	0.024	2.241	0.041	-	-	0.076
71	22.217	-	0.807	2.215	0.098	-	-	0.000
72	29.704	-	1.419	2.619	0.186	-	-	0.000
73	39.454	-	1.869	3.543	0.386	-	0.088	0.006
74	45.995	-	2.373	5.147	0.895	-	0.175	0.052
75	57.931	-	3.615	5.378	0.649	-	0.176	0.085
76	63.776	5.315	4.719	5.537	0.472	0.080	0.044	0.237
77	48.568	5.127	3.251	5.152	4.589	0.129	0.202	0.132
78	41.619	3.457	2.570	5.251	6.134	0.145	0.206	0.205
79	49.523	5.087	3.140	6.165	7.263	0.224	0.522	0.193
80	50.994	5.410	3.753	6.225	7.743	0.279	0.428	0.337
81	28.104	4.522	2.393	4.724	10.073	0.314	0.397	0.179
82	24.662	3.285	1.503	5.157	6.239	0.120	0.329	0.059
83	22.546	3.512	0.877	2.996	1.895	0.164	0.221	0.103
84	41.952	5.469	1.198	2.566	3.302	0.310	0.227	0.213
85	41.243	5.775	1.600	3.139	3.294	0.534	0.216	0.259
86	46.388	6.544	2.245	6.558	5.456	0.525	0.200	0.467
87	39.802	5.747	2.010	3.593	6.658	0.522	0.599	0.641
88	30.604	4.753	1.360	1.854	9.299	0.776	0.843	0.357
89	26.955	3.942	1.493	2.617	6.308	1.227	0.903	0.223
90	22.012	2.350	1.140	1.911	2.871	0.891	0.542	0.551
91	13.896	1.718	0.589	1.983	3.171	0.447	0.365	0.174
92	12.054	2.004	0.532	1.570	4.446	0.569	0.486	0.164
93	21.885	2.735	0.908	1.096	2.892	0.611	0.518	0.336
94	38.491	4.049	1.180	1.308	2.748	1.204	0.544	0.283
95	17.584	1.423	1.155	1.210	3.138	0.948	0.721	0.327
96	10.291	0.899	0.500	0.714	5.273	1.689	0.985	0.235
97	15.731	1.662	0.777	0.702	6.384	1.909	1.199	0.138
98	18.158	2.409	0.766	0.589	5.469	1.756	1.208	0.101

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Comparative Analysis of Grain Post-production Operations and Facilities in South China

by
He Yong
Professor and Head
Agric. Engineering College
Zhejiang University
Hangzhou 310029
Zhejiang, P. R. of China

Bao Yidan
Lecturer
Agric. Engineering College
Zhejiang University
Hangzhou 310029
Zhejiang, P. R. of China

Abstract

Based on the analysis of the present situation and characteristics of grain postproduction system, according to a series of field trials and survey in Jinhua, Jiaxin and Ningbo, Zhejiang province, China, a comparative analysis was taken to evaluate grain postproduction operations and patterns using four indexes, i.e., cost, efficiency, grain quantity loss and grain quality index. On the basis of this analysis, some improved patterns were observed.

Introduction

According to the census of FAO, the average rate of grain post-production losses is about 10% and the rate in developing countries is as high as 20-40%. Some 40-100 billion kgs. of grain are lost yearly if the rate of grain postproduction losses were placed at 10-25%. If the rate of grain postproduction losses were reduced to 5%, 20 billion kgs. of grain could be increased yearly which is equal the grain outputs produced from 1.33 million ha of cultivated areas, each of which can produce one ton of grain yearly. Therefore, reducing grain postproduction losses can be considerate as an important way to increase grain outputs realistically.

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Status of Grain Production and Post-production Handling

Managing the Scale of Grain Production

A great change has taken place in China's countryside since the spread of family contracted system - a special choice in China's special historical period. This system takes farm household as a basic managing unit, hence, the cultivated land areas per capita becomes smaller and smaller. According to the survey of 360 farm households at Jinghua, Jiaxing and Ningbo in Zhejiang province, 90-95% of their cultivated land areas is less than 0.67 ha each in size or their cultivated area per capita is only 0.05-0.12 ha. The income per capita in a year is about 600-1000 yuan. According to the management scale of land and the scale of post-production handling, the farm household can be roughly divided into three types: self-sufficient, specialized and family farms.

