International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.28, NO.3, SUMMER 1997

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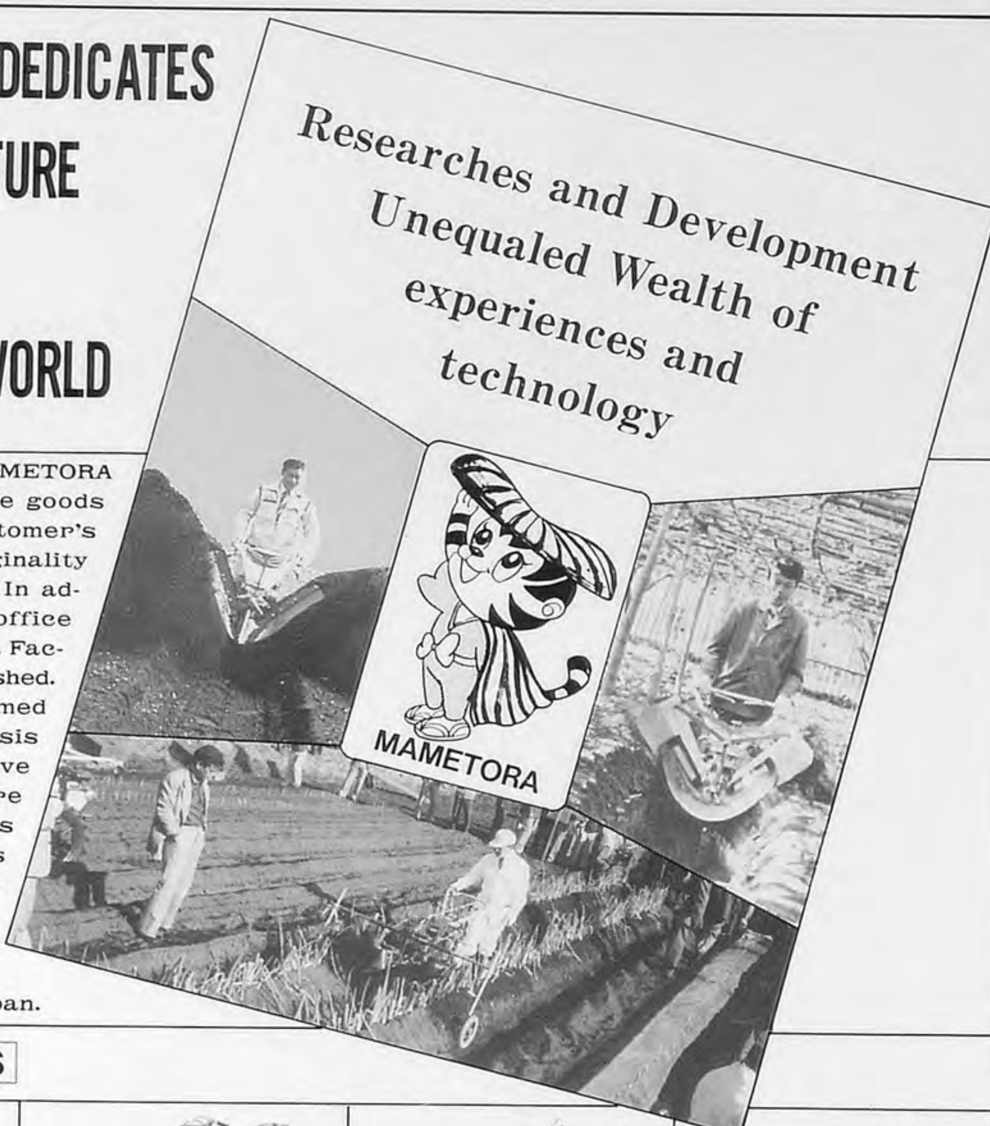

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Edited by

YOSHISUKE KISHIDA

Published quarterly by

Farm Machinery Industrial Research Corp.

in cooperation with

The Shin-Norinsha Co., Ltd.

and

The International Farm Mechanization Research Service

TOKYO

Editorial, Advertising and Circulation Headquarters
7, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo, 101, Japan

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

This is the 96th issue since its maiden issue in the Spring of 1971

EDITORIAL

In about two and a half years from now, the 21st Century will be upon us. And that length of time will soon come to pass. But much as we all want to be optimistic in seeing ahead of us a rose-colored New Century, the reality is that there are many problems that obscure our view.

Foremost among those problems is the widening gap in the race between food availability and the expanding population. Without having to cite any statistics, it is rather common knowledge that the magnitude of natural resources on a per capita basis is decreasing alarmingly each year. For example, farm lands in many countries continue to give way to deserts; forest covers disappear unabated, thus endangering the supply of water and energy, let alone the flooding in many places.

The other major problem has to do with the tendency of the rural youth to migrate to urban areas and, in the process, leaving behind ageing farmers and at the same time putting pressure on the earth's eco-system. This phenomenon and the consequent problems taht it breeds have been addressed time and agin in many national and international conferences without much visible accomplishments in terms of reversing the trend of rural migration from farms to towns and from towns to cities.

To be sure, the need to raise agricultural productivity is both real and urgent. And in order to meet this need head on, the widespread use of farm machineries and equipment has to be promoted and introduced as a public policy. Timely and precise farm work can only be achieved with the use of machineries. The situation is being aggravated by the fact that in many developing countries, even animal farm power is already in short supply.

The one irony about this situation is the fact that not too many farmers are financially able to buy and own farm machineries, especially those that have been designed and manufactured for their particular farming circumstances. This is why government policy makers and the banking systems are being challenged to give the small farmers a break — in the form of soft farm loans precisely for the purchase of machineries.

If the foregoing scenarios are not improved before the turn of the century, it will not be surprising to find that more and more people, sooner or later, will starve to death. And yet this tragedy can be prevented by increasing food availability through farm mechanization. This is the most important task of the agricultural engineers now and in the 21st century.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
July, 1997

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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* * *

Status and Constraints of Agricultural Mechanization in Kenya

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Abstract

For an agrarian and developing country like Kenya, the performance of the agriculture sector is of great concern. All factors influencing its productivity and development should be clearly understood by the Government. The role of mechanization in enhancing agricultural productivity is well recognized.

This paper reveals low level of mechanization in Kenya, particularly with the small scale farming community, where the use of hand tools is very common. Constraints facing agricultural mechanization technologies include land (tenure and fragmentation), capital, technological adaptability, product pricing structure and marketing, extension and adult education, problems related to transition to animal power, soil and water erosion, machinery operation and maintenance and lack of required infrastructure.

The paper recommends more support to the farmers by the Government in terms of financial and technical assistance and establishment of spare parts depot(s) and adaptive small-scale machinery manufacturing facilities as being some of the solutions.

Introduction

Like in most of the developing countries, agriculture will continue to play a major role in Kenya's development in, particularly, in view of the fact that the country has no major resources such as minerals for foreign currency earnings.

Apart from tourism and wildlife industry which of late has had some positive signs, agriculture is still a major foreign currency earning sector. A large portion of the country is arid / semi-arid and there is hence need for irrigated agriculture. Farm holdings are generally classified into two categories, namely; small and large scale types with a large percentage in the small scale category. In the pre-independence period and where land was not a limiting factor, subsistence / shifting cultivation was quite common with the small scale farmers. With increase in population, shifting cultivation has greatly been reduced.

The population as of the year 1992 was over 25 million and this is expected to rise to over 32 million by the year 2000. At least 70% of this is going to be in one way or the other employed by the agriculture sector. Employment opportunities and food self-sufficiency have not been favorable in the country for quite sometime now. The biggest challenges before the industry are hence meeting the growing demand of the food grains to feed the increasing population, ability to compete in quality and quantity wise in the world agricultural market in providing employment and ensuring that the country earns the required foreign currency. In order to achieve this, the productivity of both land and labor will have to be substantially increased and this will require both higher energy inputs and better management of the agricultural production systems.

Agricultural mechanization is a crucial factor influencing farm productivity and hence a clear understanding of its status, management and constraints is of vital importance. This paper presents the agricultural mechanization situation in Kenya, points out the main constraints retarding its development and recommends remedial steps.

Agricultural Potential

The total land area of Kenya is 582 000 km^2 and about 18% of this can be utilized for crop production. Agriculturally suitable land is mainly located in western part of the country. Mechanical and animal power farming methods are well developed in this region and crops such as coffee, tea, maize and beans are grown. Other crops grown in various parts of the country include wheat, rice, sugarcane and bananas. Agricultural production and means of production figures are given in **Tables 1** and **2**, respectively. The minimum annual per capita cereal requirement as estimated from references 10 and 20 for 1990s is 219 kg per capita cereal figures as given in **Table 1** are lower as compared to this minimum requirement indicating self-insufficiency in the country. The situation is even of more concern as the figures seem to show a general declining trend. Cereal growth rate averages 1.7% which is quite low compared to the population growth rates.

The most common soils found in some of the best agricultural areas are black cotton and dark red loamy soils. The black cotton soil becomes very soft during rainy seasons to such an extent that it prevents the use of tractors. During the dry season it becomes very hard and ploughs cannot penetrate it. It is hence a hindrance as regards to mechanization. The loamy soils have pH ranging between 5.5 to 6.5 and are suitable for coffee and tea production.

There are generally two rainy seasons in a year. The rainfall is, in most cases, unevenly distributed and heavy downpours of 50 mm or more within an hour are quite common in some parts of the country. High rainfall intensities are more common at low altitudes and result in soil erosions. The average rainfall figures are given in **Table 3**. Over 70% of the country's area is within the low potential category indicating the need for irrigation.

Kenyan farmers generally grow many of their crops in mixtures, the common ones being maize / beans, maize / beans / potatoes and banana / coffee. The trend is, however, to practice monocropping. Intercropping makes the use of machines almost impossible. There seems to be a trend towards small scale farming in many parts of the country. This is not preferable for farm mechanization.

Table 1. Population vs Agricultural Production During the Period 1970 to 1992

Year	1970	1975	1980	1985	1990	1992
Population (1 000)	11 500	13 750	16 640	20 600	24 030	25 850
Population growth (%)	—	3.3	3.5	4.0	2.8	2.5
Total cereals (1 000 t)	2 141	2 725	2 281	2 901	2 755	3 019
Cereal growth (%)	—	4.5	−2.7	4.5	−0.8	3.2
Root crops (1 000 t)	953	1 160	1 257	1 615	1 512	1 620
Oil crops (1 000 t)	17	20	26	20	25	26
Coffee (1 000 t)	57	72	89	94	104	90
Tea (1 000 t)	38	57	93	147	197	204
Total pulses (1 000 t)	267	292	185	177	235	235
Total meat (1 000 t)	194	217	281	312	389	352
Milk total (1 000 t)	914	968	1 070	1 513	2 473	1 954
Cattle (1 000)	8 433	9 609	10 418	12 000	13 793	11 000
Sheep (1 000)	3 935	3068	5 100	7 000	6 516	6 000
Goats (1 000)	4 237	4 167	7 761	7 500	8 000	7 500
Pigs (1 000)	62	61	89	95	105	105
Per capita cereal (kg)	186	198	137	141	115	117

Source: FAO production figures 1970/92

Table 2. Means of Agricultural Production (1970 to 1992)

Year	1970	1975	1980	1985	1990	1992
Tractors (40 kW)	6 379	6 063	6 440	10 000	14 000	14 000
Stationary* engines (9 kW)	639	606	644	1 000	1 400	1 400
Electric* motors (3 kW)	319	303	322	500	700	700
Draught* animals (0.373 kW)	21 694	23 599	25 504	27 409	29 314	30 129
Agric. active population (0.0373 kW) in (1 000)	4 199	4 883	5 729	6 614	7 033	7 645
Fertilizer (1 000 t)	46	50	61	109	116	95

*

Number of draught animals estimated from literature[6] (cultivated land by animals and estimated to be varying at an annual rate of 1.39%).
Stationary engines estimated to be a tenth of the number of tractors.
Electric motors estimated to be half of the number of stationary engines.
Source: FAO productoin figures 1970/92.
Statistical yearbooks 1970/92.

Table 3. Categories of Agricultural Land According to Rainfall (1 000 ha)

Province	High potential (857 mm or more)	Medium potential (735 to 857 mm)	Low potential (612 mm or less)	Total	All other land	Total land area
Central	909	15	41	965	353	1 318
Coast	373	796	5 663	6 832	1 472	8 304
Eastern	503	2 189	11 453	14 145	1 431	15 576
Nairobi area	16	—	38	54	14	68
North Eastern	—	—	12 690	12 690	—	12 690
Nyanza	1 218	34	—	1 252	—	1 252
Rift Valley	3 025	123	12 220	15 368	1 515	16 883
Western	741	—	—	741	82	823
Total	6 785	3 157	42 105	52 047	4 867	56 914

Source: Tokida K. (1987)

Agricultural Mechanization

The use of hand tools is quite common among the small scale farms category. A basic set of tools consists of a "panga", a shovel and a "jembe". These tools usually have wooden handles and can vary in shapes and sizes as illustrated in **Fig. 1**. Many of them are made of scrap metals and generally do not have standard professional design. They have low field capacities and are not

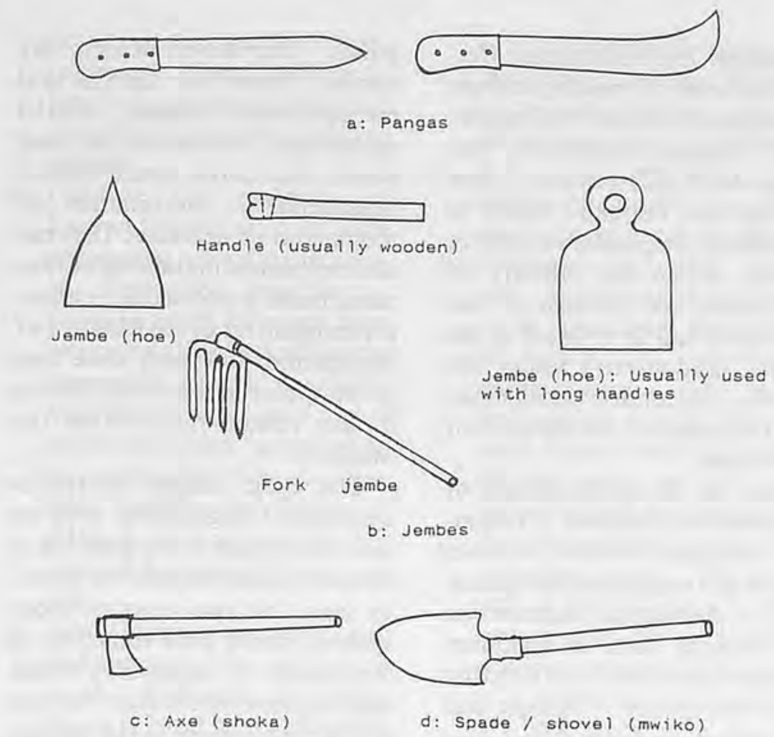

Fig. 1 Commonly used hand tools.

Table 4. Kenya's Agricultural Power (MW) Availability and Harvested Area of Maize, Wheat and Rice between 1970 and 1992

Year/Power source type	—	1970	1975	1980	1985	1990	1992
Human	—	313	364	427	493	525	570
beings	% of total	54	58	61	54	47	49
Draught	—	8	9	10	10	11	11
animals	% of total	1	2	1	1	1	1
Mechanical	—	262	250	265	411	575	575
power	% of total	45	40	38	45	52	50
Total power	—	583	623	702	914	1 111	1 156
Cultivated area (1 000 ha)	—	1 554*	1 624*	1 387*	1 529*	1 537**	1 545**
kW/ha	—	0.37	0.38	0.51	0.60	0.72	0.75

*Source: FAO production yearbooks 1970/85.
**Estimated from preceding figures at an annual expansion rate of 0.1%.

Table 5. Measures for Increasing the Net Crop Yields in Developing Countries

Criterion	Possible measures	Estimated potential yield increase (or potential reduction in loss)
Sowing technology	Modern soil cultivation and sowing techniques	15-35%
Seed quality	Use of appropriate and high yield seeds	30-150%
Chemicals	Mineral fert. and chemicals	50-500%
	Plant protecton products	100-300%
Harvesting technology	Modern harvesting machinery (e.g. combines)	20-35%
Water economics	Irrigation or sprinkling	50-500%
Number of harvests per year	Use of modern agricultural technology for carrying out work on schedule in peak periods	25-100%
Storage preservation	Modern storage and preservation techniques	10-50%
Transport	Effective handling technology matched to the local conditions	10-30%

Source: ARNO G. (1986).

efficient. The small scale farmer forms the bulk of the farming community, and coupled with the fact that agricultue is the backbone of the country, all measures have to be taken in ensuring that the productivity from this category is elevated.

Animal power farming is practiced in various parts of the country, particularly, in the western and eastern regions. The animals are generally used in pairs along with a moldboard plough. In an attempt to improve the performance in animal power farming, the University of Nairobi and Jomo Kenyatta University of Agriculture and Technology have carried out some research on harnessing systems for animal power. Results seem to encourage the use of the technology but this has to go along with more research, testing and extension.

Tractors and mechanically powered implements are far from private ownership for the small scale farmers and have mainly been provided through Government owned tractor hire services. This service has, however, been faced with many problems in the past, including lack of spare parts. It has also proved to be expensive and unreliable to the small scale farmers. Local manufacturing, particularly as regards to tractors, is still far from reasonable recognition. Changes in agricultural power availability within the period 1970 to 1992 are presented in **Table 4**. The table indicates higher figures for mechanical power. This is likely to be misleading as a number of mechanical units are usually grounded due to spare parts and other maintenance problems. Draught animal power is quite low and measures should be taken to improve it. Inspite of the relatively poor power and machinery maintenance, mechanization of most of the rainfed farming field operations of the large scale farmer is quite reasonable with all sorts of machines ranging from seedbed preparation to harvesting. Post-harvest and processing techniques still have to be improved.

Irrigation is practiced in various parts of the country even though it is being faced with a number of problems, including lack of funds for proper management. Irrigated agriculture has risen from 14 000 ha in 1965 to 55 000 ha in 1992 with most of it being under the National Irrigation Board (NIB). Various methods and equipment are used. With the high increase in population and hence need to produce more food, one of the solutions is expansion of arable land which is, in most cases, going to call for more irrigation undertakings by the public and private sectors.

Effects of various measures for increasing the net crop yields in developing countries have been reported (ARNO, 1986). **Table 5** gives some of the results from which it is noted that improvement in mechanization technologies can result in higher increases in productivity. Specific studies should, therefore, be conducted in Kenya.

Training in Agricultural Mechanization

As is realized by most engineers, in most of the developing countries the level of technological know-how in the rural areas is comparatively low. Any introduction of new technology whether improved hand-tool implements or animal or mechanically powered implements requires considerable extension effort. The front line extension / machinery maintenance workers usually receive 2 years certificate training in either general agriculture which will also cover some agricultural engineering courses or agricultural - mechanical engineering oriented courses after secondary school education. The institutions offering this level of training include the various certificate level agricultural training institutions and village level polytechnics. These workers are normally based in agricultural mechanization service stations within the Ministry of Agriculture even though of late some have had to be based at the district headquarters under the District Agricultural Mechanization Programs of the Ministry of Agriculture.

Next to the above group of personnel are Diploma / Technician Certificate holders in either agricultural engineering or agricultural / mechanical engineering. The training lasts a minimum of three years and is offered by some universities / colleges and national polytechnics. The 2-year certificate holders described above could, after thorough check up, be admitted for this training but usually the majority are freshers with relatively better grades. These diploma holders are normally stationed at the agricultural mechanization services stations or the divisional / district headquarters and are directly answerable to the station managers or divisional / district mechanization officers or engineers. Their duties usually include supervision of machinery repair / maintenance, soil / water conservation efforts, surveying and irrigation. Some could be absorbed as trainers in the certificate level training institutions.

The third category is the degree level group. These are trained within the national universities and elsewhere abroad. There are currently four universities offering B.Sc. in Agricultural Engineering. These are Nairobi, Egerton, Moi and Jomo Kenyatta University of Agriculture and Technology. Egerton and Jomo Kenyatta also offer diploma courses. Nairobi has M.Sc. programs and plans are under way to start doctoral programs. The B.Sc. holders are usually based at agricultural mechanization stations, district agricultural mechanization level where their duties would include managerial / coordination of mechanization activities. They can also be trainers in training institutions, based at provincial / national headquarters of the Ministry of Agriculture and with time and given opportunities could rise up to any related rank within the Ministry.

The B.Sc. degree course in agricultural engineering used to take three years in the past but it currently takes around five years. In their first two years or more students spend quite sometime in the faculty of engineering doing basic engineering courses. The rest of the time is spent in the faculty of agriculture covering agriculture and agricultural engineering courses. The courses are mainly divided into:

(a) Basic and applied agriculture
(b) Land and water engineering
(c) Agricultural machinery engineering and mechanization
(d) Agricultural process engineering and post harvest technology
(e) Agricultural structures and services

Constraints Facing the Agricultural Mechanization Process

The development of meaningful agricultural mechanization process is faced by a number of drawbacks as follows.

(a) *Land:* Constraints related to land include fragmentation due to physical causes such as terraces and tenure. Tenure is a direct result of the lack of an effective land consolidation policy as well as other factors such as laws of inheritance. Other land problems are topography and shape which affect mechanization from safety in operaton and difficulties in machine maneuverability process. Farm holdings in Kenya are getting smaller and this affects the mechanization process.

(b) *Capital:* The majority of Kenyan farmers are small scale and cannot afford the relatively expensive machinery. Product prices have not been increasing at a rate enabling the ownership of the machines. Machinery and spare parts prices have been increasing to the extent that even the large scale farmers are finding it difficult maintaining the ones at hand let along buying new ones.

(c) *Adaptability of mechanization technologies:* Like with most of the developing countries, Kenya is faced with a challenge consisting of the compelling need to accelerate economic growth by overcoming the greatly inhibiting cultural, institutional and political barriers. To be able to translate that challenge into a series of concrete steps, administrators and planners should be acquainted with the specific conditions that govern the production system and are capable of professionally recommending the appropriate technology perfectly fitting the conditions. In a number of cases technologies are copied exactly from their source without any awareness of the new setting in which they are to be applied. In addition to this, many of the introduced technologies are usually initially manned by experts who might not be in a position to transfer the necessary operational and maintenance know-how to the locals. The final result is failure in the technology transfer.

(d) *Product price structure and marketing:* Most of the agricultural products are faced with fluctuations in prices and marketing problems. Product prices have not been compatible with agricultural machinery prices and marketing even within the country has sometimes not been encouraging.

(e) *Extension and adult education:* These programs still have to be improved particularly in regards to agricultural mechanization. Well trained agricultural workers have to work directly with the farmers for best results and they must be particularly knowledgeable.

(f) *Problems related to transition to animal power:* The transition to animal power is often easier than to mechanical power since many farmers have some experience with animals but little if any with tractors. There are, however, instances where cattle herding and crop cultivation are separate endeavors practiced by different cultures of people. Cattle herders may be reluctant to become cultivators although hand crop farmers would like to adopt and utilize some animal power. Cattle diseases cause problems in some parts of the country and drought sometimes results in lack of natural grasses for animal feed hence affecting their health and performance.

(g) *Soil and water erosion:* These are serious problems in some parts of the country and contributing factors include high intensity rainfall, steep slopes, erosive soils, rapid decay of organic matter, arid conditions during some period within the year, overgrazing and intensive cultivation. Improperly used implements and greater animal or mechanical power may contribute to erosion.

(h) *Operation and maintenance:* Spare parts have sometimes been difficult to find particularly with some models. Prices have also been beyond the affordability of farmers. Lack of knowledgeable and skilled mechanics and operators has sometimes been a drawback.

(i) *Research, testing and data unavailability:* The universities and Ministry of Agriculture have been involved in research, testing, and data colleciton. There is, however, still more to be carried out in this area. Information related to numbers, types, uses and applications of machinery / power sources is to be continuously made available. Research into the adaptability of machine systems to local conditions and its evaluation and feasibility assessment should be exhausitively conducted.

(j) *Lack of ideal infrastructure:* Poor infrastructure in many areas results in slower and inefficient utilization of service facilities, delays the prompt handling of farm products, poor timeliness of operations and reduction in technology transfer.

Conclusion

(a) Kenya is currently self-insufficient as regards to food production and all measures need to be taken to ensure that the situation is altered.

(b) Detailed research studies on the effect of agricultural mechanization on small scale farmer's productivity should be conducted.

(c) Population growth rate should be reduced to a figure much lower than the to be raised to average cereal production growth rate.

(d) Training facilities in agricultural mechanization training institutions should be improved along with efforts to ensure effective extension.

Recommendations

The importance of agricultural mechanization as a tool for development has been realized and all measures are being sorted in enhancing the technology. This paper recommends the following:

(a) The Government and other organizations should give more support to the farmers and, in particular, in terms of financial and technical assistance.

(b) There is still more to be done in form of establishment of service, training, research and extension centers.

(c) Spare parts depots and adaptive small-scale machinery manufacturing facilities should be established.

(d) Market demand and product price structure should be analyzed to ensure that it encourages production.

(e) Establishment of agricultural machinery custom-hire facilities, cooperatives and improvement of infrastructure.

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Research in Dynamic Simulation of Separating-Planting Mechanism of Rice Transplanter

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Abstract

In this paper, errors in traditional dynamic analysis of separating-planting mechanism of rice transplanter are pointed out. Methods to set up the dynamic model and to simulate its dynamic properties by computer were studied. The new model was established by use of which the authors obtained the theoretical resuls which were quite close to test results.

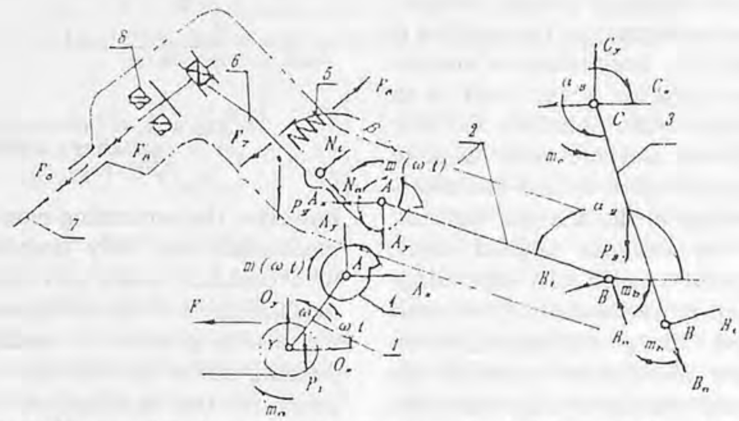

Fig. 1 Diagram of the forces applied to the separating-planting mechanism of rice transplanter.

Introduction

The separating-planting mechanism (**Fig. 1**) is the main unit of a transplanter the performance of which determines transplanting quality, functional reliability and planting frequency and planting times per minute. A computer was used to simulate the dynamic characteristics of the separating-planting mechanism, and the model estalblished could provide tehoretical basis for optimizing the design parameters if it was verified that simulating results of the model are fairly close to actual condition by test.

In the last 10 years, although many researchers have studied the dynamic analysis of separating-planting mechanism, all of their theoretical models deviate from the test results. In this paper, the methods of traditional dynamic analysis and simulation were evaluated, and the new method, which could improve the feasibility of simulation is proposed.

Evaluation of Traditional Methods of Simulation

Since the crank - and - rocker unit of the separating-planting mechanism of a rice transplanter was introduced, a lot of studies on its dynamic analysis have been carried out. The methods used could be classified in two: the mass centre path method and the applied force method.

The Mass Centre Path Method

The mass centre path method seeks the mass centre positions of mechanism in an action cycle by the use of a graphic or analytic method. The closed curve ring of mass centre path is drawn, and action stability and vibration property of mechanism are evaluated in accordance with the ring size. In fact, the dynamic characteristics are indirectly analyzed by the use of mass centre displacement. The difficiency of this method is that neither the acceleration of mass centre nor the sources of vibration (the variations of rotation centres of the crank - and - rocker, and the fluctuation of applied force on driving chain) is studied.

The Applied Force Method

The original applied force

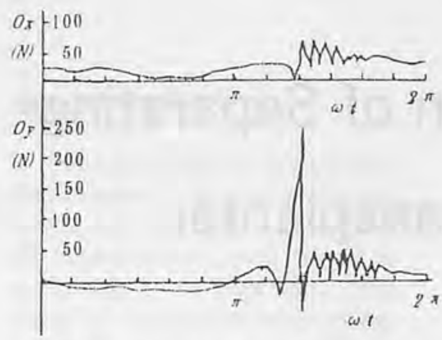

Fig. 2 Measured relation between rotating angle of crank and O_x or O_y (rotating crank speed is 200 rpm).

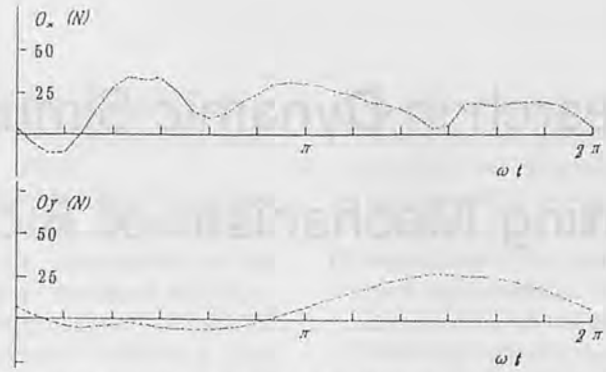

Fig. 3 O_x and O_y of theoretical analysis when the separating-planting mechanism was simplified to a common crank - and - rocker mechanism and the influence of seedling-pushing device was neglected. (speed of crank was 200 rpm.)

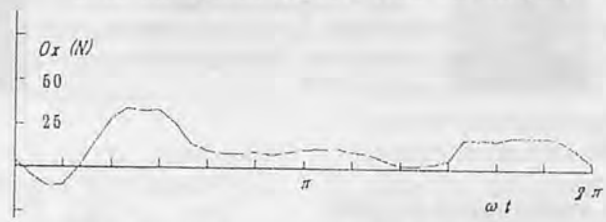

Fig. 4 O_x of theoretical analysis when the driving force was simplified as a driving torque. (rotating speed of crank was 200 rpm.)

method seeks to find the applied forces on every hinge and chain when the crank is at several different positions within an action cycle by means of graphic method. The inadequacy of this method is that it is impossible to analyze every position of the crank in an action cycle. Analysis is very difficult and the error is quite large. Besides, it also has shortcomings in the analytic method.

The analytic applied force method is to simplify separating-planting mechanism to the crank - and - rocker mechanism, set up plane coordinates, establish the dynamic model of the mechanism on the basis of kinematic analysis, work out a program, and find the driving torques and applied forces on every hinge by computer.

The cyclically varied value of the applied forces on vibration sources are directly obtained. Out of question, this method is much more advanced than the original applied force method. However, the dynamic curves which are close to the test results **(Fig. 2)** have never been gained when this method was used owing to the following causes:

(a) The seedling-pushing device in the planting arm produces fairly great impulsive force at the end of seedling-pushing process. According to the test result, the largest applied forces on hinges which are caused by the impulsive process are about 7-8 times of those produced in other processes. In the original analysis, however, the separating-planting mechanism was only simplified to a common crank and rocker mechanism, and the influence of the action process of seedling-pushing device on the force applied to the mechanism was neglected. Comparing **Fig. 3** with **Fig. 2**, O_x is similar, but O_y changes greatly (The impulsive force has disappeared.). This simplification, therefore, had caused big errors in evaluating the performance of the separating-planting mechanism.

(b) The separating-planting mechanism is driven by the chain in the form of force. However, for simplifying the problem, the force is replaced by a driving torque in the original analysis. It has little influence in O_y but has great influence in O_x that the driving force was simplified as a driving torque **(Fig. 4)**.

(c) The frictional torque on the hinges connecting the two neighbouring rods, which rotate non-directionally, were ignored in the original analysis. In fact, the frictional torque is considerable because of the effect of the gland, and it will bring about fairly big errors to neglect it.

Study on Dynamic Simulation of the Mechanism

Most of the above-mentioned problems have never been put forward in the works concerning mechanical principle and computer model design of common mechanism. For this reason, the present probe is being carried out.

Analysis of Driving Force

Chain transmission acts on the separating-planting mechanism in the form of force. If torque is used to simulate the driving of chain, the following problems will be encountered.

(a) The difference between the force applied by the chain and torque is that the force acts on rotating centre a force equivalent to the magnitude and direction of action of torque on the mechanism, which fluctuates with the change of driving force in an action cycle and cannot be ignored.

(b) When the mechanism is

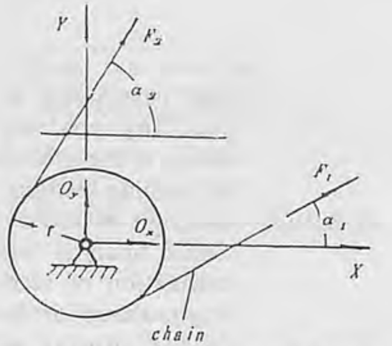

Fig. 5 Dynamic analysis of chain driving.

driven by inertia the applied force changes from F_1 to F_2 (**Fig. 5**). If the torque is used to simulate the driving of chain, it is impossible to express this kind of variation.

