International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.27, NO.3, SUMMER 1996

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.27, NO.3, SUMMER 1996

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

SHIN-NORIN Building
7, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo 101 Japan
Printed in Japan

This is the 92th issue since its maiden issue in the Spring of 1971

EDITORIAL

The price of main cereals is going on rising in world market. The world food situation has greatly changed since '70's and '80's when the price of cereals hovered low level due to the surplus cereal production. It is since late '80's that population increase has exceeded the increase of food supply. In some of the developing countries where rapid economical growth took place and the national income increased, the consumption of livestock products increased all together, by which cereal consumption has greatly increased.

China has made it a target to supply two hundreds eggs annually per capita by 2000. This needs a large amount of cereals nearly equal to whole cereals exported from Australia a year. Moreover, in China, as earning differencials between cities and rural areas are more and more expanding, young people are flowing out of rural areas to cities. There is little likelihood of large expansion of farmland and rise of agricultural production. Under such circumstances, the balance of supply and demand having been lost, China has turned into a food import country.

Prospectively there are not so many countries which can afford to export surplus food long in the future. The world population increase last year, in 1995, exceeded 100 million. Population of developing countries accounts for larger proportion in the world. As such as the state of things today, we should do everything we can to raise land productivity in agriculture of developing countries. The growth of agricultural productivity in developing countries must be a key item in improving world food situation. Agricultural mechanization is a vital step in raising productivity as well as releasing farmers from hard labour.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
July, 1996

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol. 27, No. 3, Summer 1996

Optimization of Tractor Plowing Performance

by
C. Özarslan
Assistant Professor
Agricultural Machinery Dept.
Ankara University, Ankara,
Türkiye

D. Erdoğan
Professor
Agricultural Machinery Dept.
Ankara University, Ankara,
Türkiye

Abstract

In this study, the most suitable operating conditions of tractor plowing were investigated. For this purpose, in laboratory conditions, a tractor was tested by a PTO dynamometer. Engine performance data were determined. The engine's performance characteristics were also derived from these data.

After that, the field experiments were carried out with tractor and plow combinations. Ballast, tire pressure, number of furrows, working depths and tractor gears were taken as variables during the experiments on PTO speeds and working speeds. Travel reductions were measured. Engine torques, effective powers, specific fuel consumptions and fuel consumptions per hour were determined from data measured during the tests. Moreover, field capacities and fuel consumptions per *decare* were calculated. Considering loading of engine, fuel consumption and field capacity, the most suitable working conditions were determined by the contribution of measured and calculated values.

According to these results, the optimum operations were obtained by the tractor with specific weight of 81 ... 69 kg/kW and with 6.9 ... 8.2 kg/h forward speed during plowing on heavy clay soil.

Introduction

Increased plowing efficiency and tractor plowing performance can be considered as an optimization problem. To solve this problem, the factors related with tractor, plow, soil, agrotechnical and technological factors should be considered.

An early study regarding the determination of tractor engine power in field operation was done in the 1960s. The test tractor was equipped with measuring devices to record engine speed, manifold vacuum and throttle plate position continuously. Consequently, the approximate power and speed maps for different field operations were plotted (Ricketts and Weber, 1961).

Determining the tractor performance on field conditions involves a rather complex apparatus. Therefore, a few methods were developed for various agricultural scopes by utilizing tractor test results and considering tractor mechanics in order to predict tractor performance. Basing on tractor's PTO power, forward speed and travel reduction values taken from test reports for ideal conditions, corresponding drawbar pull, drawbar horsepower, forward speed and travel reduction values in various field conditions and different tractor-machine combinations can be predicted (Zoz, 1972).

In another method developed for evaluating the torque of diesel tractor engines, the correlations of engine torque to fuel consumption, exhaust gas temperature and engine governor control lever position were determined. These correlations that help to predict engine torque were established for both maximum torque and partial torque curves separately (Souza and Milanez, 1988).

In order to determine the power demands of a tractor with various machines, equations were found by the contribution of fuel consumption values (Sumner et al., 1986).