Self-sufficient farm (traditional farm household)- The management scale of land of this type is smaller than 0.67 ha, generally, most of them possess 0.07-0.33 ha. Most of the grain is consumed by themselves and grains represent about 10-40% of the total farm product. They are rich in labor force (ordinarily, there are 3-6 family numbers and 2-3 labor force in every family.) and they need not hire farmhand. Every household's amount of post-production handling is very little, commonly less than 5,000kg. On the whole, they carry out post-production handling by means of manpower and natural force.

Specialized farm household- The management scale of land of this kind is about 0.67-1.33 ha. The production is managed mainly by the labor force of family numbers (2-3 persons). However, they will turn to friends and relatives for help in the busy season. Their grain which need to the handled are greater and represent about 60-70% of the total product. Most of the post-production handling machinery possessed by the farm household is motor thresher or electric thresher.

Family farms- Generally, the management scale of land in this type of household is more than 2ha, and most of them own 2.67-4 ha each. Only one or two of them own more than 10 ha each. Every farm handle tens of thousands kilograms of grain per year. They lack labor force seriously. In normal time, they employ few farmhands. But, they have to hire a number of farmhands during the busy season which cost them much money every year. In some areas where the economy is developed, relying on the power of collective economy, the mechanization of harvesting and threshing has been realized by agricultural machinery service teams. In order to reconcile the contradiction between shortage of labor force and high cost to hire farmhand, some households have purchased combine.

Systematic Characteristics

Grain Post-production

The family contracted system makes it possible to combine grain production with management. But the efficiency of post production treatments is comparatively low because of the small scale and the shortage of techniques and equipment (**Table 1**).

Influence of Factors

The internal structure and external environments of grain post-production system have been changing and developing. The change in grain prices, the mechanism of markets, the structure of industries, the transmitting of labor, managerial scales, economic incomes, inputs and scientific techniques will directly influence the developments of post-production system. Obviously, making agricultural policies, application of inputs and scientific techniques will greatly help to improve the system. There are three typical patterns of techniques in South China, which are:

Type I (27% of total sample farmer households) is the traditional model of post-production treatments, which mainly depends on labor and natural forces;

Type II (70% of total sample farmer households) is the semi-mechanization model of post-production treatments, which depends on agricultural machines as well as labor and natural forces; and

Type III (3% of total sample farmer households) is the mechanization model of post-production treatments, which can be realized in some households who have large scale of cultivated areas and lived in some developed regions.

Comparative Analysis of Grain Post-production Technology

Harvesting

The efficiency and revenue of the reaper were highest in harvesting (**Table 2**). Harvesting with sickle had the lowest losses but high cost. However, manual harvesting was fit to the areas where the technical and economic conditions were relatively lower and the manpower was rich. Although revenue of mechanical harvesting was better than manual harvesting, production size, value of labor and technical and economic environments limited the application of mechanical harvesting. Economic analysis on the adaptability of the major grain post-production patterns in South China indicated that combine harvester was better for the areas where the technical and economic developments were relatively advanced with the average value of labor beyond 10.32 yuan/man-day (He Yong, 1992). Therefore, with the improvements of technology and the economy, labor cost will rise and mechanization of farming will also become an inevitable trend.

Threshing

Threshing efficiency increased as the operation was mechanized. High revenues were observed by replacement of motor thresher for hand threshing and combine harvester for pedal thresher, but the selection of these replacements were determined in terms of technical and economic advancement and labor resource. The replacement of combine harvester for pedal thresher must take place in the areas where technical and economic conditions were relatively improved and the manpower was short in hand, while motor thresher for pedal thresher would be adapted in areas where technical and economic conditions were moderate (**Table 3**).

Drying and Cleaning

High efficiency, low losses and low cost, but low revenue for vibrating screen combined with electric blower were to replace wooden winnower (**Table 4**). The replacement was desirable in practice.

Storage and Milling

After replacement of wooden bin for bulking on the cement ground, although the cost of storage increased slightly, the losses in storage decreased greatly and high revenue was gained. The wooden bin storage, therefore, was a good means of grain storage and could be widely applied

Table 1. Major Ways of Grain Postproduction Processing.