(c) If the original matrix method is used, a negative F_1 instead of F_2 will be obtained when the motion of mechanism relies on inertia, which is inconsistent with the actual situation (**Fig. 6**). For this reason, the dynamic equations should be solved one at a time, insert the judging process (The computer program flow chart of which is shown in **Fig. 7**) after the torque has acted on the mechanism by the chain has been found, and seek out O_x and O_y which are applied to the crank shaft in X and Y direction of the chain.

Fig. 6 O_x of theoretical analysis when the original matrix method are used. (rotating speed of crank is 200 rpm.)

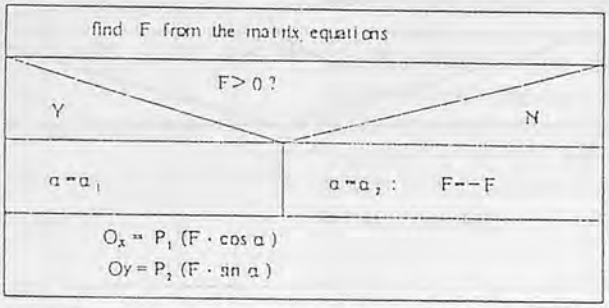

Fig. 7 Flow chart of program to find the applied force on the rotation centre of crank.

Dynamic Analysis of Seedling-Pushing Device

The seedling-pushing device is in the cavity of the planting arm which is of plane movement as well as rotation. Moreover, this device rotates around a certain point of the planting arm. As a result, its absolute motion is a complex movement, and the establishment of its dynamic model is very difficult to do. In order to solve this problem, the nonlinear differential equations of complex motion of rigid body in explanatory form were put forward, and the equations for plane motion of rigid body were given by

$$\Sigma F_{xj} = M\,[\ddot{O}_x - (\ddot{\theta}_z - \ddot{\alpha}_z)\,R_{cy} - (\dot{\theta}_z + \dot{\alpha}_z)^2\,R_{cx}] \quad (1)$$

$$\Sigma F_{yj} = M\,[\ddot{O}_y + (\ddot{\theta}_z - \ddot{\alpha}_z)\,R_{cy} - (\dot{\theta}_z + \dot{\alpha}_z)^2\,R_{cy}] \quad (2)$$

$$\Sigma(F_{yj}.L_{xj} - F_{xj}.L_{yj}) = (\ddot{\theta}_z + \ddot{\alpha}_z)\,J_z + M(\ddot{O}_y.R_{cx} - \ddot{O}_x.R_{cy}) \quad (3)$$

F_{xj}, F_{yj} — forces applied to the carried alogn axis X and axis Y
M — mass of the carried
$\ddot{O}_x$, $\ddot{O}_y$ — accelerations of the hinge connecting the carrier and the carried along axis X and axis Y
L_{xj}, L_{yj} — X and Y coordinates of the point on the carrier where the applied forces along axis X and axis Y act. (The coordinate system is fixed on the carried.)
$\dot{\theta}_z$, $\ddot{\theta}_z$ — angular velocity and angular acceleration of the carried
J_z — moment of inertia when the carried rotates about the hinge.
$\dot{\alpha}_z$, $\ddot{\alpha}_z$ — angular velocity and angular acceleration of the carrier

Calculation of the Non-directional Frictional Torque

It is easy to determine the frictional torque between the crank and its shaft because its rotation is directional, and the frictional torque on the hinge of crank and planting arm, in large measure, is caused by the effect of seedling-pushing cam, that has been obtained by test. However, the direction of the frictional torque on other hinges can be ascertained only by determining the direction of the relative angular velocity of the two neighbouring rods. The frictional torque is a non-linear function of the applied forces on the hinge. Though the number of unknowns in the dynamic equations has not increased, it becomes a non-linear equation system. Therefore, it becomes more complicated than before. The iterative calculations of improved Eular's method are carried out. If the initial value of Mi equal zero, the convergence speed of iterative calculation is very fast. The following is the flow chart of program

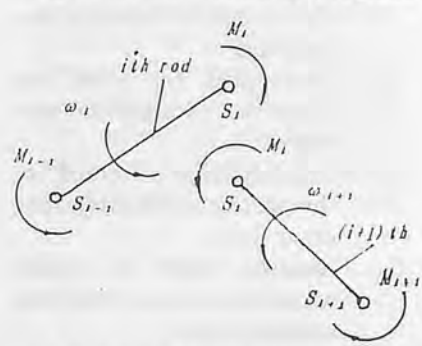

Fig. 8 Setting of the frictional torque on hinge connecting the two neighboring rods.

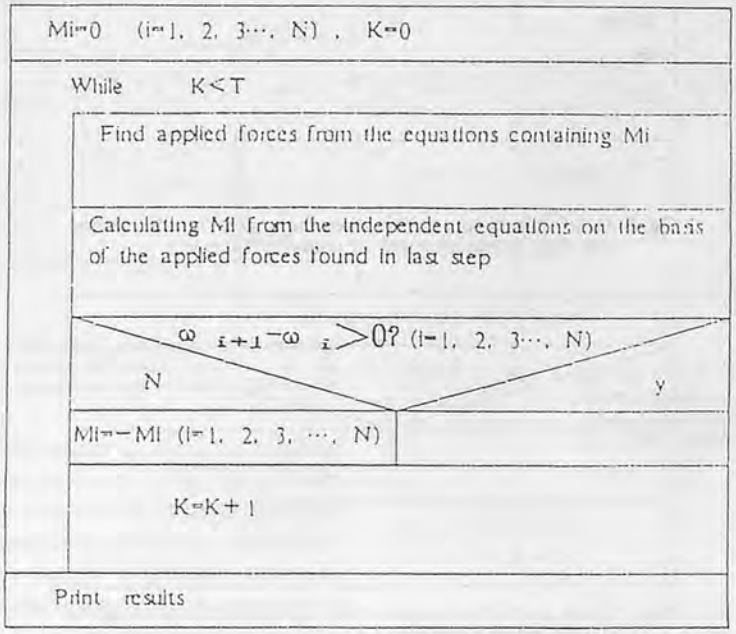

Fig. 9 Flow chart of the program to calculate the applied forces and torques after taking the frictional torques into consideration.

for iterative calculation (**Fig. 9**).

Where:

ω_i - angular velocity of the rod

T - given times of iteration

N - number of rods

M_i - frictional torque on the hinge connecting the ith rod and the (i + 1)th rod

Calculation Results and Test Verification

Where:

AR - rotating angle of shifting fork in the process of pushing the seedlings

GG - position order of the crank of separating-planting mechanism

T_5 - time spent for shifting fork to get a certain position in the process of pushing the seedlings

T_6 - time spent for crank to rotate by an angle of one degree

G_5 - rotating angle of crank in the process of pushing seedling starts

G_6 - rotating angle of crank when the process of pushing seedling starts

G_1 - rotating angle of crank

F_5 - frictional force applied to seedling-pushing rod

F_6 - force appied to shifting fork by spring

F_7 - damping resistance applied to shifting fork by the oil cavity of planting arm

F_8 - impact force between seedling-pushing rod and pad

NN - force applied to shifting fork through the hinge by planting arm, which are along the direction of shifting fork

NT - force applied to shifting fork through hinge by planting arm, which are vertical to the direction of shifting fork

A_6 - the largest rotating angle of shifting fork

M_2 - mass of planting arm, including the mass of shifting fork and seedling-pushing rod

M_5 - mass of shifting fork

M_6 - mass of seedling-pushing rod

SUBprog1 - program for the kinematic analysis and calculation of separating-pushing mechanism

SUBprog2 - program for the kinematic analysis and calculation of seedling-pushing device in the process of pushing seedling

SUBprog3 - program of the dynamic analysis and calculation of seedling-pushing device in the process of pushing seedling

SUBprog4 - program of the dynamic analysis and calculation of the impact force between seedling-pushing device and pad at the end of the process of pushing seedling

SUBprog5 - program for the dynamic analysis and calculation of separating-planting mechanism

Inputting the parameters of the separating-planting mechanism of 2ZT-935 rice transplanter, O_x and O_y by are calculated means of the dynamic model set up on the basis of the above-mentioned study. The flow chart of the program for analyzing and calculating the dynamic properties of separating-planting mechanism is shown in **Fig. 10**. **Fig. 11** shows the results of calculation. Under the condition of no load, O_x and O_y were measured on the testing table (shown in **Fig. 2**). Through comparison, the calculated r esults and the test results were almost identical. This shows that the computer model established is fairly close to the actual condition, and could be used to optimize the design parameters of the separating-planting mechanism.

Conclusions

1. The method, used for setting up the dynamic model of separating-planting mechanism, is also suited for establishing dynamic model of other common

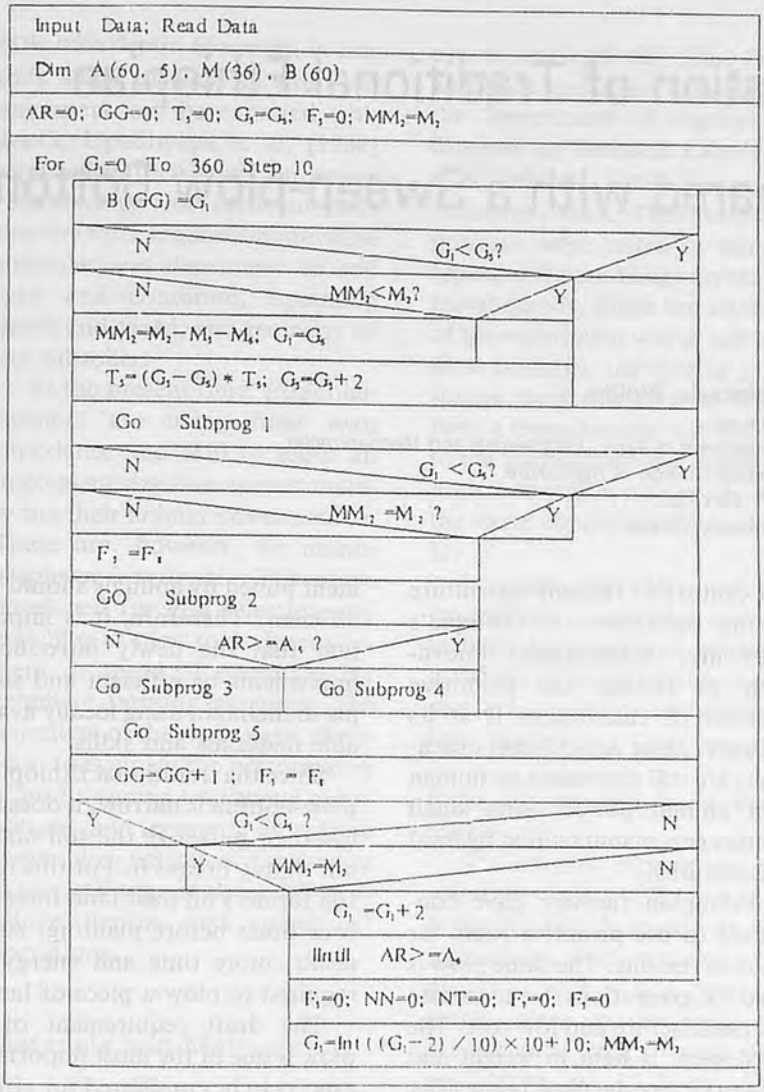

Fig. 10 Flow chart of the program for analyzing and calculating the dynamic properties of separating-planting mechanism.

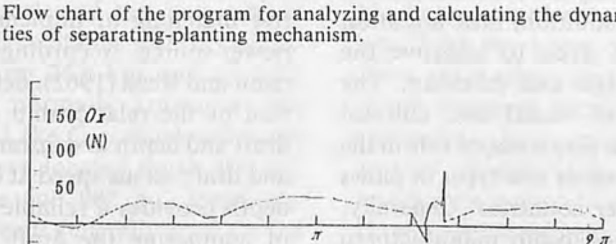

Fig. 11 Theoretical relation between the rotating angle of crank and O_x or O_y. (rotating speed of crank was 200 rpm)

mechanisms.

2. It is not sufficient to optimize the design parameters of separating-planting mechanism merely in the light of synthesizing the motion path of claw gripper, angle of gripping, and entrance angle of claw gripper. The dynamic properties of it must be considered. Now, for both the kinematic and dynamic analyses included in the computer model, it could be used to optimize the design of the lengthes of rods in separating-planting mechanism, the relative position of rotation centre of crank to rotation shaft of rocker, and so on.

3. The dynamic model needs to be improved continuously in the application.

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Performance Evaluation of Traditional Ethiopian Plow-bottom Compared with a Sweep-plow Bottom

by
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Abstract

A study was conducted at Stillwater, Oklahoma, USA, to evaluate the performance of a traditional Ethiopian tillage bottom in comparison with a sweep-plow bottom. These plow bottoms were tested in three depths and speeds of operations in sandy loam soil. The study revealed that the draft of these two plow bottoms was significantly affected by speed and depth. The average draft requirements of the sweep and traditional plow bottoms was found to be 1.27 and 1.1 KN, respectively. Besides, a sweep-bottom was observed to have lower specific draft requirement than the traditional plow bottom.

Introduction

The plow is a tillage tool that is highly associated with the development and history of human beings over the centuries. In recent decades, improvements and innovations in designs and materials have resulted in the production of efficient modern plowing implements.

Ethiopia is a country where 90% of the agricultural practices are done using primitive tools and methods which have been in use for centuries. Though agriculture is the backbone of Ethiopia's economy, technological innovation to change the primitive method of cultivations is at its infancy. Most agricultural operations are still dependent on human and animal power using small implements manufactured by local blacksmiths.

Ethiopian farmers have continued to use primitive tools for various reasons. The same plow is used for generations due to its ease of manufacture and low cost. The implement is light in weight and farmers carry the plow home after work. In addition, little attention has been given to improve the plow design and hitching. The strength of social and cultural bonds also play a major role in the introduction of new types of plows from other countries. Generally, the range of locally manufactured animal powered implements is too limited and the equipment is poorly designed and made. According to Goe (1987), research on animal drawn implement has been carried out in Ethiopia since the 1950s. However, follow up and evaluation of implement performance at the small-holder level has often been limited in scope. Moreover, Smith (1981), emphasized the importance of improving simple implements, and stated that equipment pulled by animals should be efficient. Therefore, it is important that the newly introduced implements be efficient and simple to maintain using locally available materials and skills.

Since the traditional Ethiopian plow-bottom is narrow, it does no invert or pulverize the soil mass, but simply breaks it. For this reason farmers till their land three to four times before planting. As a result, more time and energy is required to plow a piece of land.

The draft requirement of a plow is one of the most important aspects to be considered for effective matching of implement and power source. According to Harrison and Reed (1962), determination of the relationship between draft and depth at constant speed, and draft versus speed at constant depth provides a reliable method of comparing the draft requirements of two or more similar implements. Plows are frequently compared to each other in terms of their ability to invert the soil in addition to draft requirement per unit width of tillage. Reaves and Schafer (1975) compared three geometrically similar moldboard bottoms in four different soil types by varying the speed and depth. They concluded that for normal operating depths, 20 to 25 cm, the specific draft requirement changes little with depth. However, in clay soils some increase in draft requirement can be expected with depth. Upadhyaya et al. (1984) reported in their study on power requirements for different soils that the force required to move the subsoiler was dependent on soil type and condition, operating depth and speed, and geometry of the subsoiler.

At the present time, Ethiopian farmers are using their own experience and skill to select an implement size that approximately fits their animal power source. There are, however, no nomographs or functional relationships developed for best selection and matching of plow to draft requirement or speed of operation for primitive farming practices. The objectives of the study were, therefore, to evaluate the performance of an Ethiopian traditional plow-bottom and compare it with a sweep-plow bottom of similar size in one soil type at three different tillage depths and speeds of operations.

Materials and Methods

The selected test area was at Oklahoma State University Blackwell farm 25.6 km west of Stillwater, normally known as the Upper Lake Carl Blackwell water shed area located north 30° 03′ latitude and 98° 40′ longitude. This area is generally good for the cultivation of crops, though it is affected by occasional severe flooding. The area is dominated by port silty loam, known as fine silt, mixed, Thermic, Cumulic Haplustol.

The Ethiopian traditional plow bottom is tapered at one end and weighs 1.5 kg with a nose angle of 20°. At the widest point, it measures about 5.75 cm and was 2.54 cm thick. A sweep-plow bottom was 11.43 cm wide with a nose angle of 40°. The frame and other accessories were made in the Department of Agricultural Engineering Research Laboratory at Oklahoma State University, Stillwater, USA. These two plow bottoms were tested in one soil type at different tillage depths and travel speeds. Since the intention of the experiment was to test these plow bottoms, the type of power source used was tractor. Therefore, a sweep bottom was attached to the traditional plow frame and both bottoms were tested under the same conditions (**Figs. 1** and **2**).

In order to carry out this experiment a computer program in basic language was written to assist the data collection process and was saved on diskettes for later analysis.

Field Layout and Land Preparation

A factorial experiment with split-plot design of 2 plow types, 3 depths and 3 speeds in three replications which made up a total of 2 × 3 × 3 × 3 = 54 experiments were carried out. The experimental area of each block was 10.98 × 15.25 m^2 Three blocks were randomly selected *in-situ*. Each block was divided into three main plots that were randomly assigned for three depths treatments. Each main plot was further divided into sub-plots which were randomly assigned for three speed treatments. The sub-plots were again divided into two sub-sub-plots for two plow types, which were the Ethiopian traditional plow and the sweep-plow bottoms.

Draft Measurement

A drawbar (BLH) load cell with a manufacturer's rated capacity of 500 lb (2.224 KN) was used to measure the draft requirement of these two plow-bottoms. The load cell was held in a horizontal posi-

Fig. 1 Ethiopian traditional plow bottom.

Fig. 2 Sweep-plow bottom.

Fig. 3 Tractor attachment and instrumentation set up.

tion between a rectangular frame and was designed to slide along the vertical frame to regulate the height of the hitch point off the ground (**Fig. 3**).

The output of the load cell was logged into the analog to digital converter (ADC-1 Remote Measurement Systems) via a low pass filter (**Fig. 4**). The converted digital signals were sent to a Tandy (Radio Shack) lap top computer via RS-232 cable. Previous research results by Young et al. (1984) and Summers et al. (1985) indicated that the cyclic variations in the draft could be seen with a pattern of approximately 2 Hz and 10 Hz. Further research study conducted by Erickson et al. (1982) suggested that frequencies above 12 Hz are insignificant. Therefore, the first order low pass filter was designed using 10 000 ohm resistor and 1 μf capacitor for a cut off frequency of 15 Hz. For this experiment a sampling frequency of

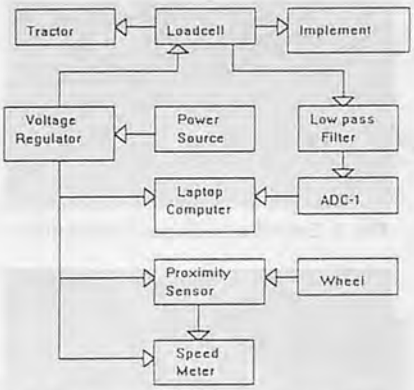

Fig. 4 Block diagram of the instrumentation system.

60 Hz at 11 bit resolution was used to collect data over a travel distance of 15.25 m. Hence, 688 samples at the fastest speed of 1.33 m/sec, 1 028 samples at 0.89 m/sec and 1 365 samples at the slowest speed of 0.67 m/sec were recorded at intervals of 0.0166 seconds per sample (**Fig. 5**). These readings were converted to draft using the calibration equation and an average was computed (**Table 1**).

The power source for this instrumentation was an automotive battery with an output of 12 volts. The source was connected to the tractor battery charging system to keep it charged throughout the data collection. A voltage divider was built to reduce the 12 volts output of the battery to 10 volts used by the lap top computer and ADC-1 and 9.7 volts used for excitation of the load cell.

Speed and depth are the most important parameters for the evaluation of implement draft requirements. An optical proximity sensor GX-18H and a rate meter (speed meter) with a five-digit display was used for speed measurement. The sensor was attached to the bearing frame of a rubber wheel that has a diameter of 30.48 cm and the wheel and sensor assembly were trailing behind the tractor. Each time the wheel rotated, the sensor perceived the head position of a bolt fixed to a rotating wheel and a signal was sent to the rate meter to display rotational speed (rpm) of the rubber wheel. The sensor was activated by a 12-volt input from the tractor battery, and was reset by a single pole switch which could be turned "on" and "off" as required. The selected tractor speeds for the test were 0.67 m/sec, 0.89 m/sec and 1.33 m/sec and it was calibrated on concrete surface. The speed of the tractor was regulated by adjusting the hand throttle until the required revolutions per min (rpm) was displayed on the rate-meter.

The tractor and implements were run through a 15.25 m test plot and operated at depths in the

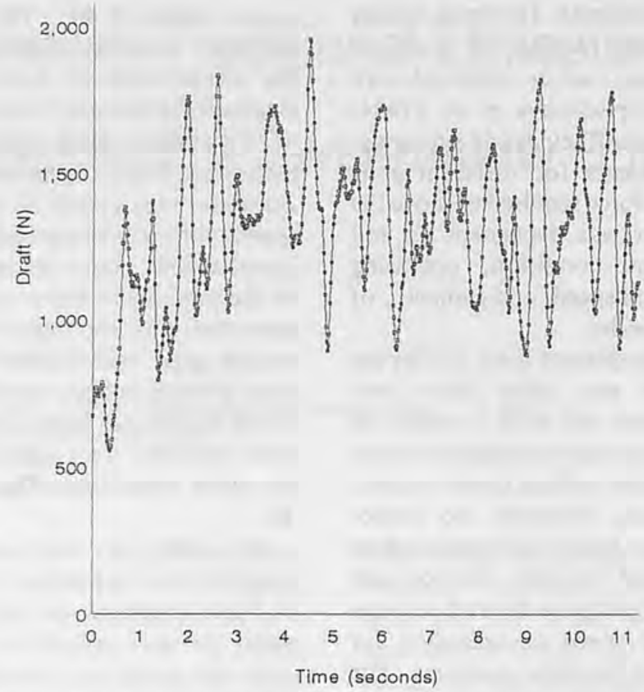

Fig. 5 A typical draft vs. time pattern for a sweep-plow bottom at 1.33 m/sec.

Table 1. Draft Requirement of the Two Plow Bottoms at Different Speeds and Depths

Item					Speed of Operations						
					S_1* = 0.67 m/sec		S_2** = 0.89 m/sec		S_3*** = 1.33 m/sec		
Plow bottom type	depth of tillage (cm)	moisture content (%)	dry bulk density (g/cc)	width of cut (cm)	draft (N)	draft/ width (N/cm)	draft (N)	draft/ width (N/cm)	draft (N) (N/cm)	draft/ width (N)	Grand average
Traditional	6-8	14.95	1.44	6.12	739	121	912.3	149.07	1 074	175.49	
	8-10	16.04	1.57	6.12	1 015	165.85	1 002	180.07	1 298	212.09	
	10-12	16.52	1.69	6.12	1 090	178.11	1 290	210.78	1 370	224.18	
		Average draft			948		1 068.1			1 247.3	1 087.8
Sweep	6-8	14.95	1.41	7.734	963	124.52	1 063	137.45	1 230	166.89	
	8-10	16.04	1.57	7.734	1 123	145.2	1 323	171.06	1 390	179.73	
	10-12	16.52	1.69	7.734	1 162	150.24	1 500	193.95	1 650	213.34	
		Average draft			1 082.67		1 295.3		1 423.3		1 267.1

Key: *- average of 1 365 observations.
**- average of 1 028 observations.
***- average of 688 observations.

range of 6-8, 8-10 and 10-12 cm. The average moisture content of the soil for these three depth measurements was 18.4% which was within an acceptable range for cultivation. For each furrow length, 11 depth and width measurements were taken at an intervals of 1.50 m using a steel rule and an average was computed.

Results and Discussion

The analysis was done using MSTAT and SYSTAT statistical packages. Draft was significantly affected by these three treatments, speed ($p<0.01$), depth ($p<0.05$), and plow bottom types ($p<0.01$). However, for this particular experiment interaction among the treatments did not affect the draft significantly. Therefore, it was highly likely that the draft of the two plow types was affected by speed and depth of operation. This result was quite identical with the findings of other researchers on tillage implements (Row, et al. 1961).

The draft of the two plow bottom types versus depth at different speeds of operation is shown in **Figs. 6** and **7**. A regression line was fitted for each speed treatment and a Chow test was done to investigate the effect of speed on draft **(Table 2)**. The analysis shows that the computed F-value was greater than the tabulated value implying that the three regression lines on **Figs. 6** and **7** were completely independent and the effect of the speed on draft was highly significant. This output of the Chow test further strengthened the result that was deduced from the analysis of variance. Similarly, Upadhyaya et al. (1984) have found out that the effect of speed on draft was high. This indicated that increased speed might result in more rapid acceleration of the soil mass which eventually increased the normal load on the soil engaging surface due to frictional force and the kinetic energy imparted to the soil.

Moreover, a pair of comparison of draft was carried out for each treatment of the main plot, sub-plot and sub-sub-plots to evaluate their level of significance. Accordingly, a comparison of draft averaged over all speeds and plow types among the three depths was done. The mean draft difference between depth-1 and depth-2 was highly significant ($P<0.01$).

Table 2. Regression Results for Draft of the Two Plow Bottoms

Plow bottom type	Speed* (m/sec)	Constant	Slope	r^2
Traditional	S_1	0.001 (0.108)	0.102 (0.011)	0.92
	S_2	0.17 (0.231)	0.096 (0.024)	0.71
	S_3	0.341 (0.212)	0.148 (0.02)	0.89
Sweep	S_1	0.201 (0.276)	0.09 (0.028)	0.60
	S_2	1.184 (0.621)	0.225 (0.056)	0.70
	S_3	0.104 (0.317)	0.121 (0.029)	0.72

*Speed:
S_1 - 0.67 m/sec.
S_2 - 0.89 m/sec.
S_3 - 1.33 m/sec.

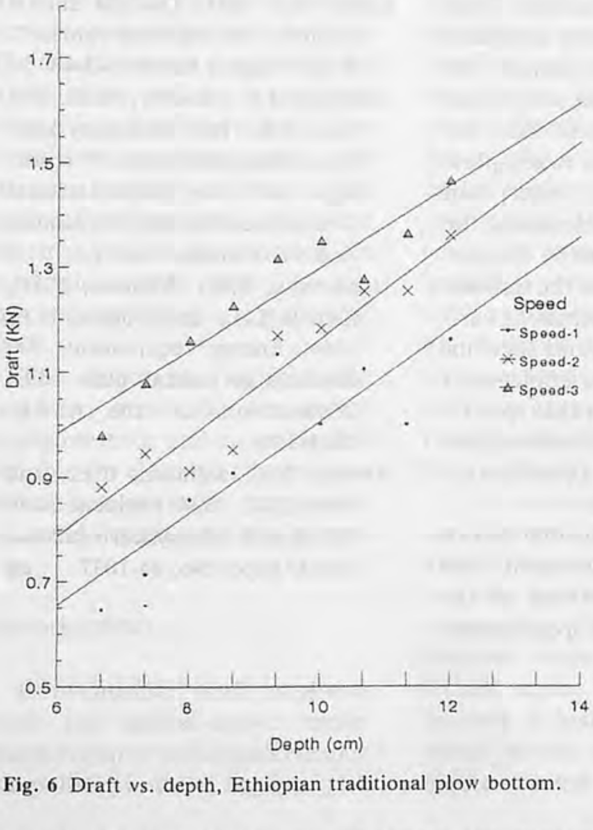

Fig. 6 Draft vs. depth, Ethiopian traditional plow bottom.

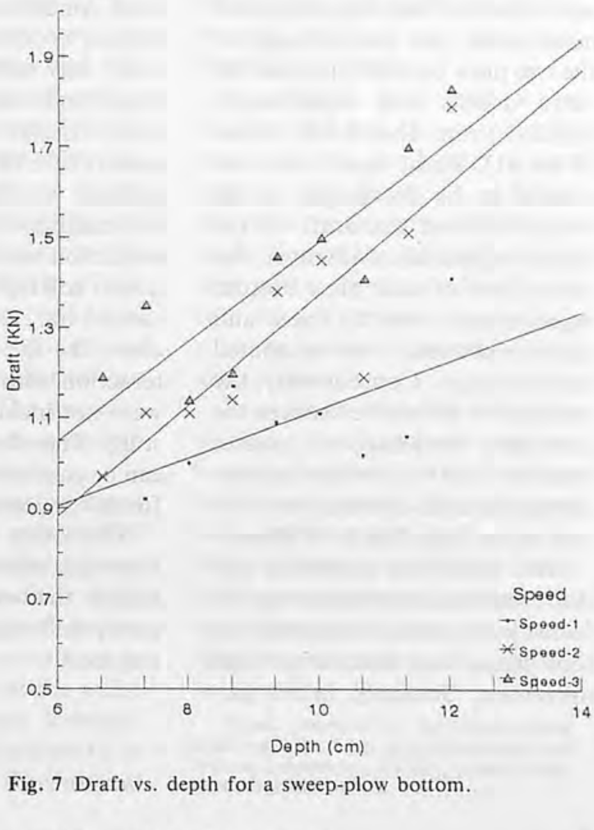

Fig. 7 Draft vs. depth for a sweep-plow bottom.

Appendix Table

Plow bottom type		Average draft values in KN								
		Depth - 1 6-8 cm			Depth - 2 8-10 cm			Depth - 3 10-12 cm		
Traditional	S_1	0.97	0.92	1	1.17	1.09	1.11	1.01	1.06	1.41
	S_2	0.97	1.11	1.11	1.14	1.38	1.45	1.19	1.51	1.79
	S_3	1.19	1.35	1.14	1.2	1.46	1.5	1.41	1.7	1.83
Sweep	S_1	0.64	0.71	0.85	0.90	1.13	1.00	1.10	1.00	1.16
	S_2	0.88	0.94	0.91	0.95	1.17	1.18	1.25	1.25	1.36
	S_3	0.98	1.07	1.16	1.22	1.31	1.35	1.27	1.36	1.46

*Referred to as data for Figs. 6 and 7.

However, the mean draft difference between depth-2 and depth-3 was insignificant ($P > 0.05$). For most tillage tools, depth has a considerable effect on draft. However, for this particular experiment, while depth level 1 and 3 affected the draft significantly, depth level 2 did not. This was possibly due to a narrow difference between the consecutive depth levels. Otherwise, the fact that an increase in draft, caused by increased area of disturbed soil as a result of an increment in depth of tillage, remained the same (Kepner, et al. 1980).

A similar test has been made for the three speed treatments. It was observed that the computed mean draft, that was average for the two plow bottom types and the three depths was significantly higher than the LSD value ($P < 0.01$). Thus, speed was considered to be the major factor which affected the draft of the tillage implements. Moreover, the mean draft of each plow bottom type averaged over all speed and depth treatments was computed and evaluated. Consequently, the mean draft difference between the two plow bottoms was greater than the LSD value which indicated that the draft of these plow bottom types was clearly different.

The final soil condition and draft requirement of plows are affected by the initial soil condition, tool shape and manner of tool movement. Similarly, in this particular study the variation in the geometry of the two plow bottoms resulted in a significant difference in their energy requirement. Even for geometrically similar tillage tools, there would be difference in draft due to the variation in depth and speed of operations.

Conclusion

The findings of this experiment have shown that depth and speed were the major variables that affected the draft of the two tillage tool bottoms. Moreover, the effect of the geometry of these plow bottom types has been observed in the final condition of the soil. Even though no quantitative measurement was taken to evaluate the final condition of the soil, it has been visually assessed that the quality of tilth by the sweep-plow bottom was by far better than the traditional one. However, the deduction was limited to the particular soil type where the test was carried out. Other pertinent variables like soil types and their interaction with tillage implements were not included in this specific study. Therefore, this information can be considered as a base line for further investigation.

The other conclusion drawn from this experiment was that the higher the width of cut of the plow, the lower is the specific draft required.

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An Instrumented Swingletree for Direct Draft Measurement of Animal-drawn Implements

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Abstract

A direct draft measurement system was developed based on the swingletree — the pivoted swinging bar to which traces of a harness are fastened and by which an implement is pulled in a single-animal harnessing (or yoking) system. The prototype was made from a tube on which four strain gages were attached. The pull of the draft animal through the traces or ropes causes the beam to bend. The bending strain is sensed by the strain gages and the bridge converts this to a voltage signal. Two plumbs or counterweights keep the tube vertically oriented as the angle of pull changes, which end bearings follow the variations in the angle of pull. Hence, the voltage output is proportional to the draft.

The device has highly linear response, acceptable sensitivity, negligible error and hysterisis. It is suitable for electronic data acquisition, non-intrusive, easy to attach and detach, and low in cost.