In studies designed to determine the engine operating point and the effects of static load and tyre (inflation) pressure on specific fuel consumptions, the increased static load in each tyre pressure enhanced the drawbar power and engine power. In general, this resulted in a decrease in specific fuel consumption (Lyne et al., 1984).

A model was constructed to examine the effects of machine operating width on time and fuel consumption for a given machine type, tractor power and field conditions. It was found that the optimum field speed for each tillage and seeding operation were related to proper power unit and machine operating width (Wu et al., 1986).

The study aimed to asses the most appropriate working conditions for tractor during plowing in

Middle Anatolia conditions.

Materials and Method

Materials

The Fiat 480 tractor used in this research has a water-cooled, four stroke and three-cylinder diesel engine. It is a standard tractor that has four tyre wheels. The gear box has 6 forward and 2 backward gears.

In order to load the tractor during the tests, two and three furrow semi-digger plows that were equipped with skimmer and disc coulter were choosen.

During the field tests, a pulse type tachometer was used to measure PTO speed. This tachometer fixed to tractor PTO could produce impulses of 1/200 revolution sensitivity. These impulse signals were directly transmitted to data logger that had a 256 KB memory, commanded by 8085 microprocessor and charged with 12 V DC from accumulator.

Method

A method that was started a few years ago was used to determine tractor performance with admissable corrections in field conditions. This method could be carried out easily by non-complex measuring sets. Close examination of successive field and laboratory tests were necessary in the application of this method.

Laboratory Tests

Initially, the tractor was tested according to standard OECD tests in laboratory conditions. The PTO speed, torque, fuel consumption and test intervals were recorded.

Measuring was done on 11 points starting from 2 707 ℓ/min up to 950 ℓ/min engine speed. Before taking data from these points, observations have to wait for a particular period until the engine was stable. The maximum power value obtained was regarded as maximum PTO power.

Fuel consumption per hour was also measured while determining engine power. By considering the power values of the same test, specific fuel consumptions were calculated.

Values obtained from both measurements and calculations were graphically illustrated. Thus, the variety of torque, power, specific fuel consumption and fuel consumption per hour due to engine speed could be obtained.

Statistical Analysis of Laboratory Test Results

Regression equations were made by the contribution of data from laboratory tests in order to determine engine torque and specific fuel consumption at any point. The relation between engine torque and speed was considered essential. Three equations: one for maximum torque and two for partial torque curve were obtained. The correlation coefficients of the equations were also determined.

Field Tests

The system used to measure PTO speed was done during field test measurements **(Fig. 1)**. The impulse signals produced by electromagnetic tachometer was transmitted to and recorded on memory data logger. Then the data was converted to a computer in the office.

Field tests were done on three adjacent plots of 50 × 500 m size. During the tests, the plots were divided into sub-plots of 125 m long.

In field tests, the following factors were considered as the controlled variables.

1. Specific weight: 81, 69, 57 kg/kW.
2. Tyre inflation pressure: 140, 120, 100kPa.
3. Number of furrows (working width): 2, 3 furrow (0.64, 0.92 m).
4. Working depth: 0.18, 0.22, 0.25 m.
5. Gears: first, second, third, and fourth.

The measured PTO speed for each field test was converted to engine torque and specific fuel consumption with the use of regression equations.

Travel reduction was obtained by the calculated theoretical forward speed and measured actual forward speed. Engine idling was neglected in calculating field capacity of the tractor-plow combination.

Evaluation Method

The main factors limiting the tractor performance during plowing are fuel consumption and field

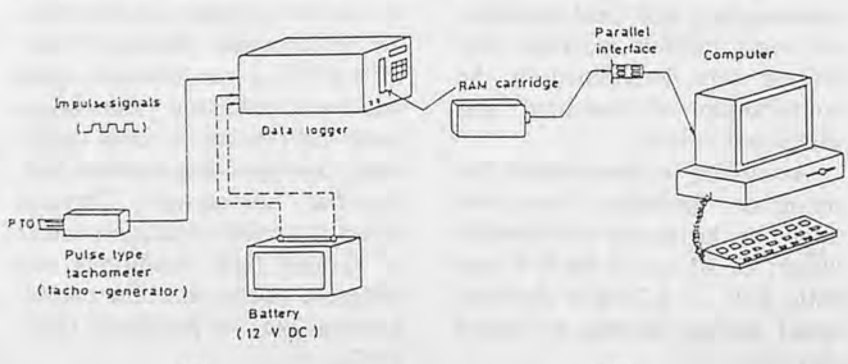


Fig. 1 Schematic presentation of the measuring system.