Harvesting	Threshing	Drying	Storing	Transporting
Sickle 95%	Hard threshing 35.6%	Sunlight 98.3%	Stack on the ground 67.8%	Shoulder and handcart 40.9%

Date source: Inquiring investigation of 1386 farm households in Ningbo, Jiaxing and Jinghua, Zhejiang province.

Table 2. Comparative Analysis of Grain Post-production Technology in Harvesting Operation

Item	Efficiency	Losses	Cost		Revenue	
	ha/hour	(%)	yuan/ha	yuan/50kg	yuan/ha	yuan/50kg
Combine for Sickle	0.10	1.39	-43.65	-0.42	51.15	0.48
Reaper for Sickle	0.09-0.17	—	-33.15	-0.32	76.05	0.72

(**Table 5**). Of course, other closed containers such as cement cabinet and warehouse owned by collectives should be adopted according to rural economic conditions. Since most of the milling machines used in rural areas were outdated and resulting in heavy losses in processing, milling machines should be renewed or improved as soon as possible.

Comparative Analysis of Patterns of Grain Post-production System

Investigation done in Jinhua, Jiaxing and Ningbo areas found that three major types of grain post-production patterns co-existed in the province (**Table 6**).

Comparative Analysis of Operation Costs among Grain Post-production Patterns

The total cost in post-production system was 30 percent of whole grain production system (including production, post-production) for labor force, fuel and electricity, machine depreciation and repair charges. The costs of labor force took about 70-80 percent of the total cost in post-production. Based on the survey in Jianghua, Jiaxing and Ningbo, the cost distribution of different post-production patterns in summer harvesting season is shown in **Table 7**. The cost of pattern III with highly mechanized level was less than that of the pattern I, in which each operation was mainly carried out manually. The costs of harvesting and threshing of pattern I were higher than that of other patterns.

Comparative Analysis of Efficiency in Grain Post-production Pattern

The operation efficiency of different patterns is shown in **Table 8**. The operation efficiencies of patterns I, II and III were 0.002, 0.025, and 0.072 ha/hour, respectively. Pattern III was obviously superior to pattern I since the efficiencies of harvesting and threshing by manual labor were much lower.

Comparative Analysis of Quantity Losses

The field trial indicated that the total losses in each pattern differed greatly with the patterns of post-production (**Table 9**)

Comparative Analysis of Quality Losses

In the whole processes of grain

Table 3. Comparative Analysis of Grain Post-production Technology in Threshing Operation

Item	Efficiency	Losses	Cost		Revenue	
	ha/hour	(%)	yuan/ha	yuan/50kg	yuan/ha	yuan/50kg
Pedal thresher for hand beating	0.004	—	-26.85	-0.26	+3.75	+0.04
Motor thresher for hand beating	0.009-0.016	—	-60.45	-0.58	+30.15	+0.29
Motor thresher for pedal thresher	0.005-0.012	+0.72	-33.60	-0.32	+26.40	+0.25
Combine for pedal thresher	0.081	+0.76	-37.65	-0.40	+42.30	+0.40

Table 4. Comparative Analysis of Grain Post-production Technology in Cleaning and Drying Operation

Item	Efficiency	Losses	Cost		Revenue	
	ha/hour	(%)	yuan/ha	yuan/50kg	yuan/ha	yuan/50kg
Dryer for sunlight	0.025-0.027	—	—	—	—	—
Mechanical vibrating screen combined with an electric blower for wooden winnower	+0.013	-0.66	-7.80	-0.07	-15.75	-0.15
Mechanical vibrating screen combined with an electric blower	+0.010	-1.20	-3.15	-0.03	-44.10	-0.42

Table 5. Comparative Analysis of Grain Post-production Technology in Storage Operation

Item	Efficiency	Losses	Cost		Revenue	
	ha/hour	(%)	yuan/ha	yuan/50kg	yuan/ha	yuan/50kg
Wooden bin for fenced bin	—	-1.78	+9.6	+0.09	65.4	+0.62
Wooden bin for bulking on the cement ground	—	-5.25	+14.7	+0.13	193.5	+1.84

Table 6. Three Basic Patterns of Grain Post-production in Zhejiang

Pattern	Harvesting	Threshing	Cleaning	Drying	Storing	Transporting	Milling
I	Sickle	Pedal thresher	Wooden winnower	Sunlight	Wooden bin	Shoulder handcart	No.2 rice miller
II	Sickle	Motor thresher	Electric blower	Sunlight	Fenced bin	Shoulder handcart	No.2 rice miller
III	Combine	Combine	Vibrating screen and electric blower	Sunlight	Bulking on the ground	Shoulder handcart	No.2 rice miller