Introduction

Conventional draft measurement for animal-drawn implements requires two measurements: the pull (F) and the angle of pull (ø). Draft (D) is measured indirectly by the relationship, $D = F * \cos ø$. Pull is measured by force transducers which link the implement hitch to the ring of the swingletree, or the yoke and the drawbar, or the yoke and the swingletree. The angle of pull is usually determined by measuring the length of the rope from the center of the yoke section to the hitch point (L), the height of the center of yoke section from the ground H_f, and the height of the hitch point from the ground H_r. **Fig. 1** shows these dimensions in a typical single-animal harnessing (or yoking) system. The angle of pull is derived from $ø = \arcsin(H_f - H_r/L)$.

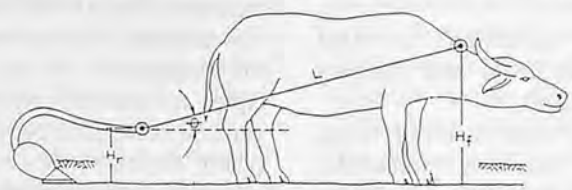

Fig. 1 Dimensions required in conventional measurement of angle of pull.

Two error-prone assumptions are inherent in this method of angle measurement: the ground is always level and the distance H_f is constant. The angle of pull is obtained when the animal is in relaxed stance, but when it pulls, its neck is instinctively lowered, which reduces H_f. Distance H_f is further varied when the animal steps on the unplowed land and not on the furrows. A 12-cm change in H_f, for instance, could result in an 8° change and a 6 kgf (59 N) change in draft which may not be reflected in the data (Pasikatan, 1992).

A tension load cell when hooked between the swingletree ring and the implement hitch, lengthens the distance L and thus decreases the angle of pull. The introduction of the load cell, therefore, alters the angle of pull — a case of a transducer interfering with the measured parameter (or measurand).

In order to overcome this error of constant angle of pull assumption and to permit instantaneous draft measurements, load cells and inclinometers were used (Lawrence 1987, O'Neall et al, 1989). These data-capture systems can measure other parameters, such as speed, physiological parameters, weather

Paper presented at the International Conference for Agricultural Machinery and Process Engineering, KOEX, Seoul, Korea, October 19-22, 1993.

conditions, etc. and offer higher accuracy but the system may be too costly for researchers in developing countries where draft animal power measurements are most needed.

An alternative technique to the load cell-inclinometer system is a direct draft measurement through an instrumented swingletree. This offers the following advantages:

(a) Non-intrusive, that is, the device does not change the angle of pull;
(b) More sensitive, since the load tube is in bending, not axial strain;
(c) Easily attached to and detached from the harness system; and
(d) Can be manufactured using locally available materials, skills and equipment, hence competitive in cost.

A dynamometer for instantaneous draft measurement of animal-drawn implements based on the swingletree was designed. It was evaluated in terms of linearity, sensitivity, hysteresis, accuracy and overall field performance.

Design of the Swingletree Dynamometer

Design Concept

The swingletree dynamometer consists of a metal tube substituting for the typical wooden swingletree in an animal harness for pulling implements. Strain gages mounted near the center, on each side, sense the pulling forces acting on each end of the tube. Counterweights or plumbs fix the tube to a vertical orientation, and bearings on each end of the tube follow the inclination of the ropes, so that draft is instantaneously monitored.

Design of the Strain Beam

In the Philippines, the traditional swingletree of a single-animal harnessing system is 480 mm long. This dimension was retained for the loading tube. A maximum force of 60 kgf (589 N) was assumed to act on each end of the swingletree. To test the principle, a tentative material, galvanized iron (GI) pipe was selected (yield strength, Sy = 235-375 N/mm^2). Using a safety factor of 1.5 for a weaker but sensitive beam and a 40% assumed reduction in Sy due to substandard pipes, the section modulus was calculated as 1 510.9 mm^3. A 26 mm outside diameter-pipe (3/4 in nominal, schedule 40) has a section modulus closest to this value.

Principle of the Strain Beam

The analysis of the bending of the beam under the action of the forces on each end and the corresponding conversion to voltage by the strain gage bridge has been derived elsewhere (Pasikatan, 1992). The relationship of the bending force F at the gage location x (x_1 and x_2 for eight strain gage bridge), to the output voltage E_o (**Figs. 3** and **4**) was expressed as

$$F = \frac{E_o\, E\, ll\, (d^4 - di^4)}{16 \times d\, G\, E_i}$$

(for four-gage bridge)

$$F = \frac{E_o\, E\, ll\, (d^4 - di^4)}{16\,(x_1 + x_2)\, d\, G\, E_i}$$

(for eight-gage bridge)

where:
G = gage factor
E_i = input voltage (V)
E = modulus of elasticity of the strain beam (N/mm^2)
d = outside diameter of the strain beam (mm)
d_i = inside diameter of the strain beam (mm)

These equations indicate F is linearly proportional to voltage E_o. The sensitivity S of the strain beam - strain gage bridge system is given by

$$S = \frac{E_o}{F} = \frac{16 \times d\, Ei\, G}{ll\, E\, (d^4 - di^4)}$$

(for four-gage bridge)

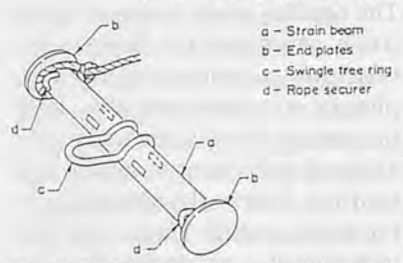

Fig. 2 Basic parts of a swingletree pull dynamometer.

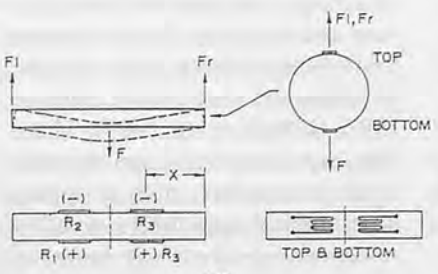

Fig. 3 Forces acting on a swingletree strain beam. (a) orientation of four strain gages on the beam, and (b) arrangement of strain gages in a wheatstone bridge.

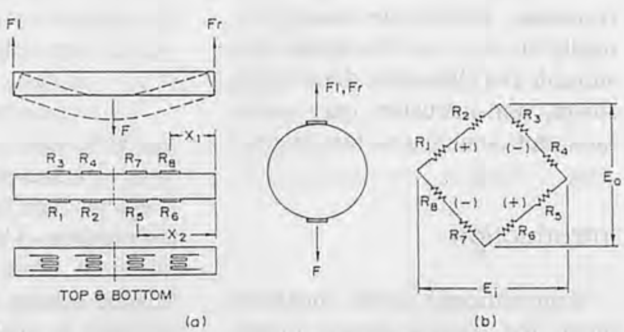

Fig. 4 Forces acting on a swingletree strain beam. (a) orientation of eight strain gages on the beam, and (b) arrangement of strain gages in a wheatstone bridge.

$$S = \frac{16(x_1 + x_2)\, d\, Ei\, G}{\pi E (d^4 - di^4)}$$

(for eight-gage bridge)

The quantity $(x_1 + x_2)$ indicates improved sensitivity for an eight-gage bridge as compared to a four-gage bridge.

Dynamometer Development and Evaluation

The Test Model

The first model, essentially a pull dynamometer was used to test the principle. It was made from 480 mm long, 26 mm outside (3/4 in nominal) diameter schedule 40 GI pipe, in the middle of which a hitching ring was welded (**Fig. 2**). Circular plates and round bar strips were welded to both ends of the beam to secure the ropes in place.

Four strain gages were attached to the beam as shown in **Fig. 3**. They were covered with moisture-proof coating and electrical tape for protection. The lead wires for input voltage and output voltage were connected to an RS232 plug for connection to a Polycorder (a portable data logger). The Polycorder supplied a 5 Vdc excitation to the strain gage bridge circuit.

Calibration results showed the kgf-mV relationship was linear ($r^2 = 0.99$). The sensitivity was 1.391 mV/V, slightly lower than the usual 2 mV/V sensitivity of commercial load cells, mainly because of the low elasticity of the tentative material used. Hysteresis and error were 0.6%, and 4% fs, respectively. Field tests showed ease of attachment to the ropes and the plow hitch, and sufficient protection against water.

The Direct Draft Dynamometer

After the swingletree pull dynamometer concept was validated, the second model - a direct draft dynamometer was developed. For trial purposes the circular strain beam was made from unmachined GI pipe, of the same dimensions as the test model. Eight strain gages were mounted for added sensitivity. A counterweight on each side was attached to the beam through a ring and fixed by a set screw. Three bearings - two on each end, and one at the middle of the strain beam, enabled the device to follow the changes in the angle of pull. When in use, the outer race of the bearings followed the line of pull while the counterweights kept the strain beam and the inner race of the bearings from rotating such that a fixed vertical reference was maintained. Hence, the millivolt output of the device was due to the draft, not the pull.

Calibration results showed a linear response ($r^2 = 0.99$) and a much improved sensitivity (1.778 mV/V). Hysteresis ranging from 0.43% to 1.44%, and error ranging from 0.8 to 1.4%, were observed. Both were angle of pull-dependent. A machined strain beam was therefore necessary to make accuracy independent of the angle of pull. Field tests proved the validity of the design but these showed the following parts which need improvement: heavier counterweight to prevent rotation out of reference, end bearing housing with easy slip-on rope attachment with a shear pin overload protection device.

The Improved Direct Draft Dynamometer

The improved direct draft swingletree dynamometer integrated these modifications (**Fig. 5**). The circular strain beam, 152.4 mm long, was machined from mild steel. Eight strain gages were mounted on this. Counterweights on each side were attached to the beam through threaded connection. The middle ring and the end bearings were all easily detachable (and attachable) through retaining rings. For added protection, a strain gage housing made of steel tube was employed.

The direct draft dynamometer was calibrated at angles of pull, $\phi = 0°, 10°, 15°$, and 20° to simulate the range of values which could be expected from the field. For each angle, loads were incremented step by step up to 140 kgf (1 373 N) and decremented by the same steps down to zero. Four replications were done for each angle.

The calibration results showed the kgf-mV relationship was linear. The regression equation was mV = 0.041888 * kgf - 0.30268 ($r^2 = 0.99$). The sensitivity was 1.2 mV/V, less than the previous models because of larger cross-section to permit machining.

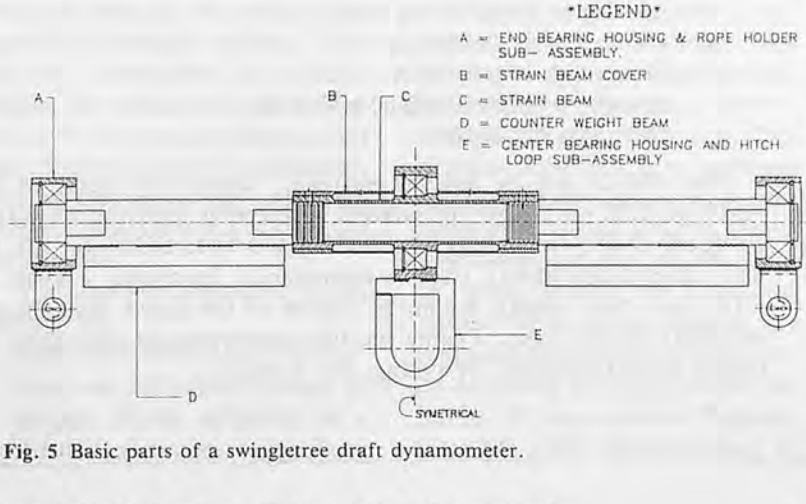

Fig. 5 Basic parts of a swingletree draft dynamometer.

The hysteresis and error were 0.1% and 0.7% fs, respectively, and were angle of pull-independent. Field tests showed the counterweights could keep the strain beam properly oriented while ropes follow the changes in the angle of pull. The dynamometer was used in draft measurements of an animal-drawn wetland twin furrow plow developed at the International Rice Research Institute in Los Banos, Philippines.

Conclusions

A direct draft dynamometer suitable for single-animal harnessing system was developed. The dynamometer was achieved by instrumenting the swingletree - the rear component of this harnessing system. With a data logger, the dynamometer could be used for instantaneous draft measurements. Calibration showed it had a highly linear response, was reasonably accurate and fairly sensitive. Field tests showed it was non-intrusive and easy to attach to and detach from the implement hitch and harness. It could also be made in workshops using locally available materials and equipment. The bearings and strain gages may be expensive but the dynamometer is still reasonably priced but application-specific alternative to load cell-inclinometer devices.

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Analysis of Agricultural Plough Blades Using Finite Element Method

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Abstract

Interest in the analysis of behavior and stress distributed over the blade has increased in recent years. Hence, an investigation into a two-dimensional model to compute the effect of different shapes of agricultural plough blade (C-blade, L-blade and I-blade) on nodal displacements and stress distributions has been carried out using MicroField finite element package.

To simulate the boundary conditions to which the blades are subjected, the blades were assumed as moving at a certain depth of the soil and the blades were clamped along the root of the blade. The distributed pressure created in a steady motion condition was analyzed as normal and tangential pressure that acted upon the blade.The same distributed soil pressure is assumed to be subjected upon the blades from zero depth of soil to the lower part of the blade. From the analysis, L-blade created the highest displacements and stresses over the blade compared to C-blade and I-blade.

Introduction

Any engineering structure formed by elastic material displaces when subjected to loads. This characteristic is defined as structural flexibility. If loads are applied on the structure, it undergoes deformation, that is, its internal points are displaced, and stresses and strains are produced in the material.

Blades often have a complex geometry and are subjected to various kinds of loading. The need for a refined method of calculating stresses and displacements is obvious. In this study a two-dimensional model to compute the displacements and stresses distribution over plough blades, is proposed using plane strain analysis and the finite element method. The cultivator has become popular as a primary cultivating machine in many parts of the world in direct competition with the traditional plough. A plough blade working in the soil is subjected to dynamic stresses. The stresses developed in plough blades are complex in nature because of the type of loading and the complex shape of the blades. The nature, magnitude and direction of these stresses are not fully understood.

The aims and objectives of this project are:

1. Analysis of the stress distribution over difference shapes of plough blades subjected to a distributed pressure using finite element method.
2. Analysis of the displacement behavior of the various plough blades.
3. Determine which type of blade shape is most efficent for resisting stresses under specified condition of operation.

A commercial finite element analysis package was used to perform all the computational task. MicroField, a finite element package developed by University College of Swansea, was used in this project. This package was used to investigate stresses and displacements of different shapes of agricultural plough blades when subjected to a distributed pressure. Attention was paid to the theory of linear elasticity and the stress-strain relationship for plane strain to solve this problem.

Finite element method is particularly useful for solving a differential equation, together with boundary conditions, over a domain of complex shape. The process, therefore, is to represent the domain by large number of finite elements of simpler shape. The finite elements are described by nodal points, the larger the number of nodes per element, the more sophisticated the element is. By assuming an approximate variation of the required function over the finite element, and by considering element boundary conditions, the function approximation can be obtained in terms of nodal values of the function for a particular elements. Then, by considering equilibrium or compatibility at all the inter-element boundaries, together with known boundary conditions, a set of simultaneous equations will result.

Many problems in theory of elasticity are two-dimensional in nature. When forces are applied to a thin plate in its own plane, the state of stress and deformation within the plate is called plane stress. Under these conditions, and the assumption that the variation of stresses with respect to z, that is, across the body, is constant. On the other hand, a prismatic solid may be subjected to a constant condition of loading normal to its axis. If so, the solid may be analyzed as an infinite number two dimensional slices of unit thickness. This type of problem is identified by the name plane strain. Plane strain is a two-dimensional system of strain in a three-dimensional system of stress.

Hence, we observe that plane strain and plane stress may be considered as two extreme and opposite conditions whereas the first is applicable for long bodies, the latter may hold for thin bodies.

Stress Strain Relationship for Plane Strain

The case of plane strain is based on the assumptions that:

Strain $\epsilon z = 0$ Shear stress $\tau xz = \tau yz = 0$; Stress $\sigma z \neq 0$

Where strains are written in terms of stresses, we get:

$$\epsilon_x = \frac{1}{E}(\sigma_x - \nu\sigma_y - \nu\sigma_z) \quad \text{(a)}$$

$$\epsilon_y = \frac{1}{E}(-\nu\sigma_x + \sigma_y - \nu\sigma_z)$$

$$\gamma_{xy} = \frac{2(1+\nu)}{E}\tau_{xy}$$

Also,

$$\epsilon_x = \frac{1}{E}(-\nu\sigma_x - \nu\sigma_y + \sigma_z$$

Hence,

$$\sigma_z = \nu(\sigma_x + \sigma_y) \quad \text{(b)}$$

which is linearly dependent upon σx and σy. Substitution of this expression for σz into the first two of Eqs.

$$\epsilon_x = \frac{1+\nu}{E}[(1+\nu)\sigma_x - \nu\sigma_y]$$

$$\text{(c)}$$

$$\epsilon_y = \frac{1+\nu}{E}[-\nu\sigma_x + (1+\nu)\sigma_y]$$

As before, we can solve for the stresses σx, σy, τxy and in terms of the corresponding strains to obtain:

$$\sigma_x = \frac{E}{(1+\nu)(1-2\nu)}[(1-\nu)\epsilon_x + \nu\epsilon_y]$$

$$\sigma_y = \frac{E}{(1+\nu)(1-2\nu)}[\nu\epsilon_x + (1-\nu)\epsilon_y]$$

$$\text{(d)}$$

$$\tau_{xy} = \frac{E\gamma_{xy}}{2(1+\nu)}$$

The strain-stress operator C is found from Eqs. (c) and (a) as:

$$C = \frac{1+\nu}{E}\begin{bmatrix} 1-\nu & -\nu & 0 \\ -\nu & 1-\nu & 0 \\ 0 & 0 & 2 \end{bmatrix}$$

In addition, the stress-strain operator E is seen from Eq (d) to be:

$$D = \frac{E}{(1+\nu)(1-2\nu)}\begin{bmatrix} 1-\nu & \nu & 0 \\ \nu & 1-\nu & 0 \\ 0 & 0 & \frac{1-2\nu}{2} \end{bmatrix}$$

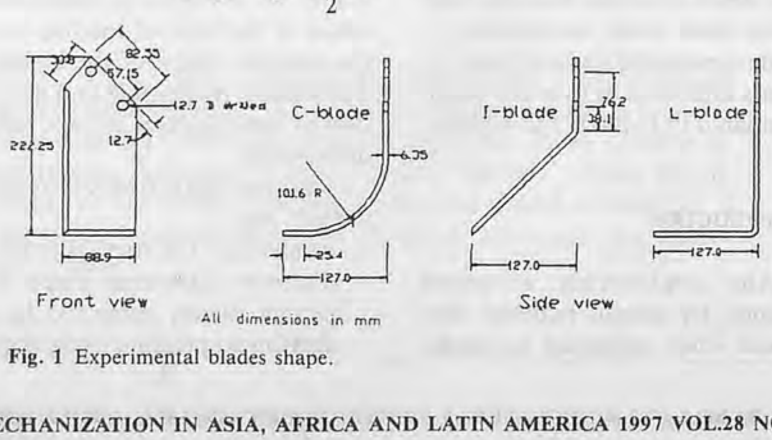

Fig. 1 Experimental blades shape.

Problem Definition and Finite Element Modelling

In this study, three agricultural blades designed by Beeny J.M. and Khoo D.C.P. [8], as shown in **Fig. 1** were the subject of investigation. These blades had the same width, thickness, length. The three blades are named C (speed), I (inclined) and L (power) according to their shapes. The roots of these blades are fixed to the drum by bolts and nuts.

Boundary Conditions

Although a blade is generally a three-dimensional problem, several cases may be treated approximately as two-dimensional from a mathematical point of view. By assuming that the width of a blade is long enough so that the strain in that direction is considerably less than other two direction ($\epsilon_x = 0$). Consequently, this condition can be regarded as two-dimensional plane strain problem.

In order to simplify the analysis of stresses, it may be assumed that these three types of blades have the same height 222.25 mm, thickness 6.35 mm, width 88.90 mm and partly embedded in the soil to a depth of 120 mm. Hence assumption was made that a trolley with the tool mounting was pulled along the rails by a rope wrapped around the drum. This drum was powered by a 2.238 kW (3 h.p.) motor through a speed reduction unit with a reduction ratio of 1:50. The magnitude of

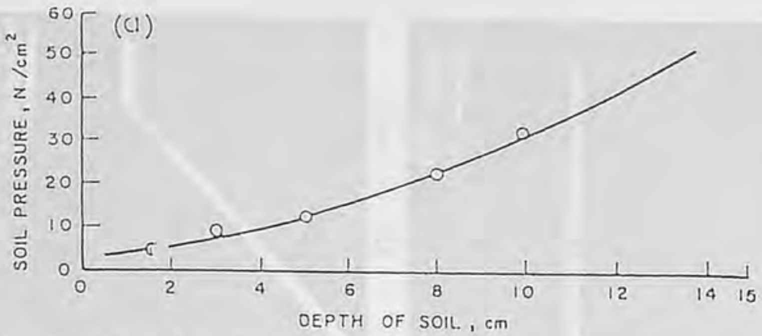

Fig. 2 Variation of soil pressure with depth of soil.

the pressure subjected upon the blade versus depth of soil is referred to the analysis that has been done by Gupta C.P. and Maheshwari R.C. [7].

The graph showing the variation of soil pressure versus depth of soil when moving in a steady condition is shown in **Fig. 2**. In this study, assuming that pressure which was acting upon an embedded blade is distributed from 40 kN/m^2 in zero depth of soil to 440 kN/m^2 in 120 mm depth of soil (lowest part of the blade). This distributed pressure created in a steady moving conditions are analyzed as normal and tangential pressure that applied to the blade.

Finite Element Modeling

The blades were modelled using an 8-noded isoparametric elements. The dimension of the structure is modeled based on the XY Cartesian coordinate. Firstly, the outlines of the experimental blades as shown in **Fig. 1** were modelled by Autocad, a computer drafting package, where the important nodes' coordinates are listed. Afterward, the coordinates of these nodes are put in nodal coordinate's activity to define the geometry of the blade in MicroField package. The structure generated here is called macro element's model. Then the normal and tangential pressures subjected upon the nodes in the edge of the blade are put in MicroField define loading activity. These distributed pressure acting along the edge of the blade start from interaction of soil surface with the blade to lower part of the blade.

Once the macro geometry and pressures have been specified, the structure then was splitted into a set of smaller elements. This activity is done by define mesh options. The frames of these three blades were modeled by 24 elements and geometrical models of the blades were formed by using 123 nodes. The total of elements and nodes are the same for all types of blades.

The blades were restrained at the root of blade from all transitional movement (XY direction) where they were hinged to the shaft. The restrained nodes were 156 mm measured from lower part of the blade. In this project, the material used for these three types of blades was high strength steel and they had the same thickness, 0.089 m with the Young's modulus of 207 × 10^9 N/m^2 and Poisson's ratio of 0.3.

Result and Analysis

Results for Displacements

Based on the output data obtained, the nodal x- and y-displacement in the edge where pressures were applied for these three types of blades along the 6-axis starting from the restrained node is plotted on **Figs. 3 and 4**. These two figures show that the displacement of the node increases when the distance from the restrained node increased. And L-blade displaced the most followed by C-blade and lastly I-blade.

Results for Stress Distribution

The maximum principal stress of C-blade is shown in **Fig. 5**. This figure illustrates that the concen-

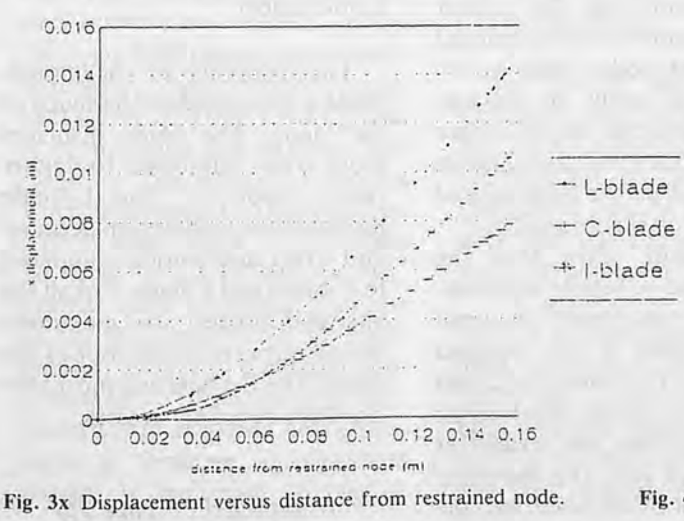

Fig. 3x Displacement versus distance from restrained node.

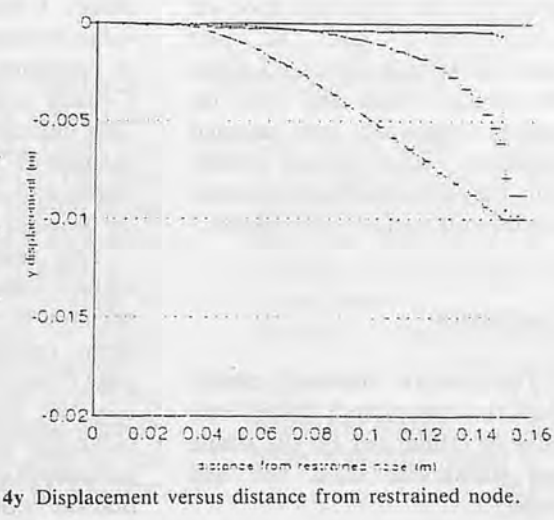

Fig. 4y Displacement versus distance from restrained node.

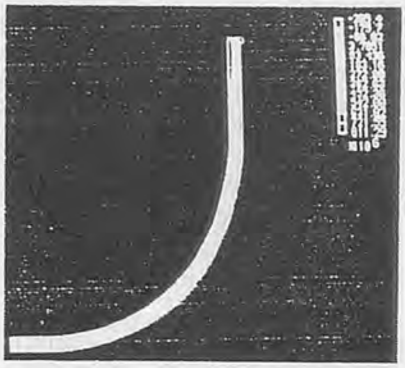

Fig. 5 Maximum principal stress over C-blade.

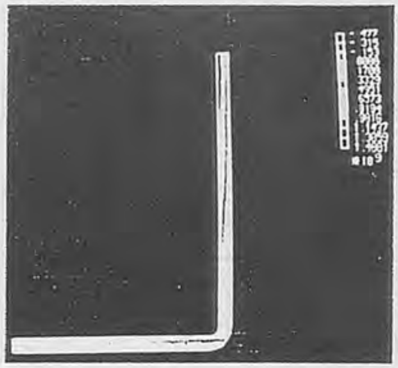

Fig. 6 Maximum principal stress over L-blade.

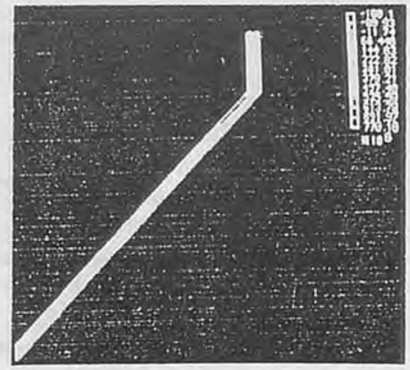

Fig. 7 Maximum principal stress over I-blade.

tration of highest principal stress occurs from the clamped edge (root of the blade) to the interaction of soil surface with the blade edge.

The maximum principal stress distribution over the L-blade is shown in **Fig. 6**. As in the C-blade, the maximum tensile and compressive stress of principal stress for L-blade occurred in the root of blade.

The distribution of maximum principal stress over I-blade is illustrated in **Fig. 7**. The highest concentration pattern of maximum principal stress was produced around the interaction of soil surface with the edge of blade.

The graph of maximum principal stress in the edge where pressure applied versus distance from the restrained node along y-axis is plotted on **Fig. 8**. The graph illustrates that the stress value almost linearly decreasing with the distance from the restrained node for C-blade and L-blade. The stress value for I-blade decreased along the vertical blade and then increased afterward and attained maximum value around 35 mm from the restrained node (interaction of soil surface with blade).

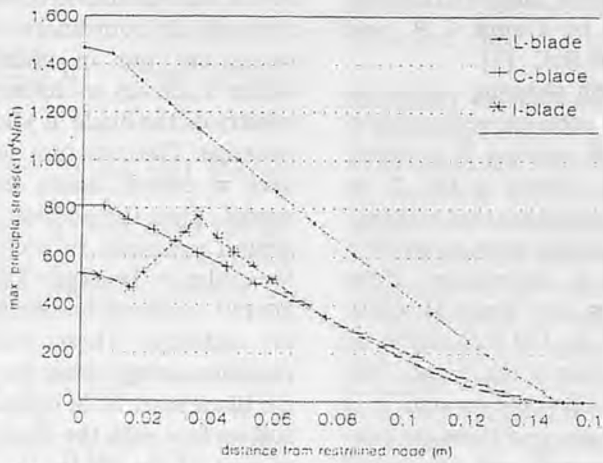

Fig. 8 Max. principal stress versus distance from restrained node.

Discussion

The results obtained clearly show that the plough blade flexibility is influenced by the shape and parameter used for this project.

It was found that the blade displaced according to how the pressures was applied upon it and how the shape of blade was designed. For the same distributed soil pressure act upon the blade, L-blade displaced the most compared to C-blade and I-blade. However, the I-blade displaced more than C-blade. L-blade has the highest value of reaction's force produced in restrained nodes followed by C-blade and, lastly, by I-blade. This indicates that the difference in shape of blade will cause uneven displacement on the blade caused by pressure it is subjected to.

The results show that the highest value of tensile and compressive for maximum principal stress occurred in the clamped edge (root of the blade) for C-and L-blades. The highest tensile stress value for I-blade was created at zero depth of soil. This indicated that the root of the blade and the intersection of soil surface with the blade edge should be hardened more compared to other edge and this can be done by material hardening. Overall, L-blade created the highest stress follow by I-blade and lastly by C-blade.

Conclusion

The flexibility of the plough blade is influenced by the shape of the blade. The blade displaces more when subjected to higher forces upon it. The L-blade produced the highest displacement and stress distribution compared to C-blade and I-blade. For all the analyzed blades, the maximum stresses accured in the root of the blade. The C-blade was most efficient for resisting stresses.

(Continued on page 36)

Evaluating Performance of Flutted Wheel for Fertilizer Metering in Sugarcane Planter

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Introduction

Sugarcane is cultivated in about 3.75 million ha in India (1). It's planting is a tedious, time-consuming and expensive operation. It involves opening of furrows, placement of insecticide solution in them, proper placement of sugarcane setts and fertilizer, covering them and then compaction.

The problem of availability of labour, higher planting cost and timely operation have compelled sugarcane growers to use more and more machines for planting sugarcane. Sugarcane planters (2,3) developed in India have gravity flow fertilizer metering system with agitator over an adjustable orifice. This system has disadvantage because the quantity of fertilizer in hopper affects the flow rate, metering is inaccurate and distribution uneven. In the field, the IISR tractor-drawn semi-automatic planter dropped on an average 49.24 g and 154.64 g urea at its minimum and maximum settings for one round of ground wheel. Both were two high and unwanted applications. They clogged 28 times in 0.2 ha area of test. Similar field problems of lesser extent was observed in the PAU planter. However, it clogged only 2 times in 0.2 ha area of field test. Accuracy in metering and placement of fertilizer in sugarcane planter is important for better germination and crop stand besides its proper utilization. With this point in view, the performance of flutted wheel (**Fig. 1**) for metering fertilizers in IISR sugarcane planter was evaluated.

Table 1. Fertilizer Application Schedule for Sugarcane

Fertilizer	Recommended dose kg/ha	Quantity of recommended dose applied at planting time
Nitrogen	120-300	One third to half
Potassium*	20-130	Half to full
Phosphate*	50-130	Full

Table 2. Total Single Row Length in 1.0 ha Plot with Different Row Spacings Using a Two-Row Planter

Row-to-row spacing cm	Total single row length m
60	16,666
75	13,333
90	11,111

Table 3. Fertilizer Application Rate for Different Row Spacings at Planting Time

Fertilizer	Fertilizer Application Rate (kg/ha)	Application Rate, g/m Row Length at Spacings (cm)		
		60	75	90
Urea	125-325	7.5-19.5	9.3-24.4	11.2-29.2
Muriate of potash	30-210	1.8-12.6	2.2-15.7	2.7-18.9
Super phosphate (triple)	100-275	6.0-16.5	7.5-20.6	9.0-24.7
Di-ammonium phosphate	125-325	7.5-19.5	9.3-24.4	11.2-29.2

Developmental Considerations

Soil fertility and row-to-row spacing in sugarcane varies from one place to another. These factors together decide the fertilizer application rate. A general range of fertilizer applied in sugarcane in India (4) is shown in **Table 1**.

The application of fertilizer in rows is recommended for sugarcane cultivation. The best results with most of the row crops have been reported when bands were 25 to 75 mm below the level of the seed and spaced 40 to 100 mm laterally from the row on one or both sides (5). Considering the row length at different row spacings (**Table 2**) the application rate per meter row length for most commonly used fertilizers is shown in **Table 3**.