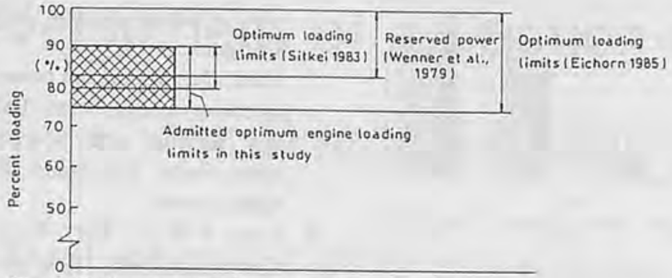


Fig. 2 Optimum operating zone of tractor engine.

capacity. One of these may become more significant depending on the working conditions and could have more influence on the optimization.

The specific fuel consumption of the engine is minimum either in maximum engine torque zone or in particular loading percent of engine due to engine characteristics. However, the engine should not work continuously in this zone owing to overstrain (Hunt, 1968). Moreover, operations like plowing involve storing reserved power in order to overcome unexpected load increases of the engine. Optimum operating zone is expressed by percent loading of the engine. In this research 75-90% of maximum engine power was accepted as optimum operating zone (**Fig. 2**).

The second limiting factor for the optimization of tractor performance is field capacity, i.e., working width and forward speed. Also, working depth is indirectly related to field capacity. Tractive resistance indicates travel reduction.

For the travel reduction that is changable due to working conditions, 25% was taken as the top limit. Exceeding values were not taken into account.

In evaluating the test results, operations that provide maximum field capacity with minimum fuel consumptions under certain parameter limits were expressed as optimum operations.

Results and Discussion

Results of Laboratory Tests

The values obtained from laboratory tests were evaluated statistically and equations concerning engine characteristics were established, thus —

The equation for engine torque in maximum torque curve is:

$$M = 114 + 0.055 \,.\, n - 0.00002 \,.\, n^2$$

where,
M: Engine torque (Nm)
n: Engine speed (ℓ/min)
and the correlation coefficient $R^2 = 0.991$

In this curve, specific fuel consumption due to engine speed and effective power can be calculated by the following equation:

$$b_e = 195 + 0.07 \,.\, n - 0.0812 \,.\, P_e^2$$

where,
b_e : Specific fuel consumptions (g/kWh)
P_e : Effective engine power (kW)
and the correlation coefficient $R^2 = 0.964$.

In partial torque curve, two different equations were established for calculating engine torque. The following equation was obtained between the range of 2 612 and 2 665 ℓ/min ($R^2 = 0.998$).

$$M = 2\,431 - 0.000339 \,.\, n^2$$

As for the range of 2 666 ... 2 707 ℓ/min the following equation was obtained ($R^2 = 0.998$).

$$M = 1\,704 - 0.63 \,.\, n$$

Furthermore, specific fuel consumption in partial torque curve can be defined as:

$$b_e = \frac{3\,310}{P_e} + 203$$

where $R^2 = 0.998$

Test Field Findings

The test field had a heavy clay textured soil. The average moisture content and cone index of the soil were obtained as 19% and 4.87 MPa, respectively.

Effective engine power, fuel consumption, forward speed, travel reduction and field capacity were calculated with computers using the changes in engine speed and field test intervals.

In some of the tests, data could not be taken owing to either stopping of the engine by overstrain or impeding of tractor advance through excessive travel reduction.

The optimum loading limits (75 ... 90%) and below 25% travel reduction were taken into account. The values that characterize the optimum operation were obtained in 81 kg/kW and 69 kg/kW of the specific weight of the tractor used in the research (**Fig. 3**). Therefore, 57 kg/kW of specific weight without ballast is not appropriate for the plowing operations. The specific weight 81 kg/kW is a preliminary value.