Table 7. Distribution of Cost for Different Post-production Patterns

Pattern	Harvesting	Threshing	Cleaning	Drying	Storing	Transporting	Milling	Sum
I	9.81	5.66	2.52	6.73	1.43	4.24	4.45	34.84
II	9.81	6.42	2.08	3.89	0.78	2.98	4.45	30.41
III	5.75	5.75	2.00	5.39	0.45	1.56	4.45	25.35

*Average cost per unit area of one crop post-production treatment.

post-production, there was not only quantitative losses but also qualitative losses, the deterioration of food grain would be devalued and might potentially affect the health of human beings and animals. The quality losses of different systems could be analyzed with the help of nine items (**Table 10**).

Conclusion and Recommendation

The studies show that a great potential can be explored by improving the post-production techniques and equipment.

Considering the technical and economic conditions in the rural areas and characteristics of grain postproduction operation, three improved grain postproduction patterns are recommended (**Tables 11** and **12**). These patterns have higher efficiency, lower labor requirement, better grain quality and less quantity losses with lower cost except that the quantity losses in pattern I' are slightly increased and so is the cost of pattern II'. The ratios of benefit to cost become high. The ratio of pattern III' increased most rapidly, hence the three improved patterns are suitable for different places in Zhejiang province, that is, pattern I' fits all areas where technical and economic conditions are relatively backward and the labor source is rich. Pattern II' is suitable for areas where the technical and economic conditions are moderate. Pattern III' is adaptable for areas where the technical and economic conditions are relatively advanced and labor sources are short. These conclusions could be applied to help the farmers make the best choice and improve grain post-production patterns.

Table 8. Treatment Efficiency of each Process of Different Pattern (Unit: hr/ha)

Pattern	Harvesting	Threshing	Cleaning	Drying	Transporting	Processing	Total
I	166.5	124.5	37.5	100.5	49.5	24.0	502.50
II	166.5	60.0	49.5	64.5	25.5	24.0	390.00
III	11.25	—	33.0	64.5	6.0	24.0	138.75

Table 9. Quantity Losses of each Process of Different Systems (Unit: percent)

Pattern	Harvesting	Threshing	Cleaning	Drying	Storing	Transporting	Milling	Sum
I	0.35	0.66	1.02	2.58	2.89	1.00	2.81	11.36
II	0.50	1.70	2.72	1.02	4.67	1.02	2.81	14.44
III	1.64	1.49	1.25	1.70	8.14	0.96	2.81	18.00

Table 10. Grain Quantity Indexes of each Process of Different Patterns (Unit: percent)

Pattern	Immature kernel rate	Wounded grain rate	Impuri rate	Germinatio rate	Sick rice rate	Milling recovery rate	Head recovery rate	White appearance rate	Acid rate
I	11.21	0.07	99.0	94.52	4.24	78.61	76.97	2.00	13.77
II	16.63	0.68	100	84.89	5.82	75.17	72.83	13.8	54.20
III	2.40	0.25	99.9	76.11	8.42	73.57	66.40	2.54	55.26

*Numbers were weighted averaged of spring grain, early maturing rice and late maturing rice with a weighted proportion of 0.1:0.4:0.5.

Table 11. Three Improved Patterns of Grain Post-production

Pattern	Harvesting	Threshing	Cleaning	Drying	Storing	Transporting	Milling
I'	Sickle	Pedal thresher	Vibrating screen with electric blower	Sun-light	Wooden bin	Handcart	No.2 rice miller
II'	Reaper	Motor thresher	Vibrating screen with electric blower	Sun-light	Wooden bin	Handcart	No.2 rice miller
III'	Combine	Combine	Vibrating screen with electric blower	Sun-light	Wooden bin	Handcart boat	No.2 rice miller

Table 12. Comparative Analysis Between Improved Patterns and Three Basic Patterns