Functional Requirements of Fertilizer Metering and Distribution Device

i) The device should distribute the fertilizer uniformly over a wide range of conditions. The discharge rate should be adjustable in the range mentioned below:

Fertilizer	Required discharge g/m row length
Urea	7.5-29.2
Muriate of potash	1.8-18.9
Super phosphate (triple)	6.0-24.7

Di-ammonium phosphate 7.5-29.2

ii) Fertilizer should be dropped in two bands spaced at about 75 mm from seed on either side.
iii) The metering device should have a positive dispensing action. It is desirable that the discharge rate be proportional to the forward speed of the implement so that the application rate per hectare will be independent of planter speed.
iv) The discharge rate should be independent of the amount of fertilizer in the hopper and distributor of required inclination to provide desired band spacing.
v) The rate should be adjustable in small increments and should have a definite relation to a suitable reference scale provided on the unit.
vi) The metering and distribution device should not clog during operation.
vii) It should be easy to empty and to dismantle for thorough cleaning.
viii) Corrosion-resistant materials should be used where feasible, and particularly, for the working parts.

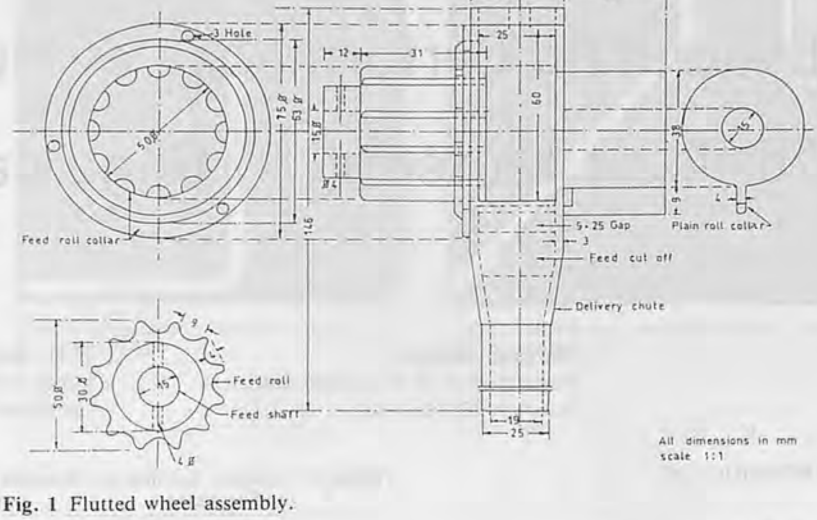

Fig. 1 Flutted wheel assembly.

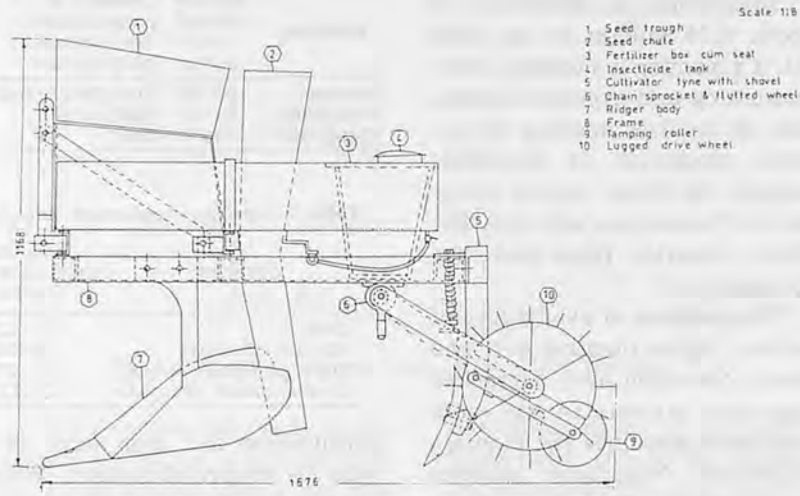

Fig. 2 IISR Improved semi-automatic tractor drawn sugarcane planter.

Mechanical Details of the Flutted Wheel

Two commercial wheels with 12 fluttes of cast aluminum were tried for evaluating their performance for metering fertilizer spreading. The details of the flutted wheel are shown in **Fig. 1** which was mounted over a shaft below the fertilizer boxes. A chain and sprocket mechanism was used for transmitting power from ground wheel to flutted wheel **(Fig. 2)**. The rate of fertilizer application was controlled by moving the shaft axially in order to vary the length of fluttes exposed to the fertilizer in the feed cup. The fertilizer falling from the flutted wheel was distributed into two equal halves for band placement on both sides of setts by a distributor fitted below the discharge chute of the flutted wheel housing.

Laboratory and Field Testing of Flutted Wheel for Fertilizer Metering

After fixing the flutted wheels to the fertilizer boxes of the IISR sugarcane planter, its performance for metering fertilizer was evaluated in the laboratory. The fertilizers commonly used in sugarcane planting viz. urea, di-ammonium phosphate, super phosphate (triple), muriate of potash and their mixtures were used for performance evaluation. The fluttes were exposed to the fertilizer in the feed cup at an increment of 3 mm. First exposure was also kept 3 mm. Thus, 8 exposure lengths of 3, 6, 9, 12, 15, 18, 21 and 24 mm, with the fertilizers and their mixtures were tested. The fertilizer dropped from both flutted wheels in 25 revolutions was collected separately and the average of these two quantities was taken to represent the quantity of fertilizer dropped at particular exposure. Observations taken on metering fertilizers and their mixtures are presented in **Table 4**.

After the laboratory tests the planter was tested for field perfor-

Table 4. Laboratory Observations on Fertilizer Metering at Different Exposures of Flutted Wheel

Fertilizer	Quantity dropped in one revolution at different exposures (mm) of flutted wheel, g							
	3	6	9	12	15	18	21	24
U	1.68	3.31	4.97	6.53	7.50	9.16	11.00	11.40
DAP	3.33	4.75	7.65	9.59	11.20	14.53	16.13	16.79
MP	2.95	4.81	7.31	9.76	11.66	13.78	16.39	17.04
SP+++	2.39	3.13	3.49	5.33	7.60	7.70	9.31	11.36
U+SP++	1.33	1.91	3.66	5.47	6.37	7.51	10.05	11.58
U+MP	1.99	3.71	5.32	7.79	9.96	11.77	13.05	13.91
DAP+MP	3.02	4.52	7.49	9.98	12.25	14.78	16.80	17.14
U+SP+MP+	1.33	1.50	2.28	4.43	3.73	6.86	9.10	10.57

\+ A little bridge formation
\++ More bridge formation
\+++ Severe bridge formation

U-Urea
DAP- Di-ammonium phosphate
MP- Muriate of potash
SP- Super phosphate

Table 5. Field Evaluation of Fertilizer Metering with the Flutted Wheels in IISR Semi-automatic Sugarcane Planters

Description	Kind of fertilizer		
	Urea	DAP	DAP+MP*
Length of fluttes exposed, mm	12	25	25
Area covered, ha	0.2	0.32	0.2
Actual fertilizer dropped, kg	20.14	48.80	31.60
Theoretical/expected fertilizer drop in covered area as per laboratory caliberation, kg	18.38	48.12	29.47
Percent variation in actual fertilizer drop in field over laboratory caliberation	(+)9.57	(+)1.40	(+)7.22
average		(+)6.06	
Possible range of actual fertilizer application, kg/ha at spacing (cm)			
60	151.06	231.32	247.26
75	120.76	185.02	197.77
90	100.72	154.32	164.95

*Mixture of DAP and MP on equal weight basis.

mance of the flutted wheels. The data on field trial is presented in **Table 5**.

Results and Discussion

Laboratory data on individual fertilizer dropped per revolution of the flutted wheel at different exposure lengths of fluttes are plotted in **Fig. 3**. For the mixture of fertilizers (on eqaul weight basis) the plotted data are presented in **Fig. 4**. It is evident from these figures that the quantity of fertilizer dropped increased almost linearly with the exposure length. The field data shows that on an average, 6.06% more fertilizer was dropped in the field compared with the expected quantity based on laboratory calibration. This appeared due to the fact that ground wheel sank into loose soil reducing its effective diameter, thereby increasing the actual revolutions per unit length in the field. The range of commonly used fertilizers that can be precisely metered

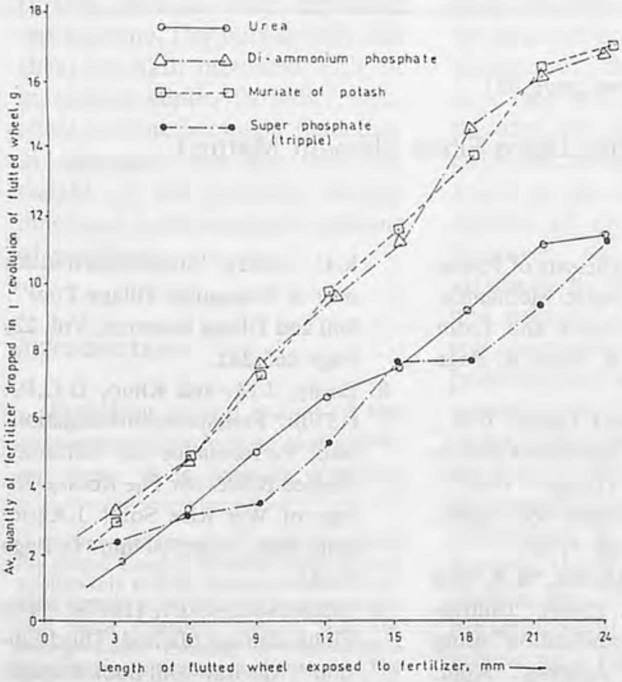

Fig. 3 Quantityof fertilizer dropped with varying exposures of flutted wheel.

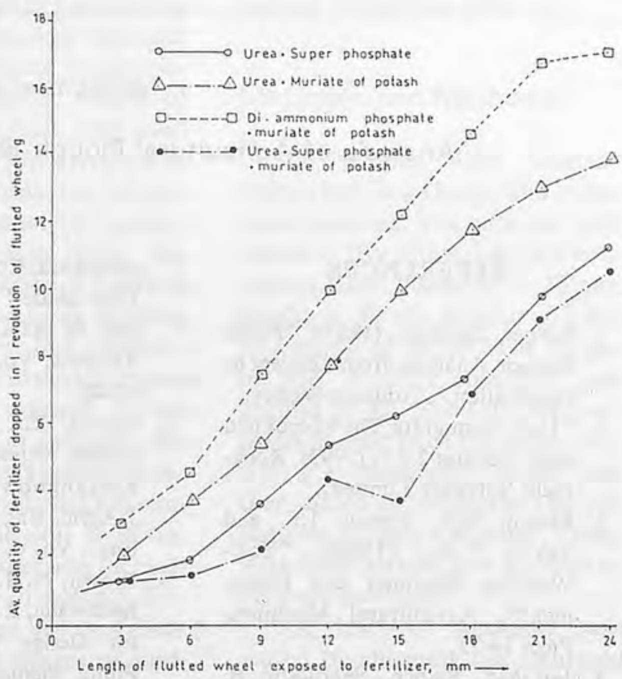

Fig. 4 Quantity of fertilizer mixtures dropped with varying exposures of flutted wheel.

Table 6. Possible Range of Fertilizer Application Metering with Flutted Wheel (12 fluttes, 25 mm length). Ground Wheel 40 cm Diam.; Transmission Ratio Ground Wheel to Flutted Wheel 1:1.

Fertilizer	Range of fertilizer application, kg/ha		
	60	75	90
Urea	0-150	0-120	0-100
Di-ammonium phosphate (DAP)	0-230	0-185	0-155
Muriate of potash (MP)	0-235	0-190	0-160
DAP + MP +	0-245	0-195	0-165

+ Equal weight mixtures

by the flutted wheel (12 fluttes, 25 mm length) at different row spacings is shown in **Table 6**.

Care and Maintenance

The flutted wheel is a precision mechanism for fertilizer metering. A coarse sieve (3 mm) should be used to remove lumps in the fertilizer being loaded in the fertilizer box.

Aluminum cast flutted wheels are to be maintained properly for longer life. After field operation the fertilizer should be removed from the fertilizer box empty and about half a bucket of water poured over the flutted wheel mechanism to clean it of any fertilizer sticking to it. This would minimize denting of the flutted wheel mechanism by the fertilizer and increase its life up to 4-5 years.

Conclusion

The aluminum cast flutted wheel could be used in sugarcane planters for precise metering of fertilizers and their mixtures. The mechanism is suitable for areas where urea, diammonium phosphate and muriate of potash are applied in the range of 100-150, 155-230 and 160-235 kg/ha, respectively. For superphosphate and its mixtures, metering is not precise because of bridge formation, however, these could also be applied in the field with less precision.

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(Continued from page 32)

Analysis of Agricultural Plough Blades Using Finite Element Method

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Puddling Effects on Soil Physical Parameters

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Abstract

Experiments were conducted to measure the changes in soil physical parameters due to puddling in respect of water content, bulk density and shear strength at five levels of puddling and over five different periods of settling time. Turbidity (as a measure of clay dispersion), electrical conductivity and reduction in aggregate size were measured to determine the extent of soil breakdown. The results show that water content of puddled layers decreased with an increase in depth of puddle. The water content at all depths was further reduced with increased settling time. Dry bulk density and shear strength increased with an increase in depth. Turbidity, electrical conductivity and reduction in aggregate size per unit dry weight of the puddled sample increased with increased amount of puddling.

Introduction

Puddling of soil is one of the common operations in rice growing areas. It is done in standing water of 5-10 cm depth in the field. The main purpose of puddling is to reduce percolation, to destroy weeds and to facilitate transplanting of paddy seedlings by rendering the soil softer. It has been reported (7) that puddling up to 10-15 cm depth is adequate to disperse organic matter at the bottom of the puddle and there appears no justification to puddle any deeper.

Numerous studies (1, 2, 3, 5, 8) have been conducted to measure the degree of puddling. For example, the viscosity of puddled soil has been used as an index, as has the ratio of the volume of (puddled) soil after and before settling for about 48 hours. Aggregate size distribution, decrease in percolation rate and specific weight of puddled soil also have been used as indices. Shear yield strength was found to be a basis for quantification of the state of puddle. However, no single index can satisfactorily describe a puddled bed because of various limiting soil characteristics. For example, puddling may not always decrease apparent specific volume. It may cause a decrease or increase, depending on soil aggregation status, the nature of colloids and ion concentrations in the soil solution. Further, if soil dispersion on puddling is low, loss of volume during settling will also be low, falsely indicating a high degree of puddling. Percolation rate in this case may remain high. Decline in percolation rate may be an ambiguous index of puddling because the soil compaction below the depth of puddling can also reduce percolation. Therefore, for application in rice research, especially for mechanical transplanting of rice, it was felt necessary to study the effect of puddling on soil physical parameters. This will enable the development of puddled beds to have both softness and desirable strength of puddled soil for ease of transplanting.

The objective of this study was to measure the changes in soil physical properties at different levels of puddling and over different periods of settling time (6).

Materials and Methods

Soil samples were collected from which large lumps and stones were removed. The samples were placed in five cylindrical steel containers (size: diameter = 37 cm; height = 38 cm; weight = 9 kg) to a depth of 30 cm. The weight of soil in each container was around 35 kg. Sub-samples were taken to determine the water content gravimetrically. Water was then added to submerge the soil samples in each container. Those were then covered and allowed to saturate overnight.

The level of puddling was varied by churning the saturated soil sample in a concrete mixer (operated at 20 r.p.m.) for one,

Acknowledgement: Thanks are due to the British Council Division which offered a fellowship to S.K. Rautaray under Technical Cooperation Training Programme to visit Silsoe Research Institute, U.K. for post-graduate training in Agricultural Engineering and to carry out this work. The facilities provided by the Silsoe Research Institute to conduct this study is duly acknowledged.

three, 10, 30 and 60 min, respectively. The samples were poured back to the respective containers, and allowed to stand for 24 h. During this process, sub-samples (about 100 g each) were taken from each container for measurement of dispersed clay (measured by turbidity), electrical conductivity and aggregate size. Using a multiple core sampler in each container, puddled soil samples from six different depths of up to 210 mm were collected. Water content, bulk density and shear strength of the soil at six different depths for each level of puddling were determined.

Shear strenght of the weak, puddled soil was measured by the fall cone apparatus (4). However, this test can only be used for the surface layer, hence for deeper puddling and for cases when water laid on the soil surface, the torsional instrument described by Watts and Dexter (8) was used.

Similar experiments were conducted to measure the changes in soil physical properties over different periods of settling time after puddling. Five samples were each puddled for three min, and were then allowed to stand for 12, 24, 36, 48 and 72 h. Samples from six different depths up to 210 mm were collected from each container to measure the changes in the water content, bulk density and shear strength of the puddled soil. Turbidity, electrical conductivity and aggregate size (determined by wet sieving) were also measured to assess the uniformity of puddling in all five samples.

Results and Discussion

The results for water contnet, dry bulk density and shear strength at six different depths for five levels of puddling and over five different periods of settling time, were analyzed.

Variation in Water Content

The water content of the puddled layers at six different depths were determined gravimetrically. **Fig. 1** shows the variation in water content with depth for different periods of settling time. It was observed that the water content of the puddled layers decreased with an increase in depth of puddle and also decreased with an increase in settling time. In general, 6-7% decrease in water content was observed from 0-35 mm to 135-210 mm layers over all periods of settling time, with a slower rate of decrease at and around 140 mm depth. The decrese in water content at all depths when compared between 12 h and 72 h settling time was in the order to 7-8%. **Fig. 2** shows the decrease in water content with depths at different levels of puddling. At higher levels of puddling, although the water content at all the depths was higher in 24 h of settling, the rate of decrease in water content with depth was low.

Variation in Bulk Density

Dry bulk density of puddled layers at different depths were plotted in **Fig. 3** for different periods of settling time and, in **Fig. 4**, for different levels of puddling. From **Fig. 3** it is observed that as the depth of puddle increased, the dry bulk density at all depths also increased. The rate of increase was gradual except in the 0-35 mm layer where the density values were not uniform because of sampling difficulty due to the presence of standing water. However, at longer periods of settling time the density values were higher at all the depths when compared with the 12-hour settling except around the top layer. Under 12-hour settling conditions, the percentage increase in bulk density at all depths when compared with the surface layer was lower because of the continuing process of settling of the dispersed particles. At higher levels of puddling **(Fig. 4)** the rate of increase of bulk density with depth was low. Lower levels of puddling gave comparatively higher values of bulk density from

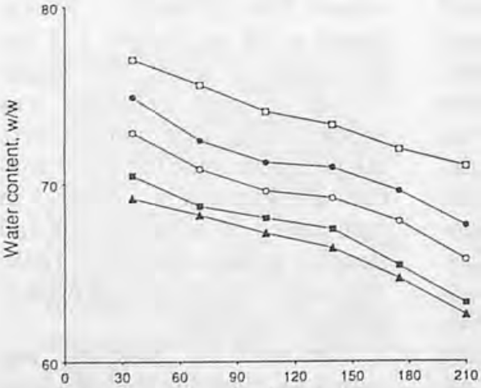

Fig. 1 Variation in water content of soil with depth over different periods of settling time (level of puddling: 3 min).

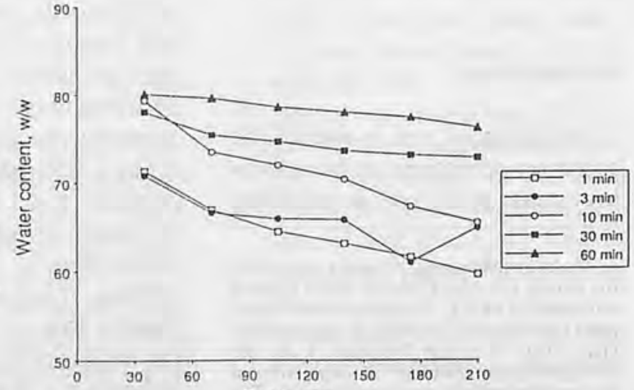

Fig. 2 Variation of water content with depth at different levels of puddling (settling time: 24 h).

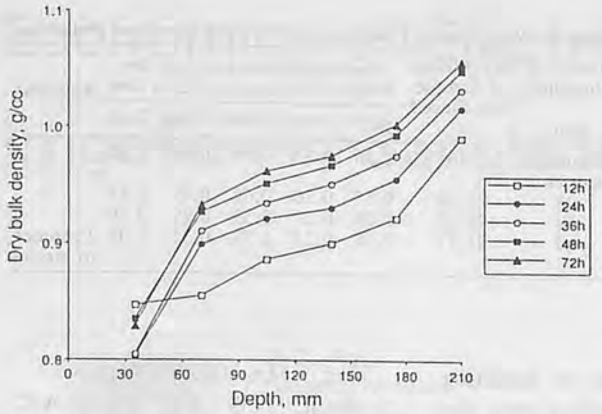

Fig. 3 Variation in dry bulk density with depth over different periods of settling time (level of puddling: 3 min).

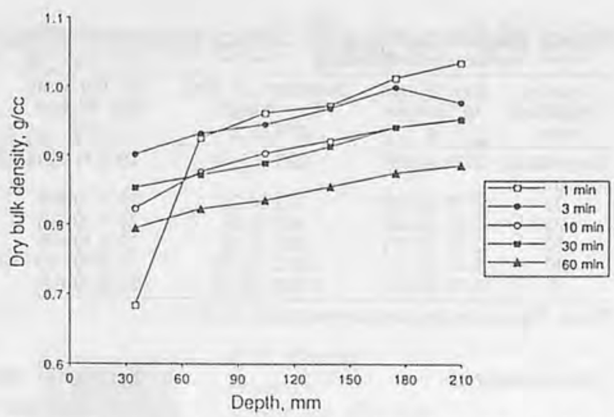

Fig. 4 Variation in dry bulk density with depth of different levels of puddling (settling time: 24 h).

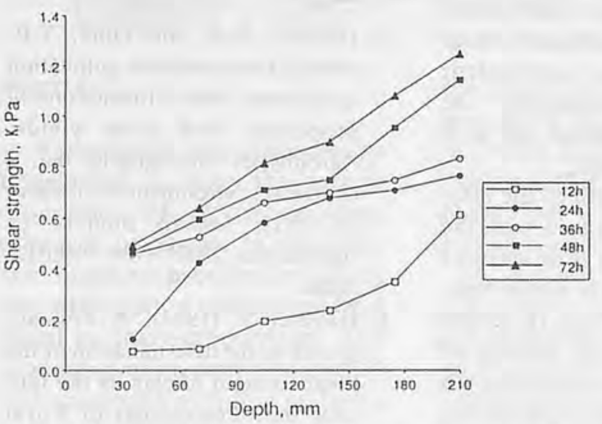

Fig. 5 Variation in shear strength of soil with depth over different periods of settling time (level of puddling: 3 min).

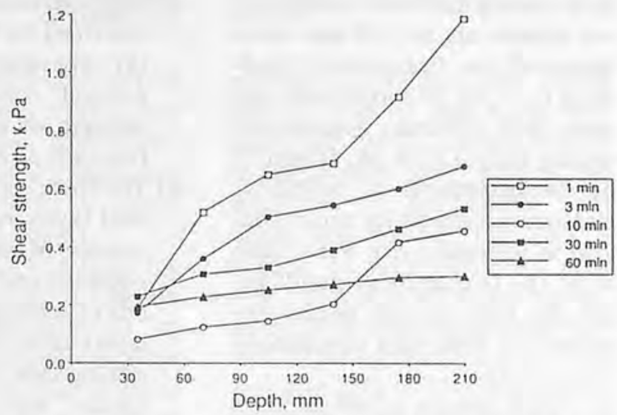

Fig. 6 Variation in shear strength of soil with depth at different levels of puddling (setting time: 24 h).

130-210 mm depths over 24-hour settling which may be due to a faster rate of settling.

Variation in Shear Strength

The shear strength of puddled layers at six different depths were measured using a fall cone apparatus. The variation in shear strength with depth over five different periods of settling time are shown in **Fig. 5**, and those for different levels of puddling are given in **Fig. 6**. It was observed that the shear strength of the puddled layers increased with an increase in depth at all levels of puddling and over all periods of settling time. Higher values of shear strength were obtained over longer periods of settling time. However, at higher levels of puddling **(Fig. 6)** with 24-hour settling time, the rate of increase of shear strength with depth was lower. This may have been due to insufficient settling time.

Effect of Puddling on Dispersion of Soil Particles

The amount of clay dispersion at different levels of puddling was determined by measuring turbidity and electrical conductivity of the samples **(Table 1)**. It was observed that at higher levels of puddling beyond 30 min the rate of incrase in turbidity with puddling time was low. However, an optimum level of puddling may be obtained by evaluating a greater number of samples with varying degrees of puddling. The percentage increase in turbidity at different levels of puddling, when compared with the turbidity of the unpuddled saturated sample, were 40.0, 79.8, 146.9, 343.8 and 389.5 for one, three, 10, 30 and 60 min puddlings, respectively.

Effect of Puddling on Soil Aggregate Breakdown

Wet sieving of samples from three different levels of puddling **(Table 2)** were compared with the wet sieving results of unpuddled saturated soil. It was observed that total percentage of aggregates retained on all sieves per unit dry weight of the sample decreased on puddling. Further, by increasing the level of puddling the percentage of aggregates retained on 2 mm size sieves was reduced with overall reduction of aggregate percentage retained in all the four sieves.

Table 1. Turbidity and Electrical Conductivity of Soils at Different Levels of Puddling

Level of Puddling min.	Dry Weight of Sample g	Turbidity per Unit Dry Weight NTU/g	EC Per Unit Dry Weight µs/g
Unpuddled saturated	2.71 (0.09)	228 (11.0)	19.2 (1.10)
01	2.70 (0.03)	320 (4.2)	20.1 (0.46)
03	2.81 (0.08)	410 (5.0)	20.1 (0.30)
10	2.71 (0.07)	563 (3.4)	22.6 (0.40)
30	3.02 (0.12)	1012 (12.0)	21.0 (0.70)
60	2.70 (0.15)	1116 (19.0)	22.4 (0.60)

Note: Figures in brackets are standard errors.

Table 2. Wet Sieving Fractions at Different Levels of Puddling

Level of Puddling min.	Dry Weight of Sample Wet Sieved g	Percentage Retained per Unit Dry Weight of the Samples on Each Sieve					Remarks
		2mm	1mm	0.5mm	0.25mm	Total	
Unpuddled saturated	21.66	0.26	0.55	0.68	0.53	2.02	
03	22.50	0.15	0.56	0.65	0.49	1.85	
30	24.17	0.04	0.27	0.39	0.29	0.99	
60	21.57	0.04	0.23	0.39	0.35	1.01	Presence of stones

Conclusions

Changes in soil physical properties in respect of water content, bulk density and shear strength at six depths up to 210 mm were measured for five levels of puddling (1, 3, 10, 30 and 60 min) and over five different periods of settling time (12, 24, 36, 48 and 72 h). Measurements of turbidity, electrical conductivity and reduction in aggregate size were made at all the five levels of puddling. On the basis of the results obtained the following conclusions were drawn;

i) Water content of the puddled layers decreased with an increase in depth of puddle at all levels of puddling and over all periods of settling time tested. With increased periods of settling time the water contents at all depths further decreased. At higher levels of puddling the water content at all the depths was higher and the rate of decrease in water content with depth was low over 24 hours of settling time.

ii) Dry bulk density increased with an increase in depth over all the periods of settling time. Higher values of dry bulk density were obtained at all the depths with longer periods of settling time. In 0-35 mm layer the bulk density values were non-uniform because of the standing water. At higher levels of puddling with 24-hour settling time, the rate of increase of dry bulk density with depth was low.

iii) The torsional instrument described by Watts and Dexter (8) provides a convenient method for measuring the strength of puddled soil as a function of depth.

iv) The shear strength of the puddled layers increased with the increase in depth at all levels of puddling and over all the periods of settling time. In deeper layers over longer periods of settling time, the shear strength values were comparatively higher. The rate of increase in shear strength with depth at higher levels of puddling over a 24-hour settling time was low.

v) Clay dispersion and electrical conductivity per unit dry weight of the puddled samples increased with the increased level of puddling. The rate of increase in turbidity from 30 to 60 min puddling was low.

vi) Reduction in aggregate size increased with the increased level of puddling.

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Economics of Electric-powered Tube Well Irrigation in Bangladesh

by

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Abstract

A case study was conducted in Bangladesh to study the present economics of electric-powered tube well irrigation. In the study area investors provided irrigation water to a group of farmers' land based on share-crop system. The economics of investor was studied and compared with that of farmer and financial analysis of each scheme was carried out considering individual projects of investors.

The study results indicate that all shallow tube well (STW) irrigation schemes are profitable (except schemes in sandy loam soil in current command area). Break-even command area of clay loam, silty loam, loam and sandy loam soil are 3.4 ha, 1.8 ha, 3.7 ha and 9.0 ha, respectively. The investor can get 4 to 6 times of current profit by covering a potential command area.

Introduction

Bangladesh is a rural based agricultural country whose 35% of total gross-domestic product (GDP) comes from agriculture (BBS, 1992). Irrigation in dry season high yielding variety (HYV) of rice crop is an important part of agriculture. In 1990, 34% of net cultivated area was covered by irrigation (82% area is irrigable) of which 84% is covered by minor irrigation (Rashid, 1992).

As dry season is less risky for agriculture, planned utilization and efficient management of water resources through irrigation is considered as the leading input for development of agriculture (Rogers et al 1989). Due to removal of import ban on irrigation equipment, suspension of ground water ordinance and giving more emphasis on rural electrification, the rate of minor irrigation development has increased rapidly.

Rural electrification is a positive input into agricultural development, specially for development of minor irrigation facilities which results in increased production and increased in cropping intensity. After 1987-88 electric powered irrigation increased rapidly in the private sector. In 1988-89 the total irrigated area increased 8% but rural electricity connection to it increased 34% (BBS, 1992 and Rahman and Mainuddin, 1992). Farmers in Bangladesh cannot install irrigation schemes themselves due to their fragmented land and poor economic condition (per capita land is 0.08 ha and GDP was $185, BBS, 1992). Tangail district in Bangladesh bears most of the categories of agricultural soils (Khan and Hossain, 1995) and a number of electric-powered tube well irrigation schemes are operated on share-cropped payment system. Most of the farmers of this area give 25% to 30% share of the harvested rice to the investor for payment of irrigation water. Share-cropped payment system is increasing day by day with effective privatization of minor irrigation schemes. Nowadays investors are very much interested to invest their capital in minor irrigation schemes but high price of electricity, low price of rice during harvesting time, high price of fertilizer during season, lower command area coverage affect their profit.

Objectives

i) To study the economics of electric-powered irrigation schemes in Bangladesh.
ii) To make suitable recommendation for economically viable and sustainable development of irrigation schemes in Bangladesh.

Methodology

Selection of Study Area

Five *thanas* (sub-districts) in the southern part of Tangail district, namely; Tangail, Kalihati, Sakhipur, Mirzapur and Basail having different types of soil texture and water table variation were chosen as study area where available minor irrigation schemes are operated by rural electricity in share crop payment system. Selected soils were clay loam, silty loam, loam and sandy loam. Twenty shallow tube well (STW) irrigation schemes (4 in each thana) were selected randomly.

Procedure for Collection of Data

All the data needed for this study were collected from various sources in Bangladesh. The investigation in this research was divided into three groups, namely; i) a farm survey as primary data; ii) review of secondary data; and iii) field measurement data. The main part of the study is based on primary data that were collected by direct interview with selected scheme investors/managers/farmers/operators as respondents using a structured questionnaire. All primary data were collected directly from the field during the operating period. The study was conducted within the period of January to April, 1995. All data were evaluated for the irrigation period of 1994.

The secondary data such as water table and soil characteristics and type were collected, respectively, from Bangladesh Agricultural Development Corporation (BADC) and Soil Resources Development Institute (SRDI), Bangladesh. Some required data were collected from various related institutes (Bangladesh Agricultural University, Power Development Board and Agricultural Extension Office).

Problem Identification

Problems of irrigation schemes at the field level were identified by asking questions to investors, farmers, operators (skilled laborers) and the authors' own observation. Technical problems were identified by the authors themselves from the field during operating period by asking questions to the investors/farmers/operators. Large-scale problems were identified by asking questions to the corresponding authorities. Other indirect problems were identified by the senior author himself by observing the whole situation in the operating period.

Methods of Evaluation

To determine the profitability of the irrigation schemes from the view point of individual investors, cost-benefit method was selected. In this study fixed cost and variable cost were considered. Compilation, tabulation, graphical representation, comparative analysis and evaluation of data were done. Optimization of investors' benefit and financial analysis were carried out.

Analytical Method

The collected data were coded, tabulated and then analyzed to obtain useful data. The activity budgets (Dillon and Harker, 1980) of irrigated HYV boro (dry season) rice were prepared by using the following equation.

$$R = P_yY + P_bB - \sum_{i=1}^{n}(P_{xi}X_i) - TFC \qquad (1)$$

Where, R, R_y, Y, P_b, B, P_{xi}, X_i, TFC, i and n are profit/ha, unit price of HYV boro paddy, yield/ha, unit price of HYV boro by product, yield/ha of HYV boro by product, unit price of ith input, total quantity of ith input/ha, total fixed costs/ha, number of individual inputs and (n = 1, 2, 3, ...), respectively.