The third gear was used in all optimum operating values. This also indicates the optimum gear scale in the test conditions, in heavy tractive operations like plowing. In these operations, forward speed was 6.9 ... 8.2 km/h and travel reduction was 8.4 ... 23% at the third gear.

The entire tests characterized the optimum operation obtained using two-furrow plow and except one at 0.22 m working depth. Thus, the most convenient tractive load was obtained in the test

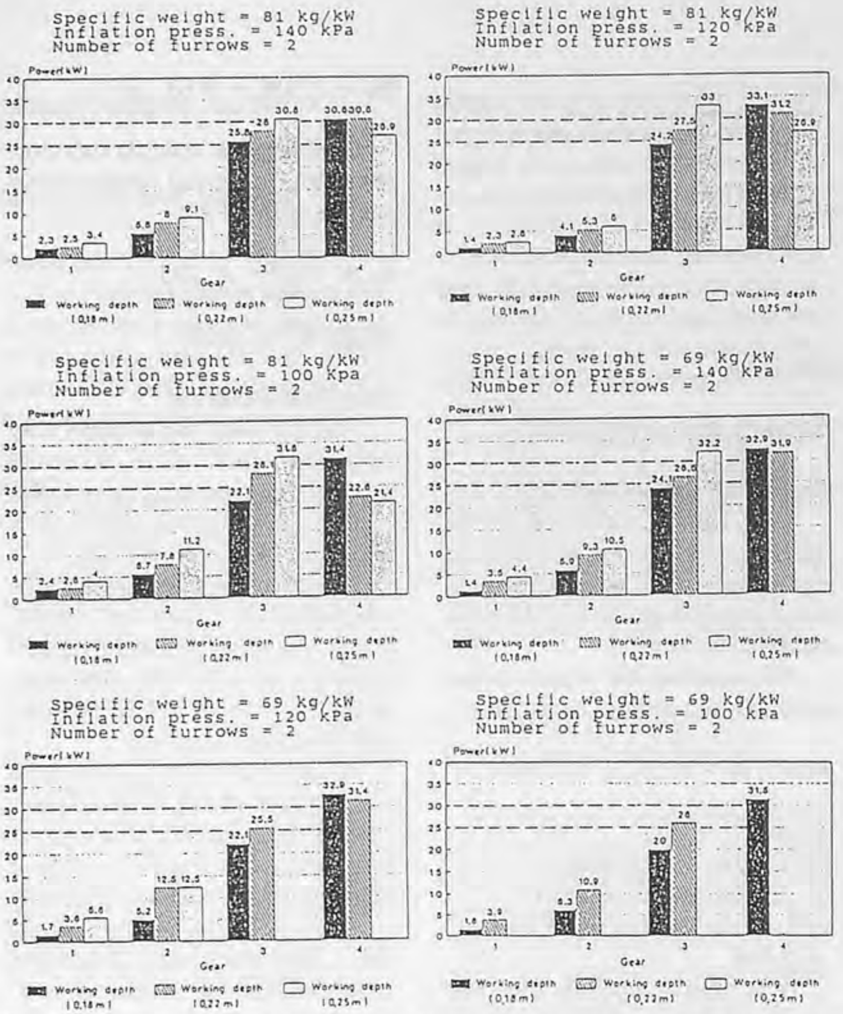


Fig. 3 Test results-characterizing optimum operation-concerning effective engine power.

conditions.

Meanwhile the field capacity obtained in the tests characterizing the optimum operating conditions were 4.4 ... 5.25 *da*/h.

The fuel consumptions per *decare* according to the values obtained in consequence of optimum operation were between 1.63 and 1.97 kg/da.

According to the identical studies of Pamir (1975), forward speed was rather low. Nevertheless the test results were thoroughly parallel to the suggestion of Sitkei (1983) regarding the usage of 7-8 km/h optimum operating speed with tillage implements. Moreover, Domier and Willians (1978) found an 8 ... 12 km/h forward speed for reaching optimum performance of tractors with 60 kg/kW specific weight. In the tests this speed range was approached at the lowest limit.