Items	I'	II'	III'
Cost in postproduction (yuan/ha)	495.9	431.55	407.25
(Cost change, yuan/ha)	-26.7	-24.6	+27.0
Handling efficiency (ha/hour)	0.0021	0.0045	0.0096
(Efficiency change, ha/hr)	+0.00013	+0.002	+0.0024
Quantity losses(%)	11.56	11.49	11.04
(Losses change %)	+0.20	-2.95	-6.96
Quality change	No change	Better	Better
Labor expense change (man-day/ha.day)	-3.75	-16.35	-31.2
Cost of preproduction and midproduction (yuan/ha)	1464.75	1464.75	1464.75
(Cost change, yuan/ha)	0	0	0
Benefits from selling grains (yuan/ha)	3250.2	3252.75	3269.25
(Change of benefits)	-7.35	+108.45	+255.75
Benefit to cost rate	1.66	1.72	1.75
(Change of benefit to cost rate)	+0.02	+0.08	+0.12

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He Yong and He Yong-sheng (1996). Estimation of Grain Post-production Operating Methods. AMA, 27(1),54-58 ■■

ABSTRACTS

The ABSTRACT pages is to introduce the abstracts of the article which cannot be published in whole contents owing to the limited publication space and so many contributions to AMA. The readers who wish to know the contents of the article more in detail are kindly requested to contact the authors.

914

Potentials for the Use of Inclined Conveyor Belt for Separation of Crop Components: **O.O. Babatunde,** Department of Agricultural Engineering, University of Ilorin, NIGERIA.

Particle motion on an inclined conveyor belt was analysed, and found to depend on such factors as gravity, crop particle shape, conveyor belt velocity, conveyor belt slope, and the coefficient of sliding friction of the crop component on belt material. Frictional coefficients of beans, rice, stone, oil palm kernel shell and palm kernel were each determined on tarpaulin, nylon and polythene sheets. Results of the analysis show that for belt slopes less than the angle of sliding friction of the crop product component, the motion of the particle is hyperbolic, and the belt system behaves as a conveyor. For belt slopes greater than the angle of sliding friction of the crop product component, the motion of the particle is sinusoidal. With sufficient belt length for the particle motion to be reversed, the crop products components can be discriminatory discharged at either the foot or the head of the conveyor belt. The tarpaulin was found to be suitable for separating palm kernel/ shell and beans/stone mixtures at conveyor belt slopes of 37.5^{o} to 45^{o}. The nylon surface was found suitable for separating rice/stone mixture at conveyor belt slopes of 30^{o} to 37.5^{o}.

916

Prediction of Solar Radiation Impinged on FRP Solar House: **Ridwan Rachmat,** Graduate Student, Lab. of Process Engineering and Machinery, Dept. of Bioproduction and Machinery, Faculty of Bioresources, Mie University, 1515 Kamihama, Tsu-shi Mie-ken, 514. JAPAN. **Kazumasa Suzuki**, Graduate Student, Same. **Kazuo Horibe**, Professor, Same.

This paper describes the phenomenon of solar global radiation impinged on a fiber reinforced plastic house. Various models were considered by assuming on average condition of the ozone, water vapor content and turbidity of the atmosphere for the estimation of hourly global solar radiation under clear sky and cloudy conditions. The direct, diffuse and global solar radiation impinged on the solar house were predicted based on the extraterrestrial values of solar radiation. The prediction result of solar global radiation impinged on an FRP house is presented and to be compared with the experimental data during the clear and cloudy days.

920

Residual Tillage Effect on Direct Drilling of Wheat after Rice: **Abdul Razzaq**, Senior Subject Matter Specialist (Engg.), Adaptive Research Farm, Sheikhupura, PAKISTAN. **Abdul Karim** (late), Assistant Research Officer, Adaptive Research Farm, Sheikhupura, PAKISTAN.

This study was conducted to evaluate residual effect of cultivator, M. B. plow and chisel used in rice on the subsequent wheat crop directly drilled under zero tillage in clay loam and loam soils. By yield, direct and residual effect of M. B. plow was significantly observed on rice and wheat, respectively. To obtain enhanced yield of wheat under zero tillage, its cross drilling in rice harvest fields cultivated with M. B. plow was found the best package in both soil types, including the straight drilling in zero tilled clay loam soil after plowing also good. Economically, direct drilling of wheat after M. B. plow was also viable.

922

Study on Rapeseed Oil as Alternative Fuel for Single-cylinder Diesel Engine: **He Yong**, Professor & Head, Agric. Engineering College, Zhejiang University, Hangzhou 310029, Zhejiang, P.R. of CHINA. **Bao Yidan**, Lecturer, Same.