Cost and Benefits of Irrigation Projects

The cost of the irrigation schemes includes fixed cost (capital cost, cost of pump house construction and installation, cost of electricity connection), labor cost and operating and maintenance (O&M) costs. In this study only the tangible benefits of the investor were considered. Investors enjoy the benefit from the production by the farmer through prearranged crop sharing system. The share of production is received by the investor in the field after harvesting, then it is threshed and valued by the prevailing market price. This is investors' income. By subtracting cost from income, the net benefit of the investor from the irrigation scheme was calculated.

Cost Estimation for Operating a Machine

The annual cost of operation a machine was calculated by using the following equation (Hunt, 1979).

$$AC = FC + \frac{A}{C}\{R\&M + (F + O + L) + T\} \qquad (2)$$

Where, AC, FC, A, C, R&M, F, O, L and T represent annual cost of operation (Tk), fixed cost (Tk), area used (ha), effective field capacity (ha/h), repair & maintenance cost (Tk/h), fuel cost (Tk/h), oil cost (Tk/h), labor cost (Tk/h) and cost for power source (Tk/h i.e. FC/h of motor), respectively.

Break-even Analysis

To take decision for economic operation, break-even point was found out by using cost and benefit data for different size of command area for irrigation schemes.

Financial Analysis of Irrigation Projects

Financial analysis of irrigation projects was carried out by determining Net Present Value (NPV) of money, Benefit Cost Ratio (B:C) and Internal Rate of Return (IRR).

Results and Discussion

The electric-powered tube well irrigation schemes of the study area were grouped according to four types of soil, namely; clay loam, silty loam, loam, sandy loam and as an overall. Investors, as the owner of the irrigation prime movers and equipment are expected to supply irrigation water, related technologies and use electricity. They had used their equipment on several farmers' land by enjoying 25% share of the production after harvesting. On the other hand, farmers were responsible for all other works and technologies and enjoy 75% share of the production of his own land after harvesting. This system has been started several years ago due to poor economic condition of farmers with fragmented land. After the failure of the Government's cooperative system, this system became popular at the study area. Satisfaction was observed in the mind of both farmer and investor. They both had tried to give optimum inputs to grow maximum production for their own benefit.

Cost, Return and Net Benefit of Investor and Farmer

Average cost, return and net benefit of investor and farmer were determined according to soil types which is shown in **Table 1**. In the case of all soils, farmers enjoyed positive net benefit although the investor had negative net benefit in sandy loam soil. It can be shown from the comparison of net benefits per hectare of investor and farmer that net benefit of farmer in each soil was 4 to 16 times higher than investor per hectare basis **(Fig. 1)**. If farmer and investor had equal amount of land in the scheme, then the individual farmer could earn more profit than the investor. But at the study area most of the farmers had small sized (even 0.04 ha) land compared with investor. The investor enjoyed income from all pieces of land of the scheme area. Investors suffered loss in sandy loam soil, and the farmer made profit **(Fig. 1)**. The application of excess irrigation water was the main reason for the negative benefit of the investor. From the above explanation, it can be noted that all soil types in the study area were suitable for rice production from the economic point of view but sandy loam soil was not economical for the investor at prevailing crop sharing system with current command area.

Table 1. Cost-benefit of Investor and Farmer and Yield of Rice

Soil type	Farmer (Tk/ha)			Investor (Tk/ha)			Yield (kg/ha)	
	Cost	Return	Net Benefit	Cost	Return	Net Benefit	Present	Potential
Clay loam	9317	17342	8026	4619	5781	1141	4106	5029
Silty loam	9761	26578	16817	4942	8859	3917	6088	8056
Loam	10248	17834	7586	5484	5945	460	4287	5148
Sandy loam	9544	14321	4778	7209	4774	−2432	3580	4565
Overall	9879	18802	8923	5313	6267	955	4500	5591

*1 U.S. dollar = 40 Taka (Tk.)

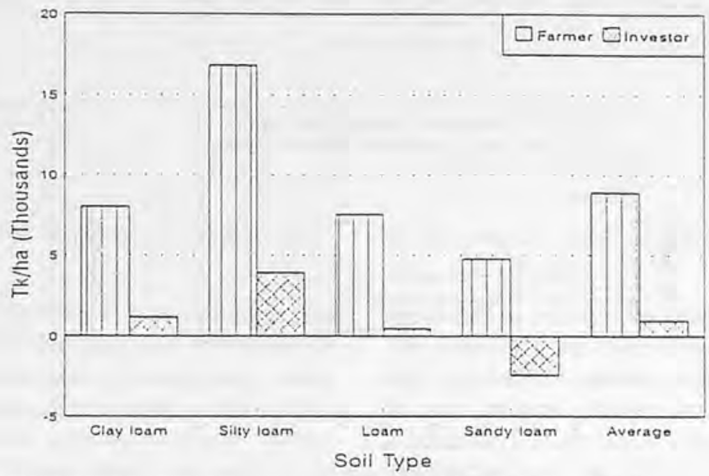

Fig. 1 Net benefits of investor and farmer in STW irrigation Schemes.

Yield of *Boro* (Dry season) Rice

The average present and potential yield of boro rice in 1994 are shown in **Table 1** which shown that potential yield in each soil was higher than it's present yield. The production of boro rice in silty loam soil was the highest (6 088 kg/ha) and lowest in sandy loam soil (3 580 kg/ha). Production in loam soil seemed to be higher than that in clay loam soil.

Break-even Analysis

Fig. 2 shows the break-even point of investor to cover different command areas in different soil types. For the commanded area under the break-even point an investor will get zero profit. The investor must cover greater command area than break-even point to make profit from irrigation schemes. It can be seen also from **Fig. 2** that for clay loam, silty loam, loam and sandy loam soil, break-even command areas were about 3.4 ha, 1.8 ha, 3.7 ha and 9.0 ha, respectively, for 1994

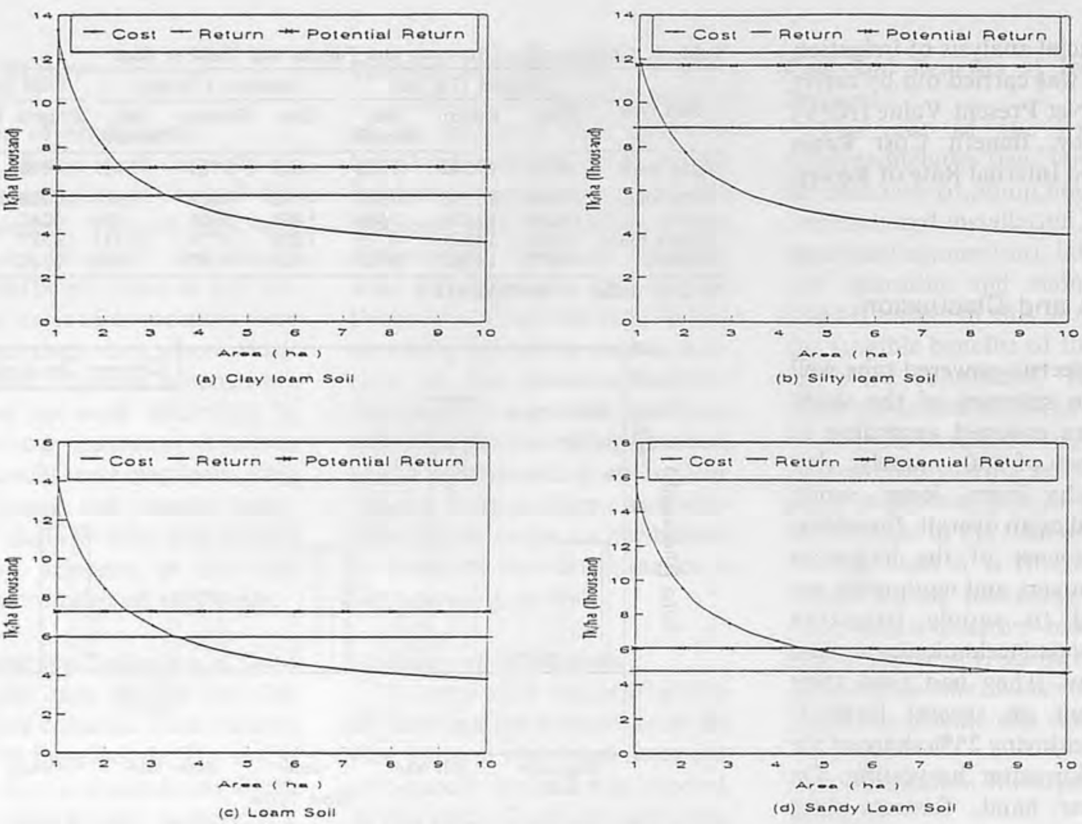

Fig. 2 Break-even command area of irrigation schemes.

operating condition and yield. But these break-even points could be changed to 2.5 ha, 1.2 ha, 2.5 ha and 4.6 ha for potential yield at the same condition, respectively. An investor must make a decision about the soils and command area to make profit before starting his investment.

Economics of Present vs Potential Command Area

Potential command areas of STW schemes for different soils based on the study result at present condition are 13.11, 16.96, 11.83, 11.27 and 12.65 ha, respectively, in clay loam, silty loam, loam, sandy loam soil and overall. The investor had to share a lower benefit for covering lower command area. If he could cover potential command area, his net benefit would be increased. It can be seen from **Fig. 3** that an investor could make net benefit of Tk. 12 828 and Tk. 55 363, Tk. 33 840 and Tk. 146 071, Tk. 7 289 and

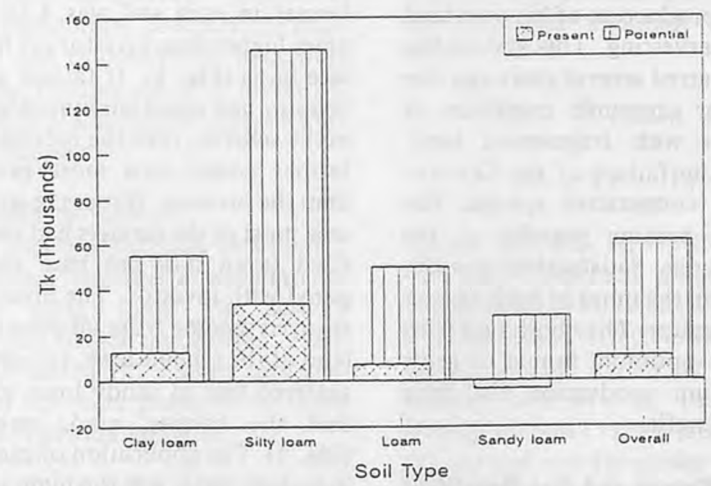

Fig. 3 Net Benefit at present and potential command area.

Tk. 49 833, Tk. 3 626 and Tk. 28 247 and Tk. 10 813 and Tk. 61 257, respectively, from the schemes in clay loam, silty loam, loam, sandy loam soil, and overall covered by present and potential command area. The net benefit in potential command area was 2 to 6 times than that of the present (utilized) command area. The investor of sandy loam soil suffered loss (Tk. 3 626/ha) by covering the present command area but he could make profit (Tk. 28 427/ha) by covering potential command area. If investor could reduce his share to a lower rate (<25%), then there would be an excellent opportunity to cover the potential command area without any difficulty.

Problems of Irrigation Schemes

Both investor and farmer have to sell their paddy at the local market immediately after harvesting. Due to the start of rainy season at harvest time, they have to harvest, thresh and dry their received paddy within a very short period by hiring labor at higher cost. The market price of paddy and fertilizer (urea) for different months is shown in **Figs. 4(a)** and **4(b)**. It can be seen from this figure that the lowest price of paddy was in May (Tk. 5 250/t; harvesting period) but was highest in March (Tk. 10 000/t; shortage period). For lack of storage and drying facilities, rainy season starting at harvest time and need for cash for both farmer and investor, supply of paddy into local market increased but demand was reduced to a very low level. These reasons were observed for lowest market price of paddy at harvesting season. January to April is the season for boro rice cultivation. In Bangladesh, urea is applied in March as top dressing which is the most important application out of three for optimum yield. It can be seen from **Fig. 4(b)** that in March, the price of urea increased to the highest value (2.4 times of Government rate) due to increasing demand and scarcity of supply. In off-boro season, the price of fertilizer seemed to be nearly constant. Farmers could not apply optimum amount of fertilizer to their land owing to higher price and low supply. For this reason, yield is reduced and the production cost of paddy is increased. The government failed to manage fertilizer distribution in 1995 boro season. Givinġ fertilizer to open market without control, creaated crisis although production was bumper. The market economy policy was the main reason for creating fertilizer crisis in 1995

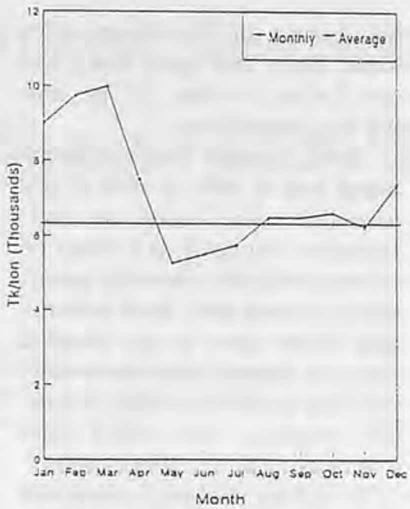

Fig. 4(a) Market Price of Paddy (Coarse).

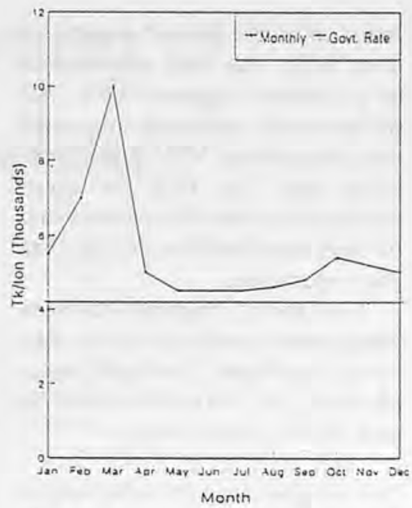

Fig. 4(b) Market Price of Fertilizer (Urea).

(GOB, 1995). Investor had to pay excess electricity bill for bearing a long service voltage drop since meters were located at the transformer instead of pump house. The investor had to deposit a large amount of money and had to pay connection and reconnection fee, consultancy fee, transformer cost and other costs to PBS (Pally Bidyut Samity, i.e., rural electrification cooperative) which was not payable for PDB (Power Development Board) consumers. Late transplantation of boro rice was observed in some farms due to delay in harvest of mustard and long rice transplantation time due to shortage of draft power. Various varieties of rice were used at the same command area. Suspension of ground water ordinance by the Government of Bangladesh without other alternative may be one reason for covering lower command area. After June 1994, the Government completely stopped the irrigation work through BADC (Bangladesh Agricultural Development Corporation) without offering any alternative.

Financial Analysis of Irrigation Schemes

Irrigation schemes at the study area were working like projects. The investors had been investing their capital in irrigation schemes to earn money. But an investor would not further invest his capital in irrigation if he did not make profit. If the investor could get more benefit, new investors would be attracted to it and every year new area would come under irrigation (at present 34% land, out of 82% irrigable, are under irrigation in Bangladesh). Considering irrigation schemes as projects from the investor's point of view, financial analysis by Net present Value of Money (NPV), Benefit Cost ratio (B:C) and Internal Rate of Return (IRR) were completed.

The result indicated that only irrigation schemes with present command area in sandy loam soil had negative NPV; but all other projects had positive NPV. Benefit cost ratio (B:C) of clay loam, silty loam, loam, sandy loam soil and overall for irrigation project with present and potential command area were 1.23 and 2.52, 1.78 and 3.81, 1.08 and 2.43, 0.66 and 1.73 and 1.17 and 2.63, respectively. Only in sandy loam soil with present command area had B:C lower than 1 (0.66). The silty loam soil project had the highest B:C. For irrigation schemes in sandy loam soil with present command area IRR was not determined as it showed negative NPV. All projects with potential command area had positive NPV at the operating year. So, IRR for these projects were not determined due to their profitability during first year operation.

The IRR of irrigation schemes with present command area in clay loam, silty loam, loam soil, overall were 35%, 747.47%, 18.93% and 29.8%, respectively.

Conclusions

The conclusions drawn from the analysis of the case study are as follows:

1) Irrigation schemes are profitable for both investor and farmer. Schemes in silty loam soil gave the highest production of paddy (6 088 kg/ha) and profit to both investor and farmer but schemes in sandy loam soil gave the least production (3 580 kg/ha), least benefit to farmer and financial loss (Tk. 2 432/ha) to investor. Investors derived less benefit from low command area due to excessive electricity cost, over irrigation (19% to 84%), uncontrolled market price of paddy and fertilizer. Cost-benefit analysis of command area showed that break-even command area in clay loam, silty loam, loam and sandy loam soil are 3.4 ha, 1.8 ha, 3.7 ha and 9.0 ha, respectively.

2) At present utilized command area is 28% to 40% of it's potential value based on soil. Investors can get 4 to 6 times of current profit by covering potential command area. Both investor and farmer have to pay about 2 times the normal labor cost to harvest and thresh the paddy manually within a very short time (owing to start of rainy season).

3) All the studied projects are financially profitable. Internal rate of return for irrigation schemes at present varies from 19% (loam soil) to 747.47% (silty loam soil).

Recommendations

For share crop-payment system, optimum command area with uniform cropping pattern and share should be considered for profitability of investors.

The Rural Electrification Board (REB) should give connection for irrigation without any deposit money and fee and other official bindings which discourage the investors. The Government should create storage facility, give subsidy to REB like PDB (Urban electricity supplier) by creating more PBSs.

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Research and Development of a New Direct Paddy Seeder

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Abstract

A new direct paddy seeder was developed at the Agricultural Engineering Department of Huazhong Agricultural University. The seeder has main distinguishing construction features: (1) small-sized power, (2) steel slide board, (3) wheel-driven feed roller, and (4) top delivery fluted feeder. The seeder has a working width of 3 000 mm and 14 rows. The result of performance test shows that: the feed quantity can be adjusted from 30 to 150 kg/ha, the standard deviation of feed quantity identity is 2.95 g, the standard deviation of drilling evenness is 3.34 seeds, the miss drilling rate is nil, the damage rate due to metering mechanism is 0.045%, the field capacity is 0.67-0.8 ha/h, and the fuel consumption is 1.2-1.5 kg/ha. The result of use test shows that: as compared with mechanical transplanting, manual broadcasting and manual transplanting, drilling with the seeder raises yield of grain by 12.72-14.48%, reduces production cost by 1.0-15.0%, saves manpower by 27.0-484.5 man-h/ha, increases net income RMB¥429.60-740.55/ha.

Introduction

Rice is one of main grain crops in China. Between the two methods of transplanting and direct seeding for planting rice, transplanting is the traditional method in China. In the last several decades, the technique of direct seeding has became popular as the area of direct seeded fields has gradutely increased. In North China, direct dry seeding is practised. In South China, direct wet seeding is the popular practice. Besides manual broadcasting, the methods of broadcasting with broadcaster, aerial seeding, hill sowing with dropper and drilling with drill seeder all are practised in China. Generally speaking, drilling with direct seeder is believed to be the main method to replace manual broadcasting.

In China the systematic research for direct paddy seeder was begun in the 1950s. Now the direct seeder can be classified as follows: direct dryland seeder and direct wetland seeder, and direct dual-purpose seeder also. The early direct dryland seeder was remade from animal-drawn or power-drawn grain drill. Then a special dryland paddy seeder was designed on the basis of refitment. As a result, a combined paddy seeder has been developed, with a combination of cultivator and seeder and combination of paddy seeder and herbicide spreader.

The early direct wetland seeder was also refitted on the paddy transplanter by replacing the seedling boxes and plant-setting mechanism with seed boxes and distributor mechanism but the travelling speed of this seeder was too slow. Now there are many types of specialized wetland paddy seeder which may match the walking tractor, four-wheel tractor and even track-type tractor. Most of the seeders have 6-18 rows and a 1.2-3.6 m working width.

The key problems in developing the direct paddy seeder are still to improve working quality and reliability, to raise field capacity and to reduce operation cost. For these purposes, a wetland paddy seeder was developed at the Agricultural Engineering Department of Huazhong Agricultural University and appraised by the Agriculture Ministry. A state patent was given in 1993.

Working Principle and Structural Characteristics

Working Principle

The direct paddy seeder can be matched with a 3.3 kW head of single-wheeled tillage machine or of paddy transplanter to set a unit **(Fig. 1)**. The seeder consists mainly of slide board, seed boxes, seedmeters, seed tubes, seed press boards, ridge-formers, furrow opener, mudguards, driving wheel, transportation wheels,

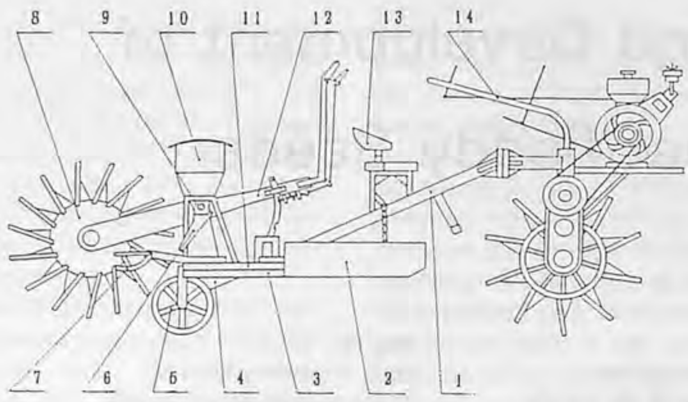

Fig. 1 The diagram of the seeder. (1. Draw frame 2. Mudguard 3. Ridge-former 4. Furrow opener 5. Transportation wheel 6. Seed tube 7. Seed press board 8. Driving wheel 9. Seedmeter 10. Seed box 11. Slide board 12. Lifting mechanism for driving wheel 13. Operator seat 14. Draw power)

draw frame, operator seat, and lifting mechanism for driving wheel.

Fig. 2 shows the working state of the unit in the field. When it works, the seeder is drawn forward by the head. The seeder supported on the slide board, which levels the field, slides on the surface of the field. The seeding ridges and irrigation furrow are formed by ridge-formers and furrow opener which are fixed on the bottom of the slide board. While the unit is moving forward, the driving wheel turns the metering roller shaft to work through the chain, and the seed is distributed by the seedmeters. With the help of the force of gravity, the seed drops on the seeding ridges through the seed tubes, then the seed is lightly pressed into mud by the seed press boards. When the unit travels on the road, the seeder is supported by the transportation wheels.

Structural Characteristics

The seeder has the following structural characteristics.

Small-sized power — The power of the seeder may be ahead of the single-wheeled tillage machine or paddy transplanter. It has many advantages due to the ready-made small power which is easy to manufacture, and the cost is low. The seeder unit can work in small-sized fields. It has good towing performance, rectilinear ride performance and mobility in mud.

Steel slide board — When the seeder works in the field, the body is supported on steel slide board which slides on the surface of the field not only reduces towing resistance but also improves ride performance in the mud. The ridge-formers and furrow opener can be directly fixed on the slide board which makes the seeder construction simplified. The slide board is made of common angle steel and steel sheet. Compared with wood slide board or plastics slide board, it has high mechanical strength and small sliding resistance.

Wheel-driven metering roller — The driving wheel is located in the center at the back. The chain drive is used between the driving wheel and metering roller shaft, hence the towing head does not need power take-off shaft. The drive has a small slip ratio and good working reliability. It is easy to control the feed quantity of the seeder in step with the travelling speed. The rotation of the metering roller shaft can be controlled with the lifting mechanism of the driving wheel. Therefore, there is no need for a cluth on the seeder.

Fig. 2 The new seeder in action.

Top delivery fluted feeder — There is a seed stop block at the upper part of each feeder cup and a vibration block at the bottom. The seed stop block is used to adjust the width of the upper distribution outlet. The function of the vibration block is to prevent seed forming bridge in the feeder cup and to reduce contact angle between the seeds and the metering roller. The forced feeding action on the seed is weak due to upper distribution and small contact angle, so it can reduce damage on seed due to metering mechanism while drilling wet germinating seeds. Because the feeder has a small feed quantity per turn, the seeder can work well on the condition of small feed quantity. There is no problem to drill precisely hybrid rice seeds with this new seeder.

Technical Parameters

The direct paddy seeder has the following technical parameters:

Overall size (length × width × height) (mm)	2 300 × 2 990 × 1 350
Structural weight (kg)	180
Number of rows	14
Row spacing (mm)	200
Row spacing of irrigation furrow (mm)	300
Number of seedmeters	14
Working width (mm)	3 000
Total volume of seed boxes (1)	104
Diameter of driving wheel (mm)	700
Power (kW)	3.3

Minimum turning radius (mm) 3 030
Range of feed quantity (kg/ha) 30-150
Field capacity (ha/h) 0.67-0.8
Fuel consumption (kg/ha) 1.2-1.5

Results of Tests

In the process of developing the seeder, 22 sample seeders were trial-produced in 5 rounds. Before falling in a pattern, the seeder had undergone several performance tests.

Results of Performance Tests

The performance tests were conducted at the Agricultural Machinery Appraisal Station of Hubei Province. According to NJ165-78 "Technical Conditions of Grain Seeder" and NJ167-78 "Test Methods of Seeder", the performance tests were evaluated by measuring feed quantity, stability of total feed quantity, identity of feed quantity, evenness of drilling, damage rate due to metering mechanism and miss drilling rate. Also, the net hourly capacity, field efficiency and fuel consumption were calculated.

Results of laboratory tests — In the laboratory test, "837" variety of paddy was used. The volume weight of the seed was 534 g/ℓ. The angle of repose was 84°. The moisture of the seed was 22%. The germination time of the seed was 72 h. The laboratory test was conducted with three replications. The average total feed quantity was 1 085 g, and the average feed quantity per row was 77.5 g. The results of the laboratory test are shown in **Table 1**.

The results of laboratory test indicate that the seeder had good feed quantity identity of different rows and good stability of total feed quantity. The seed damage was light.

Results of field test — The area of test field was 0.257 ha. The average depth of mud was 275 mm, and the average depth of water was 35 mm. The field was prepared to create a medium condition for seeding operation. The feed quantity was 136.5 kg/ha. the speed of the seeder was 3.56 km/h. The evenness of drilling was determinated by counting grains of the seed of 80 sample sections. The actual performance was evaluated by measuring the actual travel speed, actual working time, all auxiliary time and fuel consumption. The results of the field test are shown in **Table 2**.

The results of the field tests indicate that there was not much difference among the different sections: the drilling evenness was good and no miss-drilling took place. The results of field and laboratory tests were identical. It was equally evident that the seeder has high field capacity, and efficiency and low fuel consumption.

Results of Actual Test

The actual test was conducted in two state farms in Hubei Province for three years. The total test area was 172.3 ha. In the actual test the seeders were matched with other farm implements to conduct mechanization production of planting paddy and to examine actual performance and

Table 1. Results of Laboratory Test

Item of test	Identity of Feed Quantity: standard deviation (g)	Identity of Feed Quantity: coefficient of variation (%)	Stability of Total Feed Quantity: standard deviation (g)	Stability of Total Feed Quantity: coefficient of variation (%)	Damage Rate Due to Metering Mechanism (%)
Data	2.95	3.8	8.5	0.78	0.045

Table 2. Results of Field Test

Item of test	Evenness of Drilling: Standard deviation (grain)	Evenness of Drilling: Coefficient of variation (%)	Evenness of Drilling: Miss-drilling rate (%)	Actual Performance: Net hourly capacity (ha/h)	Actual Performance: Field efficiency (%)	Actual Performance: Fuel consumption (kg/ha)
Data	3.34	26.2	0	1.062	80.7	0.78

Table 3. Paddy Characteristics and Yield

Parameter	Plant height (mm)	Plant density (spike/m²)	Average grain per spike (grain/spike)	Grain yield (kg/ha)	Straw grain ratio
Drilling with the new seeder	105.2	270.4	107.3	7 858.5	1.45
Mechanical transplanting	104.3	201.1	114.4	6 864.0	1.48
Manual broadcasting	105.1	247.8	113.0	6 972.0	1.49
Manual transplanting	105.8	208.0	117.9	6 957.0	1.43

Table 4. Economics of Different Test Parameters

Parameter	Total manpower (man-h/ha)	Output value (RMB¥/ha)	Input cost (RMB¥/ha)	Net income (RMB¥/ha)	Comparative advantage (RMB¥/ha)
Drilling with the new seeder	181.5	3 669.30	1 733.55	1 935.75	—
Mechanical transplanting	414.0	3 204.60	1 884.90	1 319.70	−616.05
Manual broadcasting	208.5	3 255.90	1 749.75	1 506.15	−429.60
Manual transplanting	666.0	3 234.30	2 039.10	1 195.20	−740.55

adaptability to different use conditions. A comparative test was also conducted to evaluate the performance of mechanical transplanting, manual broadcasting and manual transplanting under similar conditions. Other operations were done by machines, i.e., field preparation, weeding, crop protection, irrigation, harvesting and transportation. For different treatments the observations were taken for details of crop growth, input cost and output value. The results of the tests are shown in **Tables** 3 and 4.

Table 3 shows that the highest yield of grain was recorded by the mechanical drilling with the new seeder, separately 14.48%, 12.72% and 12.96% higher than in mechanical transplanting, manual broadcasting and manual transplanting. The highest yield of grain was due to the greatest plant density. There was not much difference in plant height and straw grain ratio, but the average grains per spike was a little lower for the mechanical drilling than in other treatments. **Table 4** shows that the total manpower was minimum for the mechanical drilling, followed by manual broadcasting and maximum in manual transplanting. The output value of different treatments basically corresponds to the grain yield in **Table** 3. As compared with mechanical transplanting, manual broadcasting, and manual transplanting, drilling with the new seeder reduced input cost by 8.0%, 1.0% and 15.0%, and increased net income RMB¥ 616.05, 429.60 and 740.55/ha.

Conclusions

The new seeder is a new suitable machine which is used in direct paddy seeding. The seeder has simple construction, good serviceability, high field capacity and low fuel consumption. The seeder has high drill precision and operation quality. As compared with mechanical transplanting, manual broadcasting and manual transplanting, drilling with the new seeder can increased grain yield, reduce production cost, save manpower and increase net income. The seeder can be widely put into use in paddy planting areas. ■■

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Rice Post-harvest Practices and Loss Estimates in Bangladesh — Part III: Parboiling to Milling

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Abstract

This paper reports on the common practices and loss estimates during parboiling, storage and milling operations. Loss estimates from harvesting to sundrying from the same study were reported elsewhere. The total paddy loss estimates from parboiling to milling were 5.7, 7.7 and 6.7% for 'Aman', 'Boro' and 'Aus' seasons, respectively, with the weighted average loss of 6.7%. Parboiling loss (mainly comes from drying) was high due to domestic animals and birds feeding during drying, and also due to scattering. Storage loss was highest (1.2%) in 'Boro' season because of higher insect infestation on moist grain. On three seasons average, raw paddy produced higher loss than other commodities. Milling loss was observed high (~3.8%). Raw paddy milling produced higher brokens compared to parboiled paddy due to soft kernel.

Acknowledgement: The authors are thankful to the contributions of the field and laboratory staff in observing post-harvest practices, loss assessment work and analysis of field samples.

Introduction

Bangladesh is an agricultural country with rice as the staple food. Eighty four percent of the total calories consumed comes from rice (Chen, 1975). She has 11.5 million ha of cultivable land, of which 89% is used for rice cultivation, producing more than 22 million t of paddy per year (Bangladesh Bureau of Statistics, 1990). More than 85% of the population live in the vilages and agriculture is the major occupation of the people. Bangladesh agriculture is characterized by fragmented farming, small land holding and low production output per unit area.

Rice production in Bangladesh has risen rapidly since the establishment of the Bangladesh Rice Research Institute (BRRI). It has played a significant role in developing high yielding varieties (HYVs) suitable for different climate and soil conditions in different areas of Bangladesh. The climate of Bangladesh is hot and wet during summer (April to September) but cool and dry during winter (October to March). Monsoon starts in late April accompanied by storm. Because of regional differences in climate and weather (rainfall, flood, drought, temperature, humidity) farmers in different parts of the country may produce one, two or three crops a year. Rice is harvested during 'Boro' (April to June), 'Aus' (July to August) and 'Aman' (November to December) season. Post-harvest practices, although varying among localities, are still often primitive and traditional, and as a result post-harvest losses may be high. One of the methods to increase the availability of food is the reduction of these losses.

Very little information is available about the post-harvest practices and losses to identify operations where loss prevention programme can be implemented. Bala (1978) reported that total losses in drying ranges from 1.6 to 5.0% and that in storage (due to insects and rodents) ranges from 3.1 to 7.5% in Bangladesh while the physical loss of paddy for ~3 months storage was 2.6% (Greeley and Rahman, 1990).