The quadratic regressive orthogonal design method was adopted in the experiments on a S195 type diesel engine to obtain a suitable mixture ratio of rapeseed oil and diesel oil and the relationship among four working parameters (Intake-valve-closing angle, α;Exhaust-valve-opening angle, β; Fuel-delivering angle, θ;and Injection pressure, P) and specific fuel consumption in two working conditions of the engine when a blend of 30% rapeseed oil and 70% No.0 diesel oil was used as the diesel fuel. By means of optimization technique, the optimum working parameters for two working conditions of the engine using rapeseed oil/No.0 diesel oil mixture were selected. The methods and problems in using rapeseed oil as a diesel fuel are discussed in the paper. ■■

NEWS

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April 21-24, 2002
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Fax: + 32 (9) 264 58 45

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Further information

Dr. John F. Reid

John Deere Technical Center

3300 River Drive

Tel:+ 1 309-765-3786

Fax: +1 309-765-3807

Email:j-reid1@ux1.cso.uiuc.edu

Production of Agricultural Machineries in 2000
Italy

The year 2000 witnessed record production in the sectors represented by UNACOMA with 910,454 tons of tractors and machines for agriculture and gardening and 570,000 t of earth moving machinery.

New President of the European Committee of Agricultural Machine Constructor Associations

UNACOMA's president Aproniano Tassinari has been named as the next president of the European Committee of Agricultural Machine Constructor Associations, the unit which represents agricultural machine makers Europe-wide. Tassinari was named to succeed Belgium's Paul Snauwaert for a one-year term at a session of the committee's assembly at Knokke in Belgium on June 15.

At the same meeting, New Holland's technicaldirector Massimo Parenti was named to head the committee's technical commission, which works with the relevant EU bodies to define regulations for the sector.

☆ ★ ☆

New President of IAMFE

At a meeting on June 8, 2001, at the International IAMFE Centre in Uppsala, Sweden, the position as President of IAMFE was transferred to Mr. Kolbjørn Moskvil, Norway.

Launch of IAU

The Global Institute and Agricultural University Internet Hub

IAMFE and Semec are pleased to announce the launch of the IAU - the Global Institute and Agricultural University Internet Hub. IAU will be an umbrella for extended Internet services available to all persons wishing to enroll.

The web address is http://www.iau-hub.ws/. Core members are listed in the attachments. A charter is being drafted to provide operational status. Meanwhile, development of the site is being coordinated voluntarily by Torbjorn Leuchovius and John Stevens as a combined Iamfe - Semec activity. Assistance is being provided by Prof. Oyjord, Bjorn Anderson, Martin Mayer, Prof. Hill and Hampton, Bill Stevenson, Stuart Rose and Allan and Mike at cweb.co.nz (whose server we are using). Prof. Oyjord and SLU provided initial start-up funding and guidance needed to launch IAU. This has since been matched 1:1 with additional free on-line time and programming support provided by cweb, plus additional bridging finance from other private sources in New Zealand to keep things moving.

As can be seen from the enclosed Call for founding members the overall aim is to "Improve food production and security through on-line global networking for collaborative research, education and development. This includes institutional twinning, joint ventures, partnerships and associated activities. Poverty reduction and sustainable environmental management are major considerations"

The information on the IAMFE and SEMEC web sites will be reached also as integrated parts of the IAU website.

Dr. John Stevens, Secretary of the NZAust Branch of IAMFE, has agreed to be web coordinator for IAU. We believe that he will be the right person for this important new activity iniated by IAMFE and Semec.

IAU will be a major step forward in fulfilling the IAMFE goal to act as a modern global information network. It gives the possibility to all specialists and other interested persons that wish to use the Internet as a forum for advertising educational and training resources including distance learning, establishing professional relations and joint activities as well as for exchanging knowledge and ideas.

This include links to the web sites of Iamfe branches, their parent organizations and members, and the Iamfe global drilling and Seed technology help group. There will also be links to the Semec Global Fodder Oat Network (co-ordinated by Keith Armstrong at NZCFRI) and the Semec employment and careers opportunity hub (Secoh) co-ordinated by Bill Stevenson and Larry Hendricks. Secoh is due to come on-line next month. It contains url access to more than 150 consulting firms world-wide. Direct access to "employment sites" will be added later, plus facilities to store and retrieve CVs and post vacancies and other employment opportunities.

Two global co-ordinators plus other volunteers around the world are needed urgently to help us search the web by Country, build up and catalogue on line a portfolio of home-page urls and other useful pages from institutes, universities and other organisations and agencies of interest to IAU users. If you are interested, please contact John Stevens (stevensj@ihug.co.nz). To begin with, we are focusing on sites that are in English an/or contain English translations. This could be expanded, depending on the language skills of our co-ordinators and other volunteers, combined with the willingness of others to build and host multi-lingual sections of IAU. ■■


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M Z Bardaie


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William J. Cnancellor
Professor Emeritus, Bio. and Agr. Eng. Dept., Univ. of California, Davis, CA, 95616, U.S.A. TEL(+1)-530-753-4292,FAX(+1)-530-752-2640, E-mail:wjchancellor@ucdavis.edu.

Megh R. Goyal
Prof./Agric. Engineer, Dept. of General Engineering University of Puerto Rico, P.O.Box 5984, Mayaguez PR, 006815984, U.S.A. TEL(+1)-787-265-4702,E-mail:m-goyal@rumac.upr.clu.edu

Allan L. Philips
General Engineering Dept., University of Puerto Rico, P.O. Box 9044, Mayaguez, Puerto Rico 00681-9044, U.S.A.

Graeme R. Quick
Leader, Power & Machinery Section, 200 Davidson Hall, Agricultural and Biosystems Engineering Dept., Iowa State University, Ames, Iowa, 50011-3080 U.S.A.

-ASIA and OCEANIA-

Shah M. Farouk
Professor(Retd.),Farm Power & Machinery Dept., Bangladesh Agricultural University, Mymensingh 2200, BANGLADESH TEL(+880)-91-5695ext.2596, FAX(+880)-91-55810,E-mail:smf@bdcom.com

Mohammed A. Mazed
Director General, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, BANGLADESH

Manbahadur Gurung
Store Officer, Bhutan Fruit Products Limited, Samtse, BHUTAN TEL(+975)-65369

Wang Wanjun
Past Vice Director and Chief Engineer/Chinese Academy of Agricultural Mechanization Sciences, 1 Beishatan, Beijing, 100083, CHINA TEL(+86)-(0)83-001-6488-2710,FAX(+86)-(0)83-001-6488-2710,E-mail:wwj@isp.caams.org.cn

A.M. Michael
1/64, Vattekunnam, Methanam Road,Edappally North P.O., Cochin, 682024, Kerala State, S. INDIA

T.P. Ojha
Director General(Engg.) Retd., ICAR, 110, Vineet Kung Akbarpur, Kolar Road, Bhopal, 462 023, INDIA TEL(+91)-755-290045

S.R. Verma
Prof. of Agril. Engineering, College of Agril. Engg., Punjab Agricultural University, Ludhiana - 141004, INDIA TEL(+91)-(0)161-401960/439,FAX(+91)-(0)161-400945,E-mail:srverma@pau.chd.nic.in

Sarath Ilangantileke
Regional Representative for South and West Asia, International Potato Center(CIP), Regional Office for CIP-South & West Asia, IARI(Indian Agricultural Research Institute) Campus, Pusa, New Delhe-12, 110002, INDIA TEL(+91)-11-5719601/5731481,FAX(+91)-11-5731481,E-mail:cip-delhi@cgiar.org

Soedjatmiko
President, MMAI(Indonesian Society of Agricultural Engineering and Agroindustry), Menara Kadin Indonesia Lt.29 Jl. HR. Rasuna Said X-5/2-3 Jakarta, 12940, INDONESIA TEL(+62)-(0)21-9168137,7560544,FAX(+62)-(0)21-5274485,5274486,7561109

Mansoor Behroozi-Lar
Professor, Agr. Machinery, Ph.D, Tehram University Faculty of Agriculture, Karaj, IRAN TEL(+98)-21-8259240,E-mail:mblar@chmran.ut.ac.ir

Jun Sakai
Professor Emeritus, Kyushu University, 2-31-1 Chihaya, Higashi-ku, Fukuoka city, 813, JAPAN TEL+81-(0)92-672-2929,FAX+81-(0)92-672-2929,E-mail:junsakai@mtj.biglobe.ne.jp