With a view to reducing post-harvest losses as a means of increasing availability of food, BRRI and the Food and Agriculture Organization (FAO) jointly carried out a study on the farm and village level post-harvest rice loss assessment. The objectives of this study were to observe and gather information on the existing post-harvest practices, to estimate the size and causes of post-harvest losses and to suggest methods of reducing these losses. This report covers part of the post-harvest rice loss assessment (from parboiling to milling) in 35 villages during 'Aman', 'Boro' and 'Aus' harvest seasons. The post-harvest practices and loss estimates from harvesting to field transport and threshing to sundrying are included in Haque et al. (1989) and Haque et al. (1991), respectively.

Parboiling to Milling Practices

Parboiling

Parboiling is a hydro-thermal treatment usually followed by drying before milling. It consists of soaking, steaming and drying. Majority of the Bangladeshi people eat parboiled rice.

Soaking — The process of water absorption is known as soaking, steeping or imbibition. It is a diffusion process, and as a result of water absorption, the grain swells. Soaking provides sufficient quantity of water to the starch granules for gelatinization. Paddy is usually soaked for 24 to 48 h in clay pot, aluminium pot, large clay pot 'chari', cut-drum and concrete tank with capacities ranging from 5 to 20 kg. During the wet season, farmers usually skip soaking of freshly harvested high moisture paddy and directly go for steaming.

Steaming — After soaking the paddy is steamed for about 30 min. Soaked paddy is placed in the steaming pot in such a way that 20% of the paddy is submerged in water. The pot is then placed in the 'Chula' (oven) and heated to produce steam. Boiling water parboils the submerged grain and steam parboils the remainder. This helps to seal any crack inside the grain and gives the kernel a hard texture which ultimately helps to reduce breakage during milling.

Farmers also practice double parboiling to reduce soaking time and to improve milled rice quality. In double parboiling, unsoaked paddy is steamed with little water and allowed to soak for few hours and steamed again. Burned clay pot, aluminium pot, and cut-metal drum are used for steaming. Women in the house do this job. Straw, leaves, wood, bamboo splits and rice husk are usually used as fuel for steaming.

Drying — Drying is a thermodynamic process wherein moisture is removed from the material by vapour pressure differences between grain and the ambient air. Drying is also accomplished with evaporative cooling action. Sundrying of paddy is the most common practice in Bangladesh. Wet paddy is usually spread over the hard, levelled, and mud plastered dry 'Kacha' floor with a thickness of 5 to 10 mm. Thickness is irregular over the drying floor due to ridge formed during stirring. Grain is usually stirred by foot dragging or sometimes by wooden spreaders pulled and pushed by man over the grain. During 'Boro' and 'Aus' seasons, when drying floor in the courtyard remains wet and damp, people dry paddy on woven bamboo mat plastered with cowdung and mud. They also use roadside as drying floor during the wet season.

Drying of parboiled paddy is slightly different from raw paddy. Usually, farmers dry parboiled paddy in two stages to avoid cracks in the kernel. Moisture content is reduced from ~35 to ~22% in the first day, and keep overnight in bulk storage for tempering and finally reduced to 15-16%. Tempering stabilizes moisture gradient inside the grain reducing moisture stresses.

Storage

Usually, farmers store their dried paddy as raw, parboiled or milled rice. Generally, raw paddy is stored for sale or seed for longer period (more than 3 months). Consumption paddy is stored generally as parboiled paddy and parboiled rice for shorter period (1-3 months). Storage structures may be grouped as (a) bamboo type, (b) pot type, and (c) others. Among the bamboo type structures, *gola*, *dole*, *jabor*, *baer*, *machi* and *tala* are mainly used for storage of raw and parboiled paddy. All these structures are made from bamboo, bamboo split and woven bamboo strips and plastered with cowdung mixed with mud. The shape and size of these structures vary from round to rectangular. The capacity of stores varies from few *maunds* to over 100 maunds (1 maund = 37.327 kg). Usually these stores are built or kept on elevated platform to avoid damp and rodent attack. Bamboo made gola is generally built separately with roof covers. These are large capacity stores. The ceiling of the room is called *tala*. *Machi* is built inside a room using two walls of the room and a separate woven bamboo-made wall is fixed to the other sides.

Among the pot type structures, *dabor*, *motka*, cola (*mait*), *jar*, *tin* and *metal* drums are mainly used for storage of parboiled rice and seed paddy. These burned clay pots are made by potters and placed inside the room usually with lid to save grain from insects, rodents and weather hazards. Dabor is big structure and contains about 5 to 8 maunds of rice. Motka, cola, tin, drum and jar are small structures and their storage capacities are not exceeding

100 kg. Among the other type of structures, gunny bags and floor are used for temporary storage of both paddy and rice. Bags are usually kept on pallet to avoid moisture migration from *kacha* floor and to provide ventilation.

Milling

In general, milling refers to the size reduction and separation of food grains into edible form by removing and separating the inedible and undesirable portions from them. It involves husking and polishing.

Dheki — The traditional way of removing the inedible husk from paddy is by use of a mortar and pestle device known as a *dheki*, operated by women in rural areas. The *mortar* has a wooden base set on the ground, with hard plastered walls giving a roughly cylindrical pit of approximate diameter of 15-20 cm and a typical depth of 15 cm. The *pestle* (typical height of 40-50 cm) consists of a cylindrical metal ring (typical diameter 7-8 cm) fixed to the end of a wooden ram, and projecting about 2-3 cm below it. This metal ring protects grain from breakage and help qick milling. The pit is filled and emptied manually, and the ram is raised and lowered by a foot-operated lever arrangement consisting of a pivoted beam of typical length 2 m.

Huller mill — With increasing availability of electricity in rural areas, the dheki has been largely superseded by huller mill. There the paddy is husked and whitened by a ribbed metal cylinder rotating (at 600-900 rpm) in a ribbed cylindrical housing, the lower half of which is perforated to allow the husks and bran to drop through. The huller mill is far less labour-intensive than the traditional method, and has a much higher capacity (typically 500 kg/h, in comparison with about 5 kg/h per person for the dheki). On the other hand, huller-milled rice is always over-polished, with consequent loss of nutrients and also has a much higher proportion of broken grains.

Loss Assessment Procedure

Five districts, Dhaka, Sylhet, Comilla, Bogra and Rajshahi were selected for the loss assessment study. A total of 35 villages were selected for the 'Aman', 'Boro' and 'Aus' seasons. The villages were selected based on accessibility, cooperation of the farmers and the representativeness of the villages in the cropping pattern and post-harvest practices of the district. The post-harvest operations studied were harvesting, field stacking/bundling/drying, transporting, threshing, cleaning/winnowing, sundrying, parboiling (soaking + steaming + drying), storage and milling.

In parboiling operation, loss was calculated by dividing the difference between initial and final weights by the initial weight of the grain. In storage, grain samples from the stores were collected at the start of storage after harvest and every 15 days or one month thereafter depending upon the expected duration of storage. The storage samples were analyzed in the laboratory by Count and Weigh Method and Total Weight Loss Method (Haque et al. 1987). The difference in weights between initial and subsequent samples was considered as loss. The loss was added cumulatively over the storage period and final loss was calculated by dividing the loss by the weight of the stored grain.

Loss calculation in milling was determined by taking 6% polishing of brown rice as base. Any polishing above 6% was considered loss. The husking and polishing were done at the Satake laboratory mill. Any polishing below 6% was considered gain or no loss. The weight difference between milled rice recovery from village and laboratory mill at 6% polishing was considered loss. All grain weights were converted to standard 14% moisture content (wet basis) before loss calculations of field and laboratory data were made. The detailed methods and procedures contained in the post-harvest rice loss assessment manual prepared previously for the project by Arboleda et al. (1983), was used in the study.

Results and Discussion

Parboiling

Parboiling loss was observed high, 2.12, 1.99 and 2.86% for the 'Aman', 'Boro' and 'Aus' seasons, respectively **(Table 1)**. Although grain losses were noticed around the working area, inside and outside the steaming and soaking tanks, the combined loss in these operations were observed negligible (0.11% and less). The main cause of loss in parboiling was observed during drying.

The loss in drying operation was 2.11, 1.93 and 2.75% for the Aman, Boro and Aus seasons, respectively, or an average of 2.24% **(Table 1)**. It was observed that the possible causes of loss were eating by domestic animals (chickens, birds, ducks, goats and cows) and birds; grain spillage and scattering during drying. Mannan (1983) reported that a common *myna* (*Acridotheres tristis* Linn) abundant in the country consumes ~10.9 g and a black rock pigeon (*Columba livia* Gmelin) ~51.4 g of paddy everyday. Dry matter loss could be another reason for loss. Another reason for the high loss observed during drying was the small quantity of paddy dried by the farmers as 1 kg grain lost in drying 25 kg paddy is 4% loss

Table 1. Percent Loss Estimates in Post-harvest Operations by Season*

Post-harvest operation	Aman	Boro	Aus	Weighted average
Parboiling				
Soaking	—	0.04 (31)	0.05 (17)	0.04
Steaming	0.01 (60)	0.02 (57)	0.06 (57)	0.02
Drying	2.11 (75)	1.93 (61)	2.75 (55)	2.24
Storage	0.30 (143)	1.20 (144)	0.30 (137)	0.61
Milling	3.28 (80)	4.54 (75)	3.55 (79)	3.78
Total	5.70	7.73	6.71	6.69
Harvesting to field transport	3.90	2.40	3.20	3.50
Threshing to sundrying	3.58	3.10	4.01	3.53
Grand total	13.18	13.23	13.92	13.72

*Numbers in parentheses are sample sizes.

Table 2. Percent Storage Loss Caused by Insects in Different Stores and Commodity, by Season*

Store type	Aman	Boro	Aus	Weighted average
All stores	0.3 (143)	1.2 (144)	0.3 (137)	0.61
Bamboo	0.3 (116)	1.2 (92)	0.3 (99)	0.57
Pot	0.2 (18)	1.3 (13)	0.4 (7)	0.61
Other	0.6 (9)	1.1 (39)	0.2 (31)	0.69
Raw paddy				
All store	0.4 (66)	1.1 (88)	0.4 (59)	0.69
Bamboo	0.4 (61)	1.0 (57)	0.3 (53)	0.57
Pot	—	—	—	—
Other	0.9 (5)	1.3 (31)	0.6 (6)	1.15
Parboiled paddy				
All store	0.3 (45)	1.4 (34)	0.2 (63)	0.52
Bamboo	0.3 (44)	1.5 (31)	0.2 (46)	0.57
Pot	—	—	0.2 (3)	—
Other	0.1 (1)	0.1 (3)	0.1 (14)	0.10
Parboiled rice				
All store	0.2 (32)	1.0 (22)	0.2 (15)	0.46
bamboo	0.2 (11)	0.7 (4)	—	0.23
Pot	0.2 (18)	1.3 (13)	0.5 (4)	0.64
Other	0.4 (3)	0.6 (5)	0.1 (11)	0.28

*Numbers in parentheses are sample sizes.

but is only 1% for 100 kg paddy being dried. The estimated drying loss ranges from 1-5% for Southeast Asia (De Padua, 1974) and 2% in Indonesia (Gaiser, 1981).

Storage

Results of the study showed that the storage loss caused by insects was low, 0.30, 1.20 and 0.30% for the Aman, Boro and Aus season, respectively, **(Table 1)**. Dry winter weather, low air humidity, low temperature and rainless days during and after the Aman season harvest enable the farmers to dry the grain thoroughly making the storage condition not conducive to insect infestation, resulting in lower loss values obtained. During the 'Boro' season, on the other hand, the weather was wet and the crop was harvested very wet, dried and stored during the rainy season. With moist grain in store, high air temperature and humidity, the condition for insect infestation was ideal resulting in higher storage loss. The Aus season produced lower loss due to short duration storage. The reported losses in storage ranged from 2-6% for Southeast Asia (De Padua, 1974); 4.6% in Nepal (Kumer, 1984); 7% in Korea (Lee, 1984) and 5% in Indonesia (Gaiser, 1981). These losses were caused by insects and rodents. Pilferage loss was also included.

Bamboo-made storage structure was predominant in all the districts and seasons studied. Losses from parboiled paddy was higher than those of raw paddy and parboiled rice in the Boro season **(Table 2)**. Considering three-season average, however, higher loss was obtained from raw paddy than from parboiled paddy and parboiled milled rice. Raw paddy was stored in larger quantity (~500 to ~800 kg) compared to parboiled paddy (~300 to ~600 kg) and parboiled rice (~65 to ~135 kg) in all the seasons. The average storage period of the farmers studied were 2.63, 2.78 and 1.61 months, respectively, for the Aman, Boro and Aus seasons. Although some of the farmers who stored longer than these values, the relative percentage was low. The most common storage insects observed were rice weevil (*Sitophilus oryzae* L.), lesser grain borer (*Rhizopertha dominica* F.), grain beetle (*Tribolium castenium* H.) and grain moth (*Sitotroga cerealella* O.).

Milling

The loss in milling operation during the dry, Aman season, when the farmers were able to dry or process their grain properly was 3.28% **(Table 1)**. In the wet Boro and Aus season, however, when humidity was high and short duration downpour comes, the milling loss was higher (4.54 and 3.55%, respectively). The farmers tended to overdry the grain during Aman season because of low temperature, continues sunshine and dry air. Humid air, high temperature and intermittent/continuous rain during the Boro and Aus harvest result in grain moisture content higher than the accepted level for safe storage and processing. Overdried grain is brittle while under dried grain is soft. In both cases the grain would break and the machine would scour or remove more bran than the usual milling process. The high quantity of broken grains observed in the milled rice in both villages and laboratory mills indicated a poor quality of the grain before milling. The estimated loss from raw paddy milling in huller mill ranges from 2-10% for Southeast Asia (De Padua, 1974); 4.2% in Nepal (Kumer, 1984); 1.5% in Korea (Lee, 1984) and 5% in Indonesia (Gaiser, 1981).

Small and Large Farmers

The farmers who owned less than one hectare of land are classified as small farmers while the large farmers owned more than three hectares of land. Separating the loss data between small and large farmers, the result obtained did not vary very much during parboiling and milling for any season **(Table 3)**. Statistical t-test showed that the loss difference between small and large farmers in the parboiling and milling operations studied were insignificant.

This result implies that large farmers, locally identified by the villagers, practised with the same care as small farmers did in hardling their crops in both operations. All farmers for storage study were large because small farmers did not have enough grains to store.

Table 3. Percet Loss Estimates in Parboiling and Milling Operations, by Farm Size and Season*

Post-harvest operation	Farm size	Aman	Boro	Aus
Parboiling	Small	2.15 (30)	2.06 (29)	2.61 (31)
	Large	1.93 (31)	1.82 (32)	2.92 (24)
Milling	Small	3.12 (42)	4.39 (36)	3.58 (40)
	Large	3.47 (38)	4.68 (39)	3.51 (39)

*Numbers in parentheses are sample sizes. Statistical t-test showed that the loss differences between small and large farmers were insignificant.

Conclusions and Recommendation

The aggregated loss estimate in parboiling, storage and milling was 5.70, 7.73 and 6.71% for the Aman, Boro and Aus seasons, respectively, with a weighted average of 6.69%. In actual value, this is equivalent to 940 726 mt cleaned rice from a total production of 14 061 675 mt. The estimated loss from harvesting through sundrying of raw paddy was 7.48, 5.50 and 7.21% for the Aman, Boro and Aus seasons, respectively (Haque et al. 1989, 1991). Therefore, a total of 13.7% loss was accounted for all the post-harvest operations in Bangladesh (**Table 1**).

Milling loss was observed high which could be attributed to improper processing of the grains before milling. Ideally, parboiled paddy is hard and resilient with cracks on raw paddy sealed during parboiling. It resists pressure and friction during milling while raw paddy (if not properly dried and processed) is soft and would easily break during milling. It is recommended, therefore, that proper parboiling to produce evenly parboiled paddy and proper drying to minimize cracks on the grains must be done prior to milling.

The storage loss incurred in the Aman and Aus seasons were low because of the dry weather after harvesting, while the Boro season loss was high because of the wet and rainy period during and after harvesting. It is recommended that the grains must be thoroughly dried before storage and the stored grain must be redried in times of bright sunshine in order to evaporate moisture absorbed by the grain from the humid air during storage. This process also disturbs insect activities in the store.

It was observed during the course of the study that the perceptible problems and losses known to farmers on stored rice is rodent infestation. Even if a national rodent eradication programme is existing, the accurate loss estimate in storage due to rodent is not available. Since loss assessment caused by rodents was not included in this study, it is recommended that further studies must be conducted along this line.

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Thermal Performance Tests of Solar Dryer Under Hot and Humid Climatic Conditions

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Abstract

An experimental fiber-glass greenhouse (gable-even span form) was designed, built, installed and employed as a solar dryer at the workshop of the Agricultural Engineering Department in order to study, test and evaluate its thermal performance. The meteorological data related to this research work such as ambient air temperatures inside and outside the solar dryer, internal and external air relative humidity, solar radiation flux incident and air speed were monitored, measured and recorded over different times of the day. The thermal performance and effectiveness of the solar dryer were computed at different mass flow rates ranging from 0.130 to 0.320 kg/s. A mathematical relation was developed to describe the relationship between the inlet and outlet temperatures of the air that passes through the collector. The hourly average overall efficiency of the solar dryer throughout the experimental work was 68.99%.

Introduction

Due to the steady increase in fossil fuel costs and their uncertain availability, considerable attention has been given to solar energy as an alternative or supplement to fossil fuels for heating air and, consequently, utilizing it in drying process. The energy resource for agricultural application is strongly dependent upon the development of solar energy systems that have optimum performance, good reliability and economic characteristics that compare favorably with conventional energy systems and other energy sources. This development must reach a point where satisfactory thermal performance and reliability can be achieved for numerous solar energy applications. Also to be economical, the solar energy systems must have high annual utilization, relatively long life and be properly designed for location and application. Therefore, it is important to consider the amount of solar radiation available for each location and the nature of the specific application to realistically evaluate solar energy as an alternate energy source. In drying processes, there are many methods requiring heated air at relatively low temperatures. Conventionally, the heat sources for these approaches are usually gas (LP gas) or electricity. But recent concern, as mentioned previously, has promoted new interests in the use of solar energy for at least some of these approaches. There are many types of solar grain dryers which are usually used in drying processes for agricultural products. Also, several investigations have evaluated the use of solar energy as a source of thermal energy for crop drying (Thomas and Vaughan, 1981; Cooper and Sheridan, 1982; Sabbah, 1985; Tayel and Wahby, 1989; Abdellatif, et al., 1993 and many others). Studying the possibility of utilizing solar energy for heating air inside a greenhouse and the use of that heated air in drying processes under Egyptian conditions has been studied by many investigators (Abdellatif and Helmy, 1992; El-Sahrigi, et al., 1993a; El-Sahrigi, et al., 1993b). However, there is no readily available information about the utilization of an experimental greenhouse as a solar collector (solar air heaters) under the conditions of the Eastern Province of Saudi Arabia. The main objective of the present work is to investigate under clear sky conditions the effect of the following parameres which are considered to be important in relation to solar air heater (solar dryer) performance. (1) The position of the sun at any given time in Al-Ahsa (Eastern Province) in order to compute the solar radiation available inside the experimental greenhouse (solar dryer) using an arithmetic model; (2) Air properties inside and outside the solar dryer; (3) Air mass flow rate inside the solar dryer; and (4) Effectiveness of the experimental greenhouse as solar air heater (solar dryer). To fulfill these objectives a series of experiments were carried out in September through December 1994, at the Agricultural and Veterinary Research Station of King Faisal University.

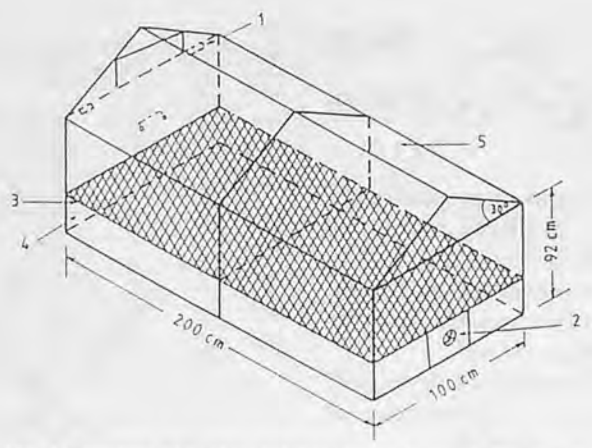

Fig. 1 Strcuture of a solar air heater (solar dryer). 1. Window (air intake); 2. Extracted fan; 3. Wire netted floor; 4. Air chamber; 5. Fiber glass cover.

Materials and Methods

Design of Solar Dryer

An experimental gable-even span greenhouse (solar dryer) was designed, constructed, installed and employed at the workshop of the Agricultural Engineering Department. The gross dimensions of the solar air heater (greenhouse) are 2.0-m long, 1.0-m wide and 1.21-m high, with an internal floor surface area of 2.0 m^2. The solar dryer structural frame is formed from an aluminum bar (2-inch wide). The rafter length is 0.58 m and gable height is 0.28 m, while the height of each side wall is 0.92 m as shown in **Fig. 1**. The rafters are inclined at 30° to maximize the solar radiation available inside the solar dryer, and otherwise, to minimize the side effects of wind load on the roof of solar air heater. Two square timber (dryer box) were made from plywood (1-inch thick). The gross dimensions of each square timber are: 1.0 m in length, 1.0 m in width and 0.3 m in height, with an internal drying floor area of 1.0 m^2. The drying floor is formed by placing the wire-netted plate on the square timbers. The air duct is the space between the wire netted plate and the bottom of the dryer box. An electric fan (60 cm diameter) for suction (extracted fan) is placed in a shelter at one side of the solar dryer. On the top of the opposite side, an open window is placed as an air intake. It has a surface area of 0.075 m^2 (0.5-m long and 0.15-m wide). The solar dryer is orientated with east-west direction in order to capture the maximum possible solar radiation flux incident on it, and covered using 5-mm thick fiber glass sheet. Air is cycled through the solar heater (which has hot air, heated by solar energy). After passing through the solar air heater, the heated air is vertically moved through the dryer box. Three different air speeds, 1.5, 2.5 and 3.5 m/s, representing air mass flow rates of 0.135, 0.225 and 0.315 kg/s, respectively, were employed throughout the experimental work.

Instrumentation

Sensors were employed to measure temperature, solar radiation, air mass flow rate and relative humidity of air outside the solar air heater (greenhouse) using thermistors, pyranometers, anemometers, as well as wet and dry bulb thermometers, respectively. Four thermistors were distributed in a 1 × 4 grid pattern on the central plane through the solar dryer. Sensors were located at 18, 36, 54 and 72 cm above the dryer box and 40, 80, 120 and 160 cm from the end of solar dryer. The external ambient air temperature was measured using one thermistor. The digital thermocouple-anemometer was employed to measure the air outlet temperature and air speed outside the extracted fan. A pyranometer was used to measure the solar radiation flux incident on a horizontal surface outside the solar dryer. The wet and dry bulb temperatures were measured using wet and dry bulb thermometers.

Thermal Performance Tests of Solar Air Heater(solar dryer)

To measure, test and compute the thermal performance of the solar air heater (solar dryer), a series of equations which have been used by several investigators (Rumsey and Fortis, 1982; Lau and Staley, 1989; Abdellatif et al., 1993) were employed as follows:

$$Q_c = R_T A_d \tau, \quad \text{(Watt) (1)}$$

$$R_T = Q_D(\text{front wall}) + Q_D(\text{back wall}), \quad \text{(Watt) (2)}$$

$$Q_D(\text{front wall}) = I_D \sin\psi (A_1 \cos\beta_1 + A_2 \cos\beta_2) + I_D \cos\psi \cos\gamma_{ss} (A_1 \sin\beta_1 + A_2 \sin\beta_2), \quad \text{(Watt) (3)}$$

$$Q_D(\text{back wall}) = I_D \sin\psi (A_1 \cos\beta_1 + A_2 \cos\beta_2) - I_D \cos\psi \cos\gamma_{ss} (A_1 \sin\beta_1 + A_2 \sin\beta_2), \quad \text{(Watt) (4)}$$

$$Q_s = Q_c - A_d U_o (T_{ao} - T_{ai}), \quad \text{(Watt) (5)}$$

$$\text{or } Q_s = m^{\bullet} Cp (T_{ao} - T_{ai}), \quad \text{(Watt) (6)}$$

$$m^{\bullet} = V A_w \varrho, \quad \text{(kg/s) (7)}$$

$$\eta_o = \frac{Q_s}{Q_c} \times 100, \quad (\%) \ (8)$$

$$D_T = \frac{T_{ao} - T_{ai}}{R_T}, (°C\,m^2/W) \ (9)$$

where:

Q_c = hourly average solar radiation available inside the solar dryer, Watt.

R_T = hourly average solar radiation flux incident on dryer surface, W/m^2.

A_d = surface area of dryer, m^2.

τ = effective transmittance of cover, decimal.

$\tau = 0.95 - 0.00437 \exp[0.0396 (\theta - 30)]$.

θ = solar incident angle, degree.

$\theta = \arccos [\cos\psi \cos\gamma_{ss} \sin\beta + \cos\beta \sin\psi]$.

ψ = solar altitude angle.

$\psi = \arcsin [\cos\phi \cos\delta \cos\omega + \sin\phi \sin\delta]$.

γ_{ss} = solar-surface azimuth angle.

$\gamma_{ss} = \arccos [(\cos\delta \sin\phi \cos\omega - \cos\phi \sin\delta)/\cos\psi]$.

ϕ = latitude angle, 25.3° for Al-Ahsa.

β = surface tilt angle, (β_1 = 90°, β_2 = 30°).

δ = solar declination angle.

$\delta = 23.45 \sin [0.9863(284 + n)]$.

ω = solar hour angle

$\omega = 15(LAT - 12)$.

LAT = local apparent time.

Q_D = hourly average solar radiation perpendicularly incident on the surface of dryer.

Q_s = hourly average useful heat collected (gain), Watt.

U_o = overall heat transfer coefficient, $W/m^2/C°$.

T_{ao}, T_{ai} = air outlet and inlet temperatures, respectively, C°.

$m^{\bullet}$ = mass flow rate of air, kg/s.

C_p = specific heat of air, 1006 j/kg/C°.

V = air speed, m/s

ϱ = density of air, 1.20 kg/m^3.

$A\omega$ = area of air intake window, m^2.

η_o = overall efficiency of solar air heater, %.

D_T = temperature rise, $C°.m^2/W$.

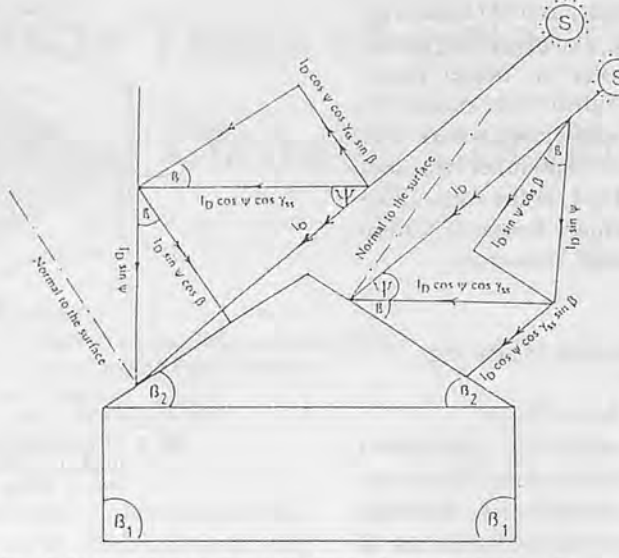

Fig. 2 Solar radiation flux incident on front and back walls.

The thermal performance tests of the solar dryer were measured and computed for different air speeds (1.5, 2.5 and 3.5 m/s). Two different arithmetic programmes were employed in this experimental work; the first one was used to compute the solar radiation normally incident on the vertical and tilted surfaces (**Fig. 2**), the second was employed to evaluate the thermal performance of the solar air heater (greenhouse). Data were analyzed and represented using programmes from Microstat Statistical Package and Cricket Graphics in order to assess and indicate the most dominant parameters affecting thermal performance of the solar air heater.

Experimental Results

Experimental testing was performed during September through December 1994, under different meteorological conditions, so that differences in efficiencies among experimental data sets were mainly due to differences in both air mass flow rates and meteorological parameters. Solar air heater data have been collected and analyzed for a total of 16 days over the last 102 days from September 20, 1994. A total of four tests were carried out during this time, and the average length of each test period was four days.

For the duration of the experiments, the daily average solar energy available inside the solar dryer was 9.495 kWh/day. Actual solar radiation data recorded on a clear day ranged from zero to about 1000 W/m^2. Thus, the solar energy available varied from sunrise to sunset according to the incoming solar radiation (**Fig. 3**). The daily average amounts of solar energy available inside the solar dryer (9.495 kWh/day) converted into useful heat collected (gain) during these experiments were 7.238 kWh/day, 6.445 kWh/day and 5.971 kWh/day for the three different air mass flow rates of 0.135 kg/s, 0.225 kg/s and 0.315 kg/s, respectively. The hourly average useful heat gain for the three different air mass flow rates was plotted in **Fig. 4**. Mathematical analysis of the measured data revealed that during early morning, just after sunrise, and just prior to sunset (when the solar

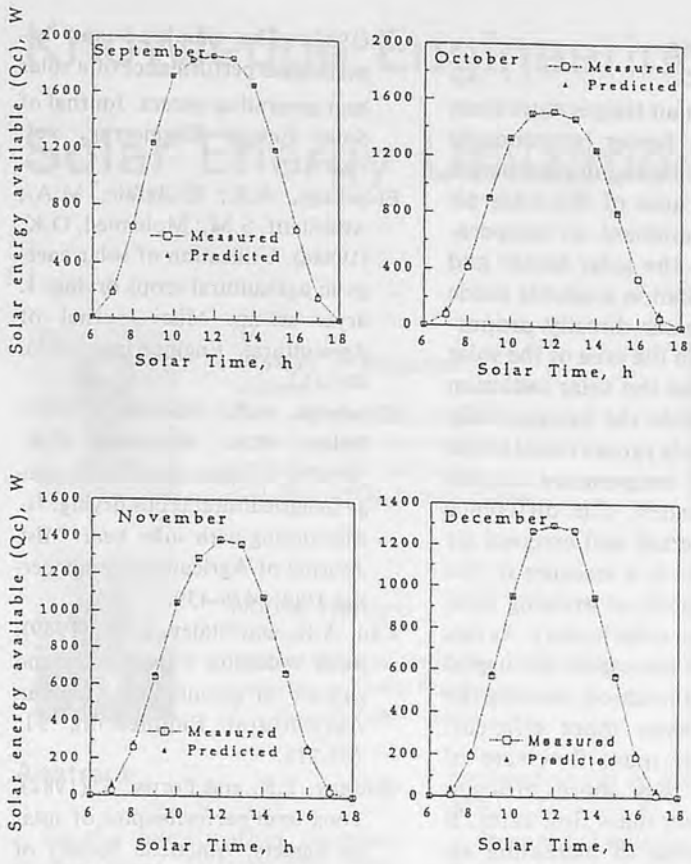

Fig. 3 Measured and predicted hourly average solar energy available inside the solar dryer for September through December, 1994.

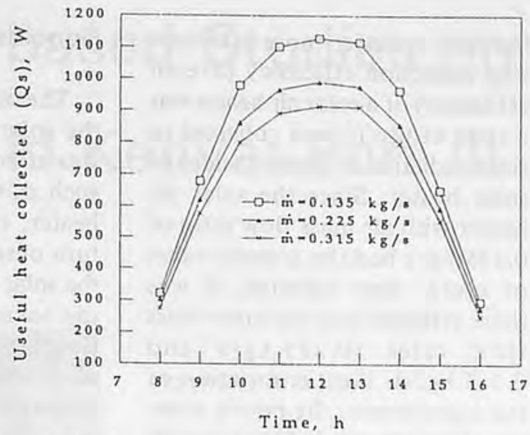

Fig. 4 Hourly average useful heat gain for three different air mass flow rates.

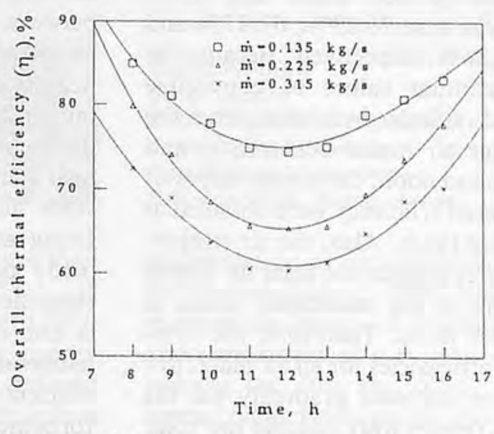

Fig. 5 Hourly average overall thermal efficiency for three different air mass flow rates.

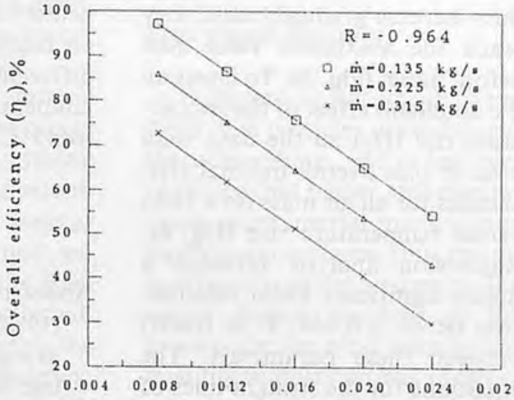

Fig. 6 Overall efficiency versus temperature rise for three different air mass flow rates.

radiation at these times was less than 200 W/m^2) very little useful heat was collected by the air passing through the solar air heater. Also, and for the same reason, there were no differences in useful heat collected between the three different air mass flow rates (Fig. 4).

Useful heat gain could be obtained only when the air outlet temperature was above the air inlet temperature. Therefore, the useful heat gain for all air mass flow rates increased gradually (as well as solar radiation available and ambient air temperature inside the solar air heater) till it reached the maximum amount at noon. It then decreased gradually until it reached the minimum value at sunset. Fig. 4 shows that a great value of useful heat was gained with air mass flow rates of 0.135 kg/s, because the amount of solar energy required to increase the ambient air temperature inside the greenhouse (solar dryer) above the air temperature outside was quite sufficient. As the temperature difference between the internal and external air temperatures was increased, the heating capacity was increased and useful heat gain was thus increased, making the heat transfer more efficient. The collection efficiency (overall efficiency) of a solar air heater was a ratio of useful heat collected to solar radiation available inside the solar heater. Since the solar air heater with air mass flow rates of 0.135 kg/s had the greatest value of useful heat collected, it was more efficient than the other mass flow rates (0.225 kg/s and 0.315 kg/s). For the duration of the experiments, the hourly average overall thermal efficiencies for the three different air mass flow rates (0.135, 0.225 and 0.315 kg/s) were 76.23%, 67.87% and 62.88%, respectively. Because the maximum values of convective and radiative heat losses from the solar air heater occurred at and around noon, the lowest values of overall efficiency were obtained at these times. Also, the air temperatures outside the solar air heater were at the maximum values at these times. Therefore, the overall efficiencies for all air mass flow rates decrease gradually (as the air temperature outside the solar heater increased) till they reach the minimum value at noon. They then increase gradually until they reach the maximum value just before sunset (**Fig. 5**). To illustrate the dominant effect of the temperature rise (D_T) all the data were used to plot overall thermal efficiencies for all air mass flow rates versus temperature rise (**Fig. 6**). Regression analysis revealed a highly significant linear relationship ($R = -0.964$; $P \leq 0.001$) between these parameters. The equations for the straight lines of best fit are:

$$\eta_o = 118.6215 - 2672.918(D_T), \quad m^* = 0.135 \text{ kg/s}.$$

$$\eta_o = 107.3422 - 2672.918(D_T), \quad m^* = 0.225 \text{ kg/s}.$$

$$\eta_o = 94.0084 - 2672.918(D_T), \quad m^* = 0.315 \text{ kg/s}.$$

Conclusions

The outlet air temperature from the solar air heater (greenhouse) was affected by many parameters such as the area of the solar air heater, the ambient air temperature outside the solar heater and the solar radiation available inside the solar heater directly proportional to both the area of the solar air heater and the solar radiation available inside the heater, while it was inversely proportional to the ambient air temperature outside the solar heater. The difference between internal and external air temperatures is a measure of the heating capacity of working fluid (air inside the solar heater). As this difference is increased, the useful heat gain is increased, making the solar air heater more efficient. Using an air mass flow rate of 0.135 kg/s was more efficient than the other mass flow rates. It is also capable of increasing air temperature rise and remains quite efficient to the solar air heater performance and is strongly dependent upon air mass flow rates. Finally, this greenhouse (solar air heater) may be utilized as a solar air heater for drying processes of different crops with drying air temperatures ranging from 25°C to 45°C.

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Knowledge Engineering-based Studies on Solar Energy Utilization in Kenya: Part III

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Abstract

In the investigation reported in this paper, PHOENICS CFD Code was used to simulate a system that can reduce the accumulation of dust on the surface of solar cell. A physical model of solar cell was also tested in a wind tunnel. From the results obtained, it was found that a wind barrier installed on the solar cell can reduce significantly the accumulation of airborne contaminants on the surface of solar cell.

Introduction

The energy reaching the earth from the sun is about 1.77×10^{14} kW. This is a huge quantity in terms of human capacity or need. However, not all of this energy is available for conversion into useful forms like electricity. The maximum conceivable efficiency of solar cell is 93% (Gribik and Osterle, 1984) found in Osterle and Swantner (1990). However, in practice the maximum efficiency reported so far is not more than 20%.

In part 2 (Mailutha et al 1994), it was reported that the energy conversion efficiency is reduced from 6.46% to 4.79% by a dust layer of 0.1 mm thickness covering the solar cell surface at 420 W/m^2 of solar energy input. This represents a drop in energy output of more than 25%.

When considering any practical application and installation of any solar energy generating system, two major factors are important: i) the amount of solar energy available in the concerned geographical location and the fraction that can actually be collected; and ii) factors that influence the generator conversion efficiency. The solar energy conversion efficiency of photovoltaic solar systems is reduced significantly by the atmospheric dust and other contaminants. The quantity of dust settling on the cell surface is influenced by the wind velocity and the quantity of dust in the environment. Efforts must be made to design systems that will limit the accumulation of the environmental contaminants. This paper presents the results of simulation and experiment of a system that reduces the dust and other airborne contaminants on the surface of solar cell.

Literature Review

Sufficient air turbulence to suspend dust particles is available in the atmosphere, and it has been observed that higher air velocities cause more inertial impaction of particles on surfaces, thus removing them from the airstream. The major factors involved in this process are the wind velocity and quantity of dust particles in the atmosphere.

Joseph et al (1973) estimated the quantity of dust in the atmosphere to be $128 \pm 64 \times 10^6$ tons per year. Long distance transport by wind has been reported. Direct measurement of reduced solar radiation penetration at Manna Loa, Hawaii, was attributed by Shaw in 1980 to dust originating thousands of kilometers away in the Gobi desert of the Peoples' Rep. China (Rosenberg et al 1983).

The processes of air and dust flow occur under complex conditions and there is no known linear relationship that describes the behaviour of the wind-dust-surface system. These types of problems can be analyzed well by methods that are capable of handling nonlinear problems such as computational flow dynamics (CFD) methods and/or neural networks. The CFD methods have been successfully applied and validated by a number of researchers in the study of both indoor and outdoor fluid flow processes in 1-D, 2-D and 3-D models (Weiner and Parkin, 1993; Jiang et al. 1995; Rieder and Delfanian, 1991; Haghighat et al. 1992). A number of CFD codes are currently available commercially, but PHOENICS is the most widely known and validated.

The dynamic force necessary for dust transport is a function of the wind velocity in the neighbourhood of the particles. The stream of air will exert a dynamic force on particles, equal to (Gorial and O'Callaghan, 1991):

$$F_d = \frac{1}{2} . C_d . \varrho_a . AV_r^2 \quad (1)$$

where

F_d = drag force; C_d = drag coefficient; ϱ_a = air density, and V_r = relative velocity between air and particle and A = surface area of the particle. This drag force accelerates the particle when introduced into the airstream with an acceleration equal to:

$$a = \frac{1}{2} . C_d . \varrho_a . (\frac{A}{m}) V_r^2 \quad (2)$$

where

a = acceleration; m = mass, and other variables are the same as before.

Dust sedimentation rate (flux towards the surface), R_d [$mg/m^2/h$], on a surface is given by the deposition velolcity, U_d [m/h], and the dust concentration, C [mg/m^3] at the outer surface of the boundary layer as (Gorial and O'Callaghan, 1991):

$$R_d = U_d C \quad (3)$$

For standard conditions of temperature and pressure, and for spherical particles of unit density, and with no slip correction, the terminal settling velocity, U_s, in terms of aerodynamic diameter, d_a is given by;

$$U_s = 0.108 d_a \hat{} 2 \quad (4)$$

There are a number of forces acting on particles to cause deposition on the surface, but for horizontal upward-facing surfaces, gravity is the only major force (Barber et al. 1991). This allows the deposition velocity to be equated closely to the terminal velocity, U_s of the particles under the force of gravity alone (Barber et al. 1991).

Fluid turbulence is a major factor in the transfer of solid particles in the atmosphere. Dust particles are set in motion only when forces generated by atmospheric wind overcome the gravitational forces, force of cohesion and particle movement about points of contact. Quoting other sources, Lyles et al. (1971) reported that wind strong enough to move soil particles is always turbulent. Turbulence may be modeled in 1- or 2-dimensional, but it is always 3-dimensional. Flow fluctuations have components in all three directions (Abbot and Basco, 1996). If the incoming flow is laminar, it has been successfully proved that the initial linear instability occurs at around a Reynold's number, R_{excr} = 9100 (Versteeg and Malalasekera, 1995).

The Governing Equations of Fluid Flow

Liquids and gases flowing at low speeds behave as incompressible fluids (Versteeg and Malalasekera, 1995). Thus, without density variations there is no linkage between the energy equation and the mass and momentum equations. The flow field can often be solved by considering mass and momentum equations only. There is no need for solving the energy equation because the problem does not involve any heat transfer. The governing equations in 2-dimension are given as follows (Weiner et al., 1993):

Mass conservation:

$$\partial \varrho / \partial t + \partial(\varrho u_i) / \partial x_i = 0 \quad (5)$$

Momentum Conservation:

$$\partial^{(\varrho u)} / \partial t + \partial^{(\varrho uiuj)} / \partial x_j = \partial / \partial x_j [\mu(\partial u_i / \partial xj \; \partial u_j / \partial x_i)] + \partial p / \partial x_i + \varrho g \quad (6)$$

where

μ, ϱ, p, g, t are dynamic viscosity, density, pressure drop, gravity and time in that order;

i, j are representatives for x and y directions, u is velocity.

Materials and Methods

System Simulation

In this investigation, the PHOENICS code was used to simulate wind flow over the surface of solar cells. The usual well-known governing equations of conservation of mass and momentum were used with appropriate boundary conditions.

In order to create turbulence, a wind barrier was installed on the surface of the solar cells. The aim was to create negative pressure (suction) distribution above the surface of the solar cell. The suction would make the wind blow

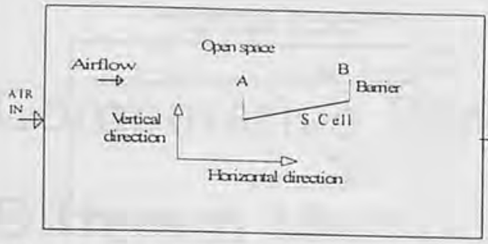

Fig. 1 Simulation setup.

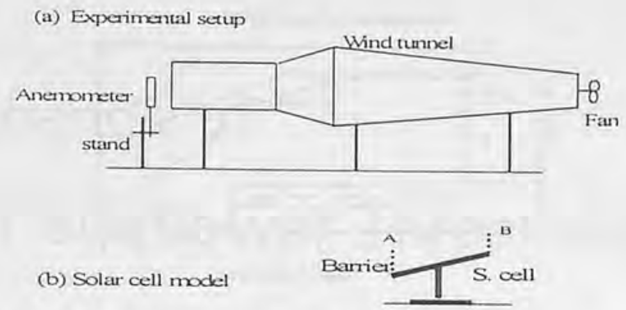

Fig. 2 Physical experimental setup.

away from the surface, thus carrying away the dust (compare the action of the vacuum cleaner). **Figure 1** shows the arrangement of the simulation set up. The barrier was varied both in size and location relative to the inclination of the solar cells, the locations being either at the bottom or top (positions A or B).

Other input variables considered were the elevation angle of the solar cell and wind velocity. Pressure distribution was monitored from the point of contact of the barrier and the panel as origin, to the far end of the solar panel. The computational grid varied between 50-70 horizontally, and 45-60 vertically. The grid was varied also within the modeling domain, with close concentration at the points of interest, near the surface.

Experiment with Physical Model

A 350 × 350 mm physical model of the photovoltaic solar cell was subjected to wind tunnel testing. The experimental setup is shown in **Fig. 2**. Airflow was generated by a four-blade fan and wind speeds were measured with a digital anemometer. Dust settlement on the surface of the cell was monitored and evaluated under the same variable parameters considered in the simulation. The locations of the barrier are defined also in the same manner as in the simulation, **Fig. 2b**.

Results of Experiment

Simulation Results

The graphs in **Figs. 3(a)-(f)**, show the results of simulation and experiment with the physical model. **Figs. 3(a)-(c)** are the results from simulation, while (d)-(f) are for the physical experiment. The pressure distribution for the simulation have similar trends, but they differ in the intensities along the surface of the cell, the differences being mainly in the distribution of the turbulence intensities. As the velocity increased, the region of full turbulence was shifted away from the middle of the cell surface, **Fig. 3(a)**. The effect of barrier size on the distribution of pressure was almost similar to that of the velocity, **Fig. 3(b)**. For barrier heights larger than 0.2 m the region of full turbulence was in the middle region of the cell surface.

The position of the barrier also had an effect on the distribution pattern, **Fig. 3(c)**. For position (B), the effect of barrier height was almost insignificant. In comparison, for position (A), the effect was very noticeable. For small heights there was no significant effect. The pressure decreases with increase in height, but later increases.

Results of Experiment with the Physical Model

Figs. 3(d)-(f) are the results from the experiment with the physical model. The quantity of dust settling on the cell surface was much higher when the barrier was on the bottom position than when on the top, **Fig. 3(d)**. For small angles the influence of elevation angle was very small, but the trend changed as the angle increased. When the barrier was in position (B) the dust accumulation decreased as the angle increased. However, for both cases the dust accumulation decreased with an increase in barrier height. From the same figure it is evident that for barrier heights larger than 1.5 cm, the dust accumulation starts to increase, more noticeable for the bottom location of the barrier.

The effect of velocity was less significant for both situations (A) and (B), though for small angles it had a tendency to increase, **Fig. 3e**, especially in the case of location (A). For both cases the dust accumulation decreased significantly with an increase in barrier height, **Fig. 3f**. Dust accumulation was much less in the case of location (A) than in that of (B). However, when the barrier height increased considerably, the dust accumulation for the bottom case started to increase, while for the top case the situation remained almost constant.

Discussion

We did not attempt to investigate the mechanism of turbulence formation, but used it to reduce the accumulation of fine airborne contaminants from the surface of the solar cell. From **Figs. 3(a)** and **(b)**, we can observe that the distribution of pressure along the solar panel surface is not uniform. For smaller elevation angles the region of full turbulence formed in the middle region of the surface (notice the case of angle = 0). On the other hand, both large angles as well as high barriers

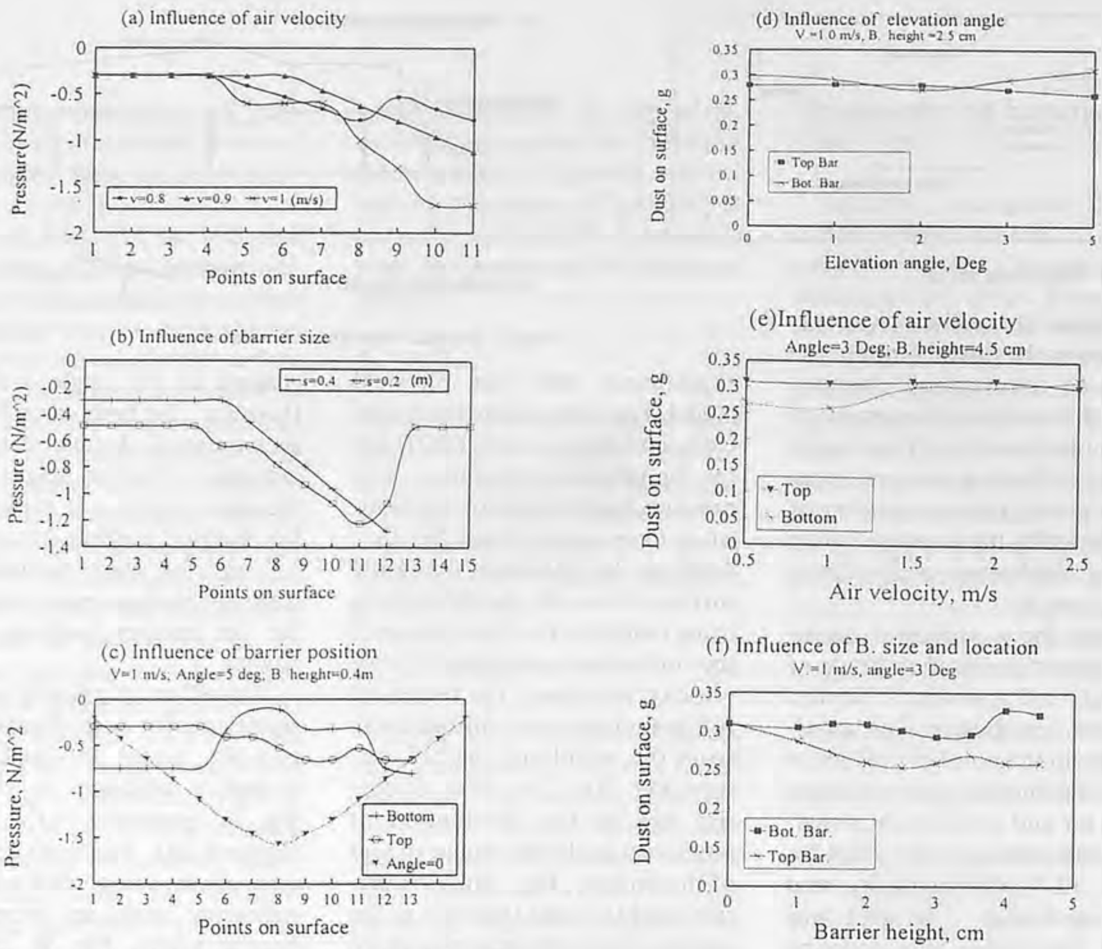

Fig. 3 Results of simulation and physical experiment.

tended to produce almost a uniform distribution on the first half of the surface, with full turbulence forming towards the second half. This trend is not unusual. Frank Eldridge (1980) pointed out that the streamlines of the windstream are compressed and its flow accelerated as it passed over a barrier or a narrow valley, thus increasing its speed due to these anomalies. The point of instability during the change from laminar to turbulent flow is always upstream of the point of transition to fully turbulent flow, Versteeg and Malalasekera (1995). The separation between the instability and transition points depends on the nature and degree of amplification of the unstable disturbances. So far we have no documented theory of the transition. However, the process may be modeled through visualization. Normally, the transition from laminar to turbulence flow is characterized by (1) the amplification of disturbances, (2) the formation of areas of concentrated rotational features, (3) the formation of small scale local motions, and finally (4) the development and combination of the small areas of local small scale motions to form the full turbulent flow. Zilker and Hanratty (1979), found in Hudson et al. (1996) reported a layering of the maxima in the velocity stream, is attributed to the formation of shear layers behind the crests of the waves.

The experiment with the physical model shows that there is a relationship between the barrier height and the quantity of dust left on the solar cell surface. Heights less than 1.5 cm are not enough to reduce the dust on the surface. The height, of course, must have relationship with the size of the solar cell. The accumulation of dust tends to increase with the rise in slope of the cell. This is especially so when the barrier is very high. This tendency can be explained by the fact that the dust will tend to settle between the cell and the barrier as the cell slope increase (the barrier is always vertical).

Conclusion

The efficiency of solar cells can be maintained by reducing the quantity of dust and other contaminants that settle on the cell surface. This can be achieved by incorporating a barrier on the wind flow path on the solar cell surface, which can then create turbulence above the surface. Neither very short nor very high barriers are recommended. The choice, however, is dependent on the surface dimension of the solar cell.

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Comparative Performance of Different Methods of Sunflower Threshing

by

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Abstract

This study was conducted to evaluate the comparative performance of two different sunflower threshing techniques. Stationary thresher and combine harvester were tested at various cylinder speeds and feed rates to thresh sunflower varying in initial moisture contents. Their performances were evaluated and compared with that of conventional manual method. It was observed that combine harvester and thresher having a threshing capacity of 1 000 kg/h and 447 kg/h leads to a threshing cost of Rs. 0.364/kg and Rs. 0.260/kg, respectively. The cost of sunflower threshing by stick beating (manual method) was Rs. 0.620/kg. The cleaning and threshing efficiencies of combine and thresher were 96.7 and 98.7 and 89.36 and 97.3%, respectively. Hence, stationary thresher is preferred to combine harvester to save labour, time and thus minimizing threshing costs.

Introduction

Edible oils are essential components of human diet and sunflower is one of the most important oil seed crops grown in Pakistan. It is grown in an area of 63 328 ha and its production is 1 315 quintals/ha. The production of sunflower in Pakistan has rapidly increasesd over the last 10 years from 18 811 t to 83312 t and is expected to increase further in the coming decade (Agricultural Statistics of Pakistan, 1991-92). One of the biggest constraints for increasing the area and production of oilseed crops has been the lack of suitable machinery for these crops. This necessitated that appropriate labour saving machineries should be used by the sunflower growers to do harvest and post harvest operations for this crop.

Traditionally, in Pakistan, sunflower crop is harvested manually with sickles and threshed manually either by stick beating or by running bullocks on sunflower heads. Because of large amount of time involved, it results in losses due to birds, weather, pests, etc. Also, cleaning is not sufficient which results in heavy losses during storage and lowers the market value. Moreover, the output of manual threshing is very low and dependent on the efficiency of the worker. Therefore, a labour-saving machine, i.e., mechanical threshing, helps a farmer for speedy and timely threshing and minimizing the tediousness involved in manual threshing.

Threshing and separation with mechanical system results in timeliness of operation, increases yield by threshing at optimum conditions and improves the storage quality and hence market value. Realizing the need of the hour, the sunflower growers have started using combines and locally manufactured sunflower thresher for threshing the crop. The sunflower thresher is a recent development and not much has been reported about the field performance of the thresher. The combine harvester generally used for cereal crops has not yet been tested as a stationary thresher for threshing sunflower heads. Considering these problems, this study was designed to evaluate the comparative performance of sunflower thresher and combine harvester for threshing sunflower heads at different moisture content levels.

Objectives

The objectives of the study were:

1. To compare the performance of sunflower thresher and combine harvester with that of conventional method; and
2. To recommend a suitable threshing machine for the local farmers based on good performance and low cost of operation.

Materials and Methods

A locally made sunflower thresher was tested for threshing the crop under various machine and crop parameters. The overall dimensions of the machine were 2.0-m length, 1.2-m width, 1.3-m high and weighing 800 kg. The cylinder was made of m.s. sheet of diameter 32.5 cm and length of 600 cm. Vertical spikes (m.s. rods) of diameter 0.6 cm and length of 6.75 cm were welded on the surface of the cylinder in staggered manner. A blower unit and sieve and shaker unit were provided in front of the thresher. The thresher was operated with tractor PTO.

John Deer Combine Harvester, a self-propelled machine driven by a 113 hp diesel engine was selected for this study. The threshing drum consisted of 8 raspbar, having a length of 104 cm and dia. of 60 cm. The harvester was used as a stationary thresher by harvesting the crop manually and feeding sunflower heads to the front of the straw walker.

Treatments

The following four treatments were evaluated. The detail of crop and machine parameters tested is given in **Table 1**.

i) Sunflower thresher-power operated;
ii) Combine harvester as a stationary thresher;
iii) Conventional method of separation of seeds by stick beating; and
iv) Conventional method of separation of seeds by tractor treading.

Table 1. Crop and Machine Parameters and their Levels

Particulars	Sunflower thresher	Combine harvester	Stick beating	Tractor treading
Moisture content (%)	7, 9, 15	9, 12	9	7
Feed rate (kg/h)	540, 648, 864	1 200, 1 500, 1 900	—	—
Cylinder speed (rpm)	350, 400, 450	1 600	—	—

Table 2. Cost Analysis of Sunflower Threshing Techniques

Item	Tractor	Thresher	Combine harvester
Life	10 years	5 years	10 years
Salvage value = (10% of purchase price)	Rs. 21 000	Rs. 2 500	Rs. 90 000
Annual use	1 000 h	400 h	1 000 h
Fixed cost			
Depreciation = $\frac{\text{(Initial cost − Salvage Value)}}{\text{Life}}$	Rs. 18 900	Rs. 3 750	Rs. 81 000
Interest = $\frac{12.5}{100} \times \frac{\text{(Initial cost + Salvage value)}}{2}$	Rs. 14 437	Rs. 1 719	Rs. 61 875
Tax and Insurance = $\frac{3}{100} \times \frac{\text{(Initial cost + Salvage value)}}{2}$	Rs. 3 465	Rs. 412	Rs. 45 000
Repair and maintenance cost = $\frac{50}{100} \times \frac{\text{Initial cost}}{\text{Life}}$	Rs. 10 500	Rs. 2 083	Rs. 14 850
Variable Cost			
Fuel cost	Rs. 20/h	—	Rs. 50/h
Lubrication cost	Rs. 4/h	—	Rs. 10/h
Labour cost	Rs. 10/h	Rs. 15/h	Rs. 50/h
Cost/h = $\frac{\text{Fixed cost/annum + Var. cost/h × Use}}{\text{Use (h)}}$	Rs. 81.3/h	Rs. 35/h	

Evaluation

For each threshing technique, the output capacity, total threshing time (man-hour), threshing losses, threshing and cleaning efficiencies, straw and seed moisture content, seed straw ratio and cost of operation (fixed costs + variable costs) per ha were calculated. Assumption for cost calculations are shown in the **Table 2**.

Before threshing, the size of the sunflower head was measured. The crop was threshed at three levels of moisture content, viz., just after harvesting, seven days after harvesting and 15 days after harvesting. After threshing, the unthreshed and uncleaned seeds were collected manually in order to calculate the threshing and cleaning efficiencies. The following formulae were used to calculate the threshing and cleaning efficiencies.

$$T_e = 100 - L_{ut}$$

where

T_e = Threshing efficiency

L_{ut} = Percentage of unthreshed seeds

$$C_e = (W_c/W_t)\,100$$

where

C_e = Cleaning efficiency, %

W_c = Weight of clean seeds, kg

W_t = Weeight of total unthreshed seeds at grain outlet, kg

Resutls and Discussion

The performance of power operated sunflower thresher was evaluated and compared with combine harvester and conventional methods of stick beating and tractor treading. The results obtained are presented in **Table 3**.

The power operated sunflower thresher has an output capacity of 447 kg/h with a threshing efficiency of 97.3% and a breakage of 4.87%. The threshing cost/kg with this unit was 0.26 Rs. which is much less than the cost of other methods of threshing in comparison.

The combine harvester has an output capacity of 1 000 kg/h with a threshing efficiency of 98.7% and breakage of 0.26%. The threshing worked out for this machine was Rs. 0.36/kg which is approximately 58.7% of stick beating method (**Table 3**).

The conventional stick beating method and tractor treading over the sunflower heads yielded the threshing capacity per hour per worker as 9 and 11 kg, respectively. Consequently, the threshing cost worked out to be Rs 0.62 and Rs 0.54/kg for stick beating method and tractor treading technique, respectively. This demonstrated that the threshing cost by both these methods were almost similar but for worker's comfort and easiness, tractor treading is preferred by the farming community when large quantities of sunflower are to be threshed.

Table 3. Performance Test Results

Particulars	Sunflower thresher	Combine harvester	Conventional method	
			Tractor treading	Stick beating
Crop variety	Hisun 33	Hisun 33	Hisun 33	Hisun 33
Grain ratio	0.87	0.89	0.90	0.89
Seed moisture content (%)	9	9	7	7
Power required (hp)	35	110	—	—
Labour required	4	10	—	—
Optimum rpm	450	2 000	—	—
Threshing capacity (kg/h)	447	1 000	—	—
Threshing efficiency (%)	97.3	98.7	98.3	98.6
Cleaning efficiency (%)	89.36	96.7	94.7	92.8
Grain losses (%)	4.46	1.4	2.5	2.0
Breakage (%)	4.87	0.26	1.2	0.95
Threshing cost (Rs./kg)	0.26	0.36	0.54	0.62

Conclusion

The cost of operation for the power operated sunflower thresher was lowest as compared to other techniques used in this research. The output capacity of this thresher was 447 kg/h thus giving a break-even point of 23.6 h. However, the tractor treading method can be used where availability of labour is a serious constraint. ■■

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Soil as Building Material:

A Study to Improve Aggregate Stability and Compressive Strength of Earthen Materials

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Abstract

An experiment aimed at identifying alternative building materials from soil and improving the strength of the same was carried out considering two soil types (Soil A and Soil B) and four stabilizers. The effect of microbial actions on aggregates stability of the different mixes were also considered. Cowdung (manure), cement, sand and straw of Tef (*Eragrostis tef Zucc.*) were the stabilizers selected to form a total of 15 mixes for the study. The compressive strength, extent of shrinkage and cracks were the criteria taken to evaluate the performance of the treatments.

From this study it was revealed that nearly all stabilizers and the microbial action for the period chosen has significantly induced extra compressive strength and reduced shrinkage than using the soil alone. Supplementing mud with cowdung improves the strength much better than the other alternatives. This effect was pronounced when these mixes were subjected to microbial actions. Generally, mixes with soil B performed better than with soil A with regard to compressive strength. However, soil B is apt to shrinkage and the formation of some cracks. The clayey soil (Soil B) performed less when used with cement than soil A and this was attributed to the interaction of clay minerals with cement.

Acknowledgement: The authors would like to express their gratitude to the Office of Research Coordination for funding the research study. They are also indebted to Mr. Sewenet Eshete for preparing the specimens and instrumentation of the experiments.

Introduction

Nowadays construction materials for houses are getting more and more expensive such that high investment is needed to build a shelter or any farm building. In developing countries like Ethiopia, forest products are the main sources of fuel wood, construction and carpentry works. Even in bigger cities construction using wood is a common practice. As a substitute for forest products which interferes highly in the balance of nature, and stones which might be scarce in some areas and might need high construction ability and investment, and use of fabricated reinforcement with other accessaries, the production of bricks from soil is highly significant (Rangwala 1981).

The remaining 2.5% of forest cover of Ethipia is insignificant to satisfy the country's need for fuel wood, construction and carpentry works. In addition to this argument, structures from earth materials are relatively stronger, cheaper and safer.

Earth is one of the oldest materials used for building construction in rural areas. Soil and earth are synonymous when used in relation to building construction (Bengtsoon et al 1984). Top soil is generally removed before any engineering works are carried out or before soil is expected for use of building material.

The advantages of earth as building material are:

- It is resistant to fire;
- It is cheaper than most alternative wall materials and is readily available at most building sites;
- It has a very high thermal capacity that enables it to keep the inside of a building cool when the outside is hot, and vice versa;
- It is a good noise absorbent; and
- It is easy to work with using simple tools and skills.

These qualities encourage and facilitate self-help community participation in house building.

Despite its good qualities, however, the material has the following weakness as a building material.

- It has low resistance to water penetration resulting crumbling and structural failure;
- It has very high shrinkage/swelling ratio resulting in major structural cracks when exposed to changing weather conditions; and
- It has low resistance to abrasion and requires frequent repairs and maintenance when used in building construction.

However, there are several ways to overcome most of these weakness as earth is a suitable building material for many purposes.

Only a few mixes can be used directly as found for building construction with good results. However, mixes can be improved to make good building material correcting the mix and/or adding stabilizers.

The aim of soil stabilization is to increase the soil's resistance to destructive weather conditions in one or more of the following ways (Bengtsoon 1984):

- by cementing the particles of the soil together, leading to increased strength and cohesion;
- by reducing the movements (shrinkage and swelling) of the soil when its moisture content varies due to weather conditions; and
- by making the soil water-proof or at least less permeable to moisture.

A great number of substances may be used for soil stabilization such as sand or clay, cement, sodium silicate (water-glass), molasses, gypsum, cowdung, straw, etc.

In this research, the authors considered soil as a building material with some stabilizers to improve the strength and durability.

The aggregate stability of the soils considered was also studied by allowing some microbial actions. Generally, though, these stabilizers are commonly used by farmers, even as they lack proper consideration and study.

The research reported in this paper had the objective of determining the compressive strength of the mixes considered and identifying the mix or treatment that performed best in the context of compressive strength and minimizing shrinkage and crack.

Experiment Design

The experiments were carried out in the Soil Mechanics Laboratory of the Department of Agricultural Engineering. Two types of soils (soil A and soil B), which are found in the Alemaya University campus and used by some farmers as building material were selected. Soil B is more clayey than soil A. **Table 1** shows a laboratory tests of the two soils.

The soil samples were taken carefully with the right sampling technique at a depth of 45 cm from the surface on two different locations after removing the top soil.

As a well-documented procedure for preparing the test specimens and compressive testing of soil as a building material was not available, the procedure adopted was the one used for concrete. The soil was grounded to pass a mesh of 0.2 mm before they are mixed with selected stabilizers for molding.