Bassam A. Snobar
Professor and Vice President, Jordan University of Science and Technology, P.O.Box 3030 Irbid, 22110, JORDAN TEL+962-2-295111,FAX+962-2-295123,E-mail:snobar@just.edu.jo

Chang Joo Chung
Emeritus Professor, Seoul National University, Agricultural Engineering Department, College of Agriculture and Life Sciences, Suwon, 441-744, KOREA TEL+82-(0)331-291-8131,FAX+82-(0)331-297-7478,E-mail:chchung@hanmail.net

Chul Choo Lee
, Mailing Address: Rm. 514 Hyundate Goldentel Bld. 76-3 Kwang Jin Ku,Seoul, KOREA TEL+82-(0)2-446-3473,FAX+82-(0)2-446-3473,E-mail:ccsslee@chollian.net

Imad Haffar
Associate Professor of Agric. Engineering, Faculty of Agricultural Sciences, United Arab Emirates University, Al Ain, P.O. Box 17555, UAE TEL+971-506436385, FAX+971-3-632384, E-mail : haffar96@emirates.net.ae

Muhamad Zohadie Bardaie
Professor and Deputy Vice Chancellor (Development Affairs), Chancellory, Universiti Putra Malaysia, , 43400 UPM, Serdang, Selangor, Darul Ehsan, MALAYSIA TEL+60-39486053,FAX+60-3-9426471, E-mail:mzbd@admin.upm.edu.my

Madan P. Pariyar
Consultant, Rural Development through Selfhelp Promotion Lamjung Project, German Technical Cooperation. P.O. Box 1457, Kathmandu, NEPAL

David Boakye Ampratwum
Associate Professor, Dept.of Bioresource and Agricultural Engineering, College of Agriculture, Sultan Qaboos University, P.O. Box 34, Post Code 123, Muscat, Sultanate of Oman, OMAN TEL+968-513866,FAX+968-513866,E-mail:davidamp@squ.edu.om

ElTag Seif Eldin
Mailing Address: Dept. of Agric. Mechanization, College of Agriculture, P.O. Box 32484, Al-Khod, Sultan Qaboos University, Muscat,Sultanate of Oman, OMAN

Nawaf A. Abu-Khalaf
Engineer, the Project Directorate in Palestinian Agricultural Ministry, P.O.Box 405, Hebron, PALESTINE, Telfax: 972-2-2227846/7, E-mail: abukhalaf @ hebronet.com

Allah Ditta Chaudhry
Professor and Dean Faculty of Agric. Engineering and Technology, University of Agriculture, Faisalabad, PAKISTAN

A.Q.A. Mughal
Vice Chancellor, Sindh Agriculture University,Tandojam, PAKISTAN

Rafiq ur Rehman
Director, Agricultural Mechanization Reserch Institute, P.O. Box No. 416 Multan, PAKISTAN

Bherulal T. Devrajani
Professor and Chairman, Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam, Sindh, PAKISTAN TEL+92-2233-5594

Reynaldo M. Lantin
Professor, College of Engineering and Agro-Industrial Technology University of the Philippines Los Baños, Laguna 4031, PHILIPPINES TEL+63-(0)49-536-2792,FAX+63-(0)49-536-2873, E-mail:rmlantin@mudspring.uplb.edu.ph

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e. have a 50 to 100-word abstract, preferably preceding the main body of the article ;
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a. Article must be sent on 3.5 inch floppy disk with MS DOS format (e.g. Word Perfect, Word for DOS, Word for Windows... **Absolutely necessary TEXT FORMAT**) along with two printed copy.
b. The data for graphs and the black & white photographs must be enclosed with the article.
c. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features :
   i) brief and appropriate title ;
   ii) the writer(s) name, designation/title, office/organization ; and mailing address ;
   iii) an abstract following ii) above ;
   iv) body proper (text/discussion) ;
   v) conclusion/recommendation ; and a
   vi) bibliography
d. The printed copy must be numbered (Arabic numeral) successively at the top center whereas the disc copy pages should not be number.Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e.g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Figure 1. View of the Farm Buildings".
e. **The data for the graph must also be included.(e.g. EXCEL for Windows)**
f. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare(t/ha) and smaller units in kilogram or gram(kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies in US dollars and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.

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