For the two soils a total of 15 treatments were considered for this study. The treatments studied were soil alone, soil with cowdung (manure), soil with cement, soil with sand, soil with straw and letting these mixes to ferment for 30 days.

A description of the mixes considered were as follows:

A-	Soil A only
AM-	Soil A with manure
AC-	Soil A with cement
AS-	Soil A with straw of *tef*
A-F	Soil A fermented
AM-F	Soil A with manure and fermented
AS-F	Soil A with straw and fermented
B-	Soil B only
BM-	Soil B with manure
BC-	Soil B with cement
BS-	Soil B with straw of *tef*
BRS-	Soil B with river sand
B-F	Soil B and fermented
BM-F	Soil B with manure and fermented
BS-F	Soil B with straw and fermented

The cement used was Portland brand and the sand is a river sand with size of 0.5 mm and below. The straw which was chopped to less than 3 cm was from Tef (a cereal grown by most farmers) is widely used and available.

After preparing the mud from the right mix it was molded using a cylindrical mould of 3.52 cm diameter and 6.25 cm high. This dimension is in the range recommended for compressive strength measurement (Keyser 1956). In order to facilitate the removal of the specimen from the mould the inner wall of the mould was coated with paraffin.

The weight of the soil used was 8 160 g and the quantity of water added ranged from 2.00-3.00 liters to get the best consistency for molding. For each treatment, 50 specimens were molded and air dried for 10 days. The moisture

Table 1. Laboratory Test Result of Experimental Soils

Soil type	Texture, Percent				Percent Organic		
	Sand	Clay	Silt	Class name	matter	PH	Color
Soil A	73	20	7	Sandy loam	0.0496	7.1	grey
Soil B	35	54	11	Clay	0.1022	6.8	Reddish

content at the time of testing was less than 7%.

The compressive load of the specimens were recorded using a compressive testing machine fitted with a highly sensitive proving ring capable of reading as low as one newton of load. For good results, the rate of loading was kept low to less than 0.4 mm/min.

Results and Discussion

Nearly all stabilizers used improved the strength of the mixes compared with using the soil alone.

Soil Alone

From the two soil types used, the clayey soil (soil B) showed higher compressive strength than soil A except that the tendency of shrinkage and crack formation was higher. Soil B also showed better performance when let to decompose for 30 days than the other soil. Soil B maintained this strength for all the mixes except when it was mixed with cement. This was due to the fact that as soon as the water is added, the cement started reacting with some of the clay minerals and starts setting.

Soil-Manure

Traditionally, farmers use cowdung as stabilizer and coating of mud walls. This has a power of binding the aggregates together and gives extra strength. From **Table 2** it will be shown that this stabilizer induces additional compressive strength than using plain soil alone. The presence of fresh organic matter in the soil increased the stability of aggregates by binding the particles together. This effect was pronounced when these mixes were allowed to ferment.

Soil-Cement

Cement improves the compressive strength and imperviousness and may also reduce the moisture movement, especially when used with less portion of clay soils. From the experiments, soil A showed good result than soil B as it is less clayey. For the reason explained above the result of mix BC was not good.

Table 2. Summary of the Experimental Results

Specimen Code	Percent Moisture Content at Moulding	Percent Content at Testing	Mix	Mix Ratios by Volume	Fermentation Period	Weight of Specimen at Testing (gm)	Average Compression Load (N)	Average Cross-sectional Area (mm^2)	Compression Strength (N/mm^2)
A	31.86	2.4	soil only	—	—	108.8	454.44	1113.32	0.408
AM	50.17	1.28	soil-manure	4:1	—	82.9	1131.45	1065.54	1.062
AC	29.00	4.41	soil-cement	6:1	—	120.45	3383.65	1173.66	2.883
As	32.92	1.46	soil-straw	4:1	—	111.1	478.12	1133.54	0.4218
A-F	33.95	1.94	soil only	—	30 days	112.42	547.34	1113.32	0.492
AM-F	52.77	1.34	soil-manure	4:1	30 days	91.17	1292.19	1065.540	1.213
As-F	34.67	1.88	soil-straw	4:1	30 days	109.2	492.36	1133.540	0.4344
B	40.58	5.43	soil only	—	—	104.8	2794.59	961.625	2.906
BM	61.18	5.74	soil-manure	4:1	—	81.3	2619.87	880.970	2.974
BC	39.86	5.90	soil-cement	4:1	—	104.65	700.97	1055.390	0.664
BRS	29.40	5.64	soil-sand	4:1	—	117.63	1748.04	980.030	1.784
BS	38.24	6.16	soil-straw	4:1	—	105.05	2814.18	961.625	2.926
B-F	39.35	5.58	soil only	—	30 days	105.02	3317.59	961.625	3.450
BM-F	59.37	6.08	soil-manure	4:1	30 days	82.47	2948.15	880.97	3.346
BS-F	42.54	1.80	soil-straw	4:1	30 days	101.44	2896.42	961.625	3.012

Soil-Straw

Most buildings in the countryside use straw of tef as stabilizer in order to produce soil materials for wall construction. The act of binding soil particles by the straw for extra strength holds true for both soil types.

Soil-Sand

Since the effect of the cement on soil B was not good, this soil was mixed with river sand. Sand is known for its stabilizing effect for clay soils as it reduces moisture movement and induces extra strength by retarding shrinkage and minimizing cracks. Also, the cohesion and strength of sandy soils is increased if clay is added to them. This is due to the fact that one improves the weakness of the other. The strength of BRS was higher than that of the BC. But this mix did not perform better than plain soil B. This may be due to improper ratio or sand of low quality.

Soil-Fermentation

After the soil is prepared with the right type of mix, it was left to some microbial action for 30 days. The stability of aggregates besides the addition of some stabilizers can be achieved either by the temporary mechanical binding action of microorganisms, that fungi with their mycelia being especially effective or the cementing action of the intermediate products of microbial synthesis and decay, such as microbially produced gums (Tisdall et al 1982). This argument was supported by the mixes which were allowed to ferment. For nearly all these treatments the compressive strength was improved significantly than those without the microbial action taking place.

In addition to compressive strength, it was also important to look into the formation of cracks and extent of shrinkage of the specimens prepared. From physical observation, soil B has higher tendency towards the formation of cracks and shrinkage due to high movement of moisture. The degree of shrinkage was clearly seen from **Table 2** cross-selectional area column that, this was smaller than that of soil A. These defects were reduced by the use of stabilizers and microbial action.

Conclusions and Recommendations

The use of soil as a substitute for constructional materials is of a paramount importance, and needs due attention. The increase of population and the escalating demand for building materials coupled with the dwindling forest cover requires diversion to the use of cheaper and safer building materials in order to save the already endangered ecology. To support the already existing tradition of using earth materials as a substitute for constructional materials with proper study, focusing on material selection, identifying proper mix and developing techniques to attain the desired strength is a challenge to builders and students of structural engineering.

Conclusions

The following conclusions are put forward:

1. Wall structures of reasonable strength can be achieved from earth materials with the right type of stabilizers.
2. The stability of the soil aggregates was increased by the selected stabilizers used.
3. Generally, soil B showed higher compressive strength than soil A. However, cracking and shrinkage were the defects observed in soil B.
4. Soil B showed poorer performance when used with cement as cement's reaction with some mineral in the clayey soil reduces this strength (Bengtsoon 1984).
5. Soil B also showed better performance when mixed with sand than with cement as the sand reduces the moisture movement of clayey soil and minimize shrinkage.
6. For the same type of soil, the addition of cowdung showed good result than plain soil and soil with straw.
7. Allowing mixes (except soil-cement mix) to microbial action for some extended time significantly increased the compressive strength and reduced cracks.
8. For developing countries like Ethiopia where agricultural structures are not big and complex this technology is promising and will be successful if studied further.

Recommendations

1. Soils of different types with ranges of stabilizers require consideration with regard to strength study.
2. Fermentation periods of different lengths should be considered and their impact on strength of earth materials should be studied further.
3. To determine the right mix ratio of soil to stabilizers further experimentation study is of paramount concern.
4. As there is no a well-organized standard for the use of soil as a building material like concrete, itmber etc, it is time that somebody developed one for the dissemination of this appropriate technology to all those in need, particularly the farmers.

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NOTIFICATION

The editorial staff of AMA introduced some change in editorial policy in 1994 in which floppy disk is used to facilitate the editorial process. With this change in policy, it was decided that the main author is given an article on floppy disk with AMA true format other than 5 free copies of the AMA issue wherein their articles are published. As of now, however, we have not yet fully prepared for the editorial process using floppy disk. Therefore the sentence "In addition, the main author is given an article on floppy disk with AMA true format." in item C, Rejected/Accepted Articles in INSTRUCTIONS TO AMA CONTRIBUTORS should be omitted and reprints of the article will be sent to each author as before.

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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.

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Movement of Herbicides into Shallow Groundwater as Affected by Water Table Management: Mirjat, M.S., Assistant Professor, Sindh Agriculture University, Tandojam, Pakistan; R.S. Kanwar, Professor, Iowa State University Ames, Iowa, USA; S.W. Melvin, Professor, Iowa State University Ames, Iowa, USA; A.Q. Mughal, Professor, Sindh Agriculture University, Tandojam, USA.

Water management practices have been introduced as a potential measure to reduce pollution hazards due to applied pesticides to groundwater system. In the post, few studies have been conducted to characterize the fate and movement of applied pesticides and their impact on surface and ground water. This study was conducted at a research farm of the Iowa State University located near Ames to evaluate the effects of water table depths (WTD) practices on the movement of two surface applied herbicides, atrazine and alachlor, into the ground water. Data were collected by using piezometers and suction tubes during the growing seasons of 1992 and 1993.

The results reveal that average atrazine and alachlor concentrations in ground water were reduced by maintaining shallow WTDs between 0.3 and 0.6 m during the two growing seasons. The average herbicide concentrations in ground water generally decreased with increased sampling depth and time. It was also observed that alachlor concentrations were lower than those of atrazine under identical WTD treatments.

Regression analysis shows that atrazine and alachlor concentrations in the soil profile linearly decreased with increased sampling depth under all WTD treatments. The concentrations of applied herbicides were always higher under deep WTD treatment, and those decreased for shallow WTDs.

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Performance of Draft Animal and Harnessing System: Miah, Md. Hanif, SEC/SCE, Asian Institute of Technology, Bangkok 10501, Thailand

Bullock, buffalo, cow and ox are commonly used as draft animals in developing south east Asian and some African countries. In most situations, draft animals are a more appropriate power source for the farmers. Traditionally, a yoke is used to take off power from the animal's neck. Compared to tractor power, very little work has been done on animal draft power and harnessing systems, their design and testing, and the economics of using draft animals. Some of the recent work on animal draft power and harnessing systems are mentioned and potential of research areas are suggested as follows:

1. Development of loading device.
2. Development of measuring device for draft force.
3. Effect of applied draft, body weight and duration of work on the working speed.
4. The work-rest cycle for animals during different seasons and hours of day.
5. Effect of climate condition on the working speed and power output.
6. Effect of age on the work output of animals and optimum age for breaking the animal for draft.
7. Time required to plough a given area with different animal-implement combinations.
8. Development of suitable management practices for draft animals.
9. Effect of animal and implement performance on the quality of seed bed preparation and crop yield.
10. Comfort and safety of farmers and animals during work (ergonomics)
11. Prediction of force or power output of a pair of animals tillage variables.
12. Development of equations for harness design based on animal and implement variables.
13. Re-design and development of yoke.

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Development of PTO Power Measuring Sensors: Miah, Md. Hanif, Research Enjgineer, SEC/SCE, Asian Institute of Technology GPO, Box 2754, Bangkok 10501, Thailand

The tractor PTO power measuring system is discussed in this paper. It is the product of PTO torque and rpm. PTO torque is measured by applying two rosette type foil strain gages applied on the solid circular shaft radially 180° apart. Torque signal is carried out by slip ring which is attached with the shaft by sleeves, so that the shaft can rotate easily but the slip remains stationary. The introduction of infra-red type photoelectric sensor in agricultural application is also discussed.

A Wheatstone bridge of four active strain gages were applied on the circular surface of a revolving shaft. The transducer was calibrated by applying static torque. It was found that applied torque and measured torque have strong positive correlation ($r^2 = 0.99$). The real measured strain was found to be very close to the theoretical strain. The application of infrared type photoelectric sensor was introduced in order to measure rational speed, because the other pulse sensors have their own limitations in field operation. ■■

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Each year, over 1.6 million tons of vegetables are exported to American markets, with Mexico at times producing up to 70% of the winter vegetables consumed in North America. Along with this, Arizona and California both have a huge agricultural industry.

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Plastics Disposal and Recycling
Aquaculture, Aquaponics, and Integrated Fish/Plant Systems
Photoselectivity in Plastic Agricultural Films for Mulches and Greenhouse Covers
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Silage Wrap and Storage Plastics
Research and Production Development of Agricultural Applications of Plastics

Abstracts are due by August 15, 1997.

Contact: American Society for Plasticulture, 526 Brittany Drive, State College, PA 16803-1420. Phone: 814-238-7045, Fax: 814-238-7051, e-mail: peh4@psu.edu

National and International Strategies for Mechanization of Field Experiments

by Prof. Egil Øyjord, Founder & President of IAMFE

Summary

The International Association on Mechanization of Field Experiments (IAMFE) was founded in Norway in 1964. The main objective of IAMFE is to assist agronomists and plant breeders in the mechanization of field experiments.

The IAMFE strategy for efficient field and associated laboratory mechanization is to provide information and to promote the development and production of efficient machines, equipment and instruments. The target is to produce the test results as fast and as cheaply as possible, and with improved accuracy.

Mechanization of field experiments should be introduced in cases where mechanization can increase the capacity and reduce the experimental error, so that new, resistant, high-yielding varieties and cultivation practices can be made available to the farmers in a shorter time. Experience has shown that mechanization is the most efficient way to ensure that the work can be done rapidly and safely.

IAMFE has an obligation to assist the developing countries in their efforts to produce more food for a growing population and to help in avoiding erosion and pollution of the environment. National Branches of IAMFE are established in Hungary, France, China, India, Russia and in the Baltic countires. Belgium, Cyprus and Norway are national members of IAMFE and can be considered as National Branches of IAMFE.

IAMFE is open to cooperation with all who wish to support the idea of international cooperation in the mechanization of agricultural research.

Introduction

After the Second World War, the impact of mechanized farm operations started to reach agricultural research institutions. The gap between mechanization of farming and mechanization of field experiments became clear and was recognized as a problem which needed attention. An important reason for increased interest in mechanization of field experiments was also the shortage of manual labor encountered in many countries. These factors created the basis for a new science, "Mechanization of Field Experiments", and of specialized manufacturers of plot research equipment. Today the manufacturers play an increasing role in the design and development of plot research equipment.

However, the small demand for specialized machinery, equipment and instruments has made it practical to develop national and international strategies which can assist in fulfilling the objectives of IAMFE.

The International Association on Mechanization of Field Experiments (IAMFE) was founded in Norway in 1964. The foundation was based on "A Plan for Efficient Mechanization of Field Experiments" (1), developed from 1958 to 1964.

The objective of IAMFE is to assist agronomists, plant breeders and others in carrying out field experiments to increase the accuracy and capacity of their research work by mechanization. One important reason for the foundation of IAMFE was to assist agronomists and plant breeders in the developing countries to get suitable, high quality research equipment. This would enable the scientists to speed up the development of new and better varieties of crops and to improve the agronomic practices of the farmers.

A collection of statements (2) shows that the IAMFE strategies have been successful.

National Strategies

National strategies on Mechanization of Field Experiments are established in many countries. These strategies are very important for securing sponsorship for national research on plot research equipment.

National Committees

Some of the national Committees have also been acting as National IAMFE Committees. They are especially useful when a country wishes to arrange national, international or regional IAMFE Conferences and Exhibitions. (In Norway we established a Committee on Mechanization of field experiments in 1950.)

National Members and Branches of IAMFE

The success of IAMFE depends on voluntary work of individual agronomists, plant breeders and agricultural engineers, but support from national authorities is very important.

Sierra Leone, Sudan, Belgium, Norway and Bulgaria became national members of IAMFE in 1968. Cyprus became a national member in 1969, Guyana in 1970 and Hungary in 1974. In 1982 Hungary established a National Board of IAMFE. This Hungarian Board of IAMFE was reorganized as a Hungarian Branch of IAMFE in May 1996. The National membership fees are paid by Ministries or by national research organizations. Unfortunately IAMFE did not get the necessary financial support to give our national members in the developing countries sufficient support, so we lost Bulgaria, Guyana, Sierra Leone and Sudan as national members of IAMFE. They are very welcome to join IAMFE at any time they may wish.

In 1985 a French National Branch of IAMFE, AFMEX, was established in France. AFMEX has been very successful and has been followed up by branches in other countries. At IAMFE/CHINA '94 it was decided to establish a Chinese Branch of IAMFE. This Branch came into operation in 1995 and functions very well. In 1994 it was also decided to establish an Indian Branch of IAMFE. This Branch also came into operation in 1995. In August 1995 the IAMFE/BALTIC '95 Conference was arranged in Lithuania and the Baltic Branch of IAMFE was established. The Baltic Branch of IAMFE includes Estonia, Latvia and Lithuania. It has a direct information link with Belarus and Ukraine. The Secretariate is in Lithuania. In March 1996 a Russian Branch of IAMFE was established. The Secretariate is in St. Petersburg - Pushkin. In May 1996 a Hungarian Brnach of IAMFE was established.

The majority of IAMFE members consists of individual reserach institutions and companies which are not organized as national branches. IAMFE wishes to continue its work for establishing national branches of IAMFE.

In order to ensure that national research funds are used as efficiently as possible, the national IAMFE committees or branches on mechanization of field experiments, consisting of bioscientists, engineers and technicians, should be concerned with the following questions:

- To identify and analyze the problems.
- To identify efficient machinery, equipment and instruments for solving the problems.
- To adapt and improve existing machinery and equipment if the existing equipment is not good enough.
- To recommend new machinery and equipment if this is necessary.
- To maintain good contact with and assist the manufacturers in their efforts to manufacture and improve machinery and equipment for field experiments.
- To identify standard components/spare parts which can be purchased cheaper in the developing countries in case of failure on imported machinery.
- To establish a national stock of spare parts if the equipment is imported and has no dealer in the country.
- To establish a national information service. To establish national training programs as seminars or workshops for complicated and expensive equipment. This is especially important in cases where the training cannot be given directly by the manufacturer or his representative upon purchase of the equipment.
- To assist in establishing joint ventures for production of research

machinery and equipment in the developing countries.

The National IAMFE Committees and Branches should cooperate with IAMFE and the manufacturers regarding:

- Proposals for plot size and shape in the cases where machinery and equipment are to be used on plots.
- Proposals for standardization requirements of research machinery and equipment.
- Proposals for testing of research machinery and equipment. Agronomists and plant breeders should cooperate with agricultural engineers during this testing.

National and Regional IAMFE Representatives

To promote IAMFE, The President of IAMFE has appointed National IAMFE Representatives in some countries and regions:

- Dr. h.c. Hans-Ulrich Hege, Vice President of IAMFE, Germany
- Dr. Hermann K.M. Augsburger, Latin America
- Prof. Guo Peiyu, Chairman (President), The Chinese Branch of IAMFE
- Professor Dr. T.P. Ojha, Chairman (President), The Indian Branch of IAMFE
- Mr. Sigitas Lazauskas, Chairman (President), The Baltic Branch of IAMFE
- Mr. Marc Jaboulet, President of AFMEX, The French Branch of IAMFE
- Dr. Vladislav B. Minin, Executive Secretary, The Russian Branch of IAMFE
- Director, Dr. Janos Lelkes, Chairman (President), The Hungarian Branch of IAMFE

National Centres

A very important part of the strategy for securing rapid progress in the mechanization of agricultural research/field experiments, should be to establish national centres of plot mechanization at national institutes of agricultural engineering or at agricultural universities. These centres should carry out tests, design equipment and help and advise the national research institutions on their mechanization problems. National centres on mechanization of field experiments have been in operation in many countries, such as: Norway, Sweden, Denmark, Canada and India. In China the Office of the Chinese Branch of IAMFE is the national centre. It is located at China Agricultural University, Beijing. In Austria, Germany, USA and in some other countries the largest manufacturers of plot research equipment must be considered as national centres on mechanization of field experiments.

National centres of hte IAMFE Branches are important because variations in soils and plants, as well as in slope, shape and sizes of the fields, can cause unexpected problems with new machinery and equipment.

Ideally, a mechanization program should not be started before an investigation of other mechanization programs, carried out under similar conditions, has been made. On the basis of such an investigation, the best machinery and equipment available should be purchased and tested and, if necessary, adapted to national as well as local conditions.

The Strategies for Institutes

The most efficient use of research funds is to mechanize the "bottlenecks". This will dramatically increase the research capacity of a given staff. As the quality of field experiments depends on high-quality research plots, it is very important that the plot drills and precision planters are self-cleaning and have a high capacity and accuracy.

Another very important operation to mechanize is threshing. Good, self-cleaning threshers and shellers for single ears, single plants and small plots should be introduced in all plant breeding programmes. As far as feasible, small, self-cleaning plot combines should be introduced in field experiments, including those in the developing countries.

The aims of each research institute should be to:

- Reduce the experimental error.
- Ensure completion of the work at the right time.
- Reduce costs of manual labour.
- Increase the research capacity of a given staff.
- Attain the goals in a shorter time.
- Overcome the lack of qualified manual labour.
- Avoid human errors in experiments carried out manually.
- Achieve a control of accuracy which is impossible in programs carried out with a large input of manual labor.

There are many reports which indicate that the research capacity has been increased 10 to 400 times or more by mechanization and, at the same time, the experimental error has been reduced. Reports from all over the world have stated that the IAMFE objectives, strategies and work during the past 32 years have played an important role in the rapid development of new and better varieties of plants, which haved increased the world's food production.

International Strategies

Rapidly progress in any field is only possible by providing reliable information about the advantages of new machinery, equipment, instruments and methods. The most efficient way of tansferring knowledge is by the arrangement of conferences with the presentation of scientific papers, test reports and by exhibitions and demonstrations of new or improved machinery and equipment in cooperation with the manufacturers.

IAMFE cooperates with national

IAMFE branches, committees, institutes, organizations, and authorities in arranging national, regional, and international conferences, exhibitions, and meetings on mechanization of field experiments.

Individuals with an interest in organizing IAMFE Conferences/Exhibitions for the purpose of establishing international cooperation have been granted short-term IAMFE Fellowships (1-7 weeks) to study the mechanization of field experiments and the work of IAMFE.

Some of the IAMFE Fellows from developing countries have played historical roles in technology transfer to their own countries.

IAMFE should continue its work for securing funds for scholarships for giving scientists and technicians from developing countries an opportunity to participate in international and national training courses.

IAMFE is working for hte establishment of National and Regional IAMFE Centres. The Regional Centres will secure larger regional interest in the IAMFE strategies for efficient mechanization of field experiments. National and/or Regional IAMFE Centres should be established in Africa and in Latin American Countries.

IAMFE offers the following publications to its members:

- Proceedings/Papers of the IAMFE Conferences
- The International Directory of Manufacturers, Machinery, Equipment and Instruments for Agricultural Reserch (The IAMFE Directory).
- The IAMFE NEWS

IAMFE Conferences

IAMFE has assisted national institutions and organizations in arranging, in total, 10 International Conferences and Exhibtions in Norway (1964), West Germany (1968), Czechoslovakia (1972), USA (1976), The Netherlands (1980), Ireland (1984), Hungary (1988), Germany (1992), China (1994) and France (1996). Our next IAMFE Conferences and Exhibitions will be arranged in 1998 in Argentina (5th Regional) and in the year 2000 in the United Kingdom (11th International).

Table 1. Number of Participating Delegates/Countries in IAMFE Conferences and Exhibitions 1964-1996

IAMFE '64, Ås, Norway June 15-27, 1964	1st International	71	/ 16
IAMFE '68, Braunschweig July 1-6, 1968	2nd International	189	/ 26
IAMFE '72, Brno, Czechoslovakia July 10-15, 1972	3rd International	173	/ 37
IAMFE '76, Ames, Iowa, USA July 5-10, 1976	4th International	168	/ 22
IAMFE/NJF '77, Ultuna, Sweden December 7-9, 1977	1st Regional	30	/ 8
IAMFE '80, Wageningen, Netherlands August 4-8, 1980	5th International	180	/ 36
IAMFE '84, Dublin, Ireland July 8-13, 1984	6th International	200	/ 34
IAMFE/CIAE '85, Bhopal, India April 11-12, 1985	2nd Regional	70	/ 3
IAMFE/ICARDA '87, Aleppo, Syria May 24-27, 1987	3rd Regional	66	/ 20
IAMFE '88, Debrecen, Hungary July 11-15, 1988	7th International	210	/ 27
IAMFE '92, Soest, Germany July 19-23, 1992	8th International	135(200[1])	/ 24
IAMFE '94, Beijing, China October 17-20, 1994	9th International	130(250[1])	/ 17
IAMFE/BALTIC '95, Kaunas/Dotnuva, Lithuania August 8-10, 1995	4th Regional	85	/ 13
IAMFE '96, Versailles, France July 8-12, 1996	10th International	230(400[1])	/ 34

[1]1 Including those who visited the exhibition.

The main idea of the IAMFE Conferences and Exhibitions is that plant and soil scientists can meet engineers and manufacturers to get up-to-date information and to discuss problems in mechanization of field experiments. The IAMFE Conferences and Exhibitions are also a forum for presentation of new ideas for new equipment. IAMFE wishes to assist in creating a world market for high quality research equipment to increase the efficiency and precision of agricultural research.

The participants of IAMFE Conferences and Exhibitions, coming from all over the world, have played very important roles in international cooperation and technology transfer since 1964. The scientists have done this in an efficient way by the purchase of efficient research machinery and equipment for their own institutions. The agricultural engineers and manufacturers have promoted technology transfer by their presentations and demonstrations of new equipment and by adopting good ideas or by copying the best ideas. Production under licence is also an important way of technology transfer and international cooperaton.

The International IAMFE Centre

In 1993 the International IAMFE Centre was moved from Norway to Sweden.

IAMFE has worked out a proposal for establishing The International Centre for Mechanization of Agricultural Research (ICMAR), but so far it has not been possible to find financing of this Centre (6).

The IAMFE Publications

The most important publications for promotion of mechanization of field experiments have been the following:

- The Proceedings of the International IAMFE Conferences 1964, 1968, 1972, 1976, 1980, 1984, 1988, 1992, 1994 and 1996, and the Proceedings of the Regional IAMFE Conferences 1977, 1985, 1987 and 1995 (3).
- The International Handbook on Mechanization of Field Experiments

(The IAMFE Handbook), 1968-1973 (4) & (5).

- The ASAE/IAMFE Directory of North American Equipment for the Mechanization of Agricultural Research 1972 (7).
- The International Directory of Manufacturers, Machinery, Equipment and Instruments for Agricultural Research (The IAMFE Directory), 1983 (8). A Second Edition was published in 1995 (9).

The IAMFE publications are described more completely in the paper: "IAMFE — 30 years of technology transfer in mechanization of field experiments". Proceedings of IAMFE/CHINA '94, Beijing Agricultural Engineering University, Beijing, October 17-20, 1994, 2-8 (3).

IAMFE News

Our new publication "IAMFE NEWS", published twice a year (10) is one of the key factors in the strategy for the operation of a strong IAMFE Network.

It is our plan that our new publication, the IAMFE NEWS, shall become a strong link between our International IAMFE Centre in Sweden and our National IAMFE Centres and Branches around the world. The IAMFE NEWS should be translated to other languages in the countries which do not easily understand English. This translation work, together with additional national information, must me done in the national IAMFE branches and centres which find this desirable.

Future IAMFE Publications

Future Editions of The International Directory of Manufacturers, Equipment and Instruments for Agricultural Research (The IAMFE Directory) are planned to be published every other or every third year. It is also planned to get this information on CD ROM.

In China the work on a IAMFE textbook on "Mechanization of Plant Breeding and Seed Processing" has started. It will be published in Chinese and English.

A new version of The International Handbook on Mechanization of Field Experiments (The IAMFE Handbook) should be worked out. It should describe Principles and Applications and be published in English with translations to Arabic, Chinese, French, German, Hungarian, Russian, Spanish and other languages, if desirable.

Standardization of Plot Sizes and Research Equipment

At the IAMFE/NORWAY '64 Conference we discussed standardization of plot sizes. The most important recommendation of IAMFE '64 was that the cutting widths of plot combines should be 125 cm, 150 cm and 175 cm. Later, cutting widths of 200 cm and 225 cm have also become standards. This came as a result of the demands from some of the customers.

An agreement of standardization of agricultural research equipment is an important strategy for reducing the costs of research equipment. "The IAMFE Plot Size Investigation" (11), carried out in 1992, is a basic source of information for this work.

Standardization of Test Methods for Research Equipment

Based on investigation of various test methods, IAMFE should adopt recommendations for standardized test methods for research equipment. In the cases where no test methods exist, IAMFE should assist in ensuring that suitable test methods can be worked out.

Information Technololgy and Process Control

With the rapid development of information technology and process control, it will be of great importance to make use of modern information technology like:

- Immediate communication and knowledge transfer by electronic mail.
- Internet WWW information. The most recent IAMFE News, and some other information, can be found on the WWW pages http://enus.lt.slu.se/IAMFE
- Information databases and Newsgroups. IAMFE has not yet started up this kind of activites on the Internet, but it would promote active discussions between persons within the IAMFE network.
- Making field trials by using process control and instrumentation that can a) make use of a range of statistical design besides common variance analysis, b) vary treatment parameters continuously in the plot, c) increase the level of background information (nutrient levels, microclimate, etc.) from the experimentation area and d) take advantage of and analyze differences in, deliberately chosen, uneven experimental fields.
- Global agriculture and environmental supervisory and or forecasting systems where field trials can be used as one of many sources of information.

Conclusions

With a rapid increase in the development of machinery, equipment and instruments for agricultural research, IAMFE with its Conferences, Exhibitions, Demonstrations and Directories will become more and more important for scientists, institutions and countries wishing to get the maximum out of their research funds, time and efforts.

IAMFE wishes to contribute to the development of international standards and quality control by testing of specialized equipment for agricultural research. This will be done in cooperation with the manufacturers of such equipment.

Individuals as well as state and private research institutes, universities, organizations, manufacturers and countries are welcome to join IAMFE and to become partners in "The IAMFE Network".

I ask for your cooperation for fulfillment of the national and international strategies of IAMFE.

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Dr. Surin Phongsupasamit, a Co-editor of AMA, Was Appointed as a Professor of Agric. Engineering, Chulalongkom University, Thailand

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Dr. Surin Phongsupasamit, a co-editor of AMA, was appointed as a professor of agricultural engineering, Chulalongkom University in January, 1997—the first professor in the field of agricultural engineering in Thailand.

Dr. Phongsupasamit has been working also as a director, Thailand-Japan Technology transfer Project, deputy head of planning, mechanical engineering dept. Chulalongkom University and vice chairman, coordinating subcomittee of agricultural machinery, National Research Council of Thailand.

He was awarded Knight Grand Cross (Royal Decoration) in 1992 and 1995 and the Prize for Innovative Hardware by Chulalongkom University in 1993. ■■

1993/94 & 1994/95 Annual Research Report, 1995/96 Status Report — Awassa College of Agriculture (ACA)

(Ethiopia)

Contact: Library and Documentation Center, Awassa College of Agriculture. P.O. Box 5, Awassa, Ethiopia.

Rice Post-Harvest Technology — March 1995

(Japan)

In many developing countries, stabilization of the food supply and demand and improvement of the self-sustaining ratio are becoming among the greatest national challenges of today and tomorrow. There is an expected increase in demand from developing countries related to post-harvest technologies to achieve maximum use of their produce.

Post-harvest technology is a general terminology of various process technologies that are needed to minimize the loss of grain during the process of harvesting, drying, storage, transportation, processing, quality control and so on. The quantity of grains saved by improved technologies would equal an increase of food production by the same amount.

Under these circumstances, the Food Agency of the Ministry of Agriculture, Forestry and Fisheries of Japan, has implemented, as a part of the ODA program, "The Project for Promotion of Cooperation in Grain Post-Harvest Technology" and has prepared this "Rice Post-Harvest Technology" as a textbook for regional leaders of developing countries, namely the leaders of the front line, to improve their knowledge, technical skill, and problem-solving ability in post-harvest technology, thus contributing to the dissemination of post-harvest technology among the farmers of each region.

This book, "Rice Post-Harvest Technology," is the product of "The Project for Promotion of Cooperation in Grain Post-Harvest Technology" by the Food Agency of the Ministry of Agriculture, Forestry and Fisheries, as a part of the ODA project of 1994. It is the final version of the English prototype edition issued last year.

Contact: The Food Agency, Ministry of Agriculture, Forestry and Fisheries, Japan.

Fluid Power Maintenance Basics and Troubleshooting

(USA)

by Richard J. Mitchell and John J. Pippenger

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March, 1997 / 392 pages, illustrated / $135.00.

Contact: Marcel Dekker, Inc., 270 Madison Ave., New York, NY 10016, USA.

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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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