Conclusion

It should be stated that tractor with specific weight of 81 to 69 kg/kW can be operated in plowing (in heavy clay soils) at 6.9 ... 8.2 km/h forward speed in order to provide optimum loading rate.

REEFRENCES

1. Domier, K.W. and Willians, A.E., 1978. Tractive efficiency-maximum or optimum? Transactions of the ASAE, Vol. 21, page: 650-653.
2. Eichhorn, H., 1985. Landtechnik, Verlag Eugen Ulmer, Stuttgart.
3. Hunt, D., 1968. Farm power and machinery management. Laboratory Manual and Workbook. Iowa State University Press, Ames, Iowa.
4. Lyne, P.W.L., Burt, E.C. and Meiring, P., 1984. Effect of tire and engine parameters on efficiency. Transactions of the ASAE, Vol. 27, page: 5-7.
5. Pamir, A., 1975. Türkiye'de imal edilen bazı traktörlerin çeşitli toprak şartlarında pullukla sürme işlemindeki çalışma karakteristikleri (Operating characteristics of some tractors produced in Turkey on plowing in various soil conditions). Unpublished PhD thesis, Ankara.
6. Ricketts, C.J. and Weber, J.A., 1961. Tractor engine loading. Agricultural Engineering, page: 236-239.
7. Sitkei, G., 1983. Einsparung von energie durch optimierung des systems ''Boden-Schlepper-Gerat''. Grundlagen der Landtechnik, H.3, page: 65-68.
8. Souza, E.G. and Milanez, L.F., 1988. Indirect evaluation of the torque of diesel engines. Transactions of the ASAE, Vol. 31, page: 1350-1354.
9. Sumner, H.R., Hellwing, R.E. and Monroe, G.E., 1986. Measuring implement power requirements from tractor fuel consumption. Transactions of the ASAE, Vol. 29, page: 85-89.
10. Wenner, H.L. et al., 1980. Landtechnik Bauwesen, Teil A. Grundlagen. Landwirtschaftsverlag Münster-Hiltrup.
11. Wu, Z., Klelgaard, W.L. and Persson, S.P.E., 1986. Machine width for time and fuel efficiency. Transactions of the ASAE, Vol. 29, page: 1508-1513.
12. Zoz, F.M., 1972. Predicting tractor field performance. Transactions of the ASAE, Vol. 15, page: 249-255.

Development of a Suction-type Metering Roll for Direct Seeding Machines:

Evaluation of different slopes of escape canal and suction forces at different rotational speed

by

P.P. Garcia
Ph.D. Student
Laboratory of Power and Energy
Dept. of Bioproduction and Machinery
Faculty of Bioresources, Mie University
1515 Kamihama, Tsu-shi
Mie-ken, 514 Japan

Nobutaka Ito
Professor
Laboratory of Power and Energy
Dept. of Bioproduction and Machinery
Faculty of Bioresources, Mie University
1515 Kamihama, Tsu-shi
Mie-ken, 514 Japan

Koji Kito
Assoc. Professor
Laboratory of Power and Energy
Dept. of Bioproduction and Machinery
Faculty of Bioresources, Mie University
1515 Kamihama, Tsu-shi
Mie-ken, 514 Japan

Xiu Lun Wang
Assist. Professor
Laboratory of Power and Energy
Dept. of Bioproduction and Machinery
Faculty of Bioresources, Mie University
1515 Kamihama, Tsu-shi
Mie-ken, 514 Japan

Abstract

Six angles of the canal's slope and three suction forces were evaluated in terms of their effect on metering precision and percentage of damaged seeds at three different rotational speeds of the modified metering roll.

The result shows that the addition of escape canal at the seed cell significantly increased the metering precision and decreased the percentage of damaged seeds when the rotational speed of the metering roll was increased. The application of suction forces, on the other hand, also significantly increased the metering precision but the percentage of damaged seed increased with an increase of the metering roll's speed.

Introduction

The production cost of rice can be greatly reduced by using direct seeding technology and, consequently, improve its competitiveness in the world market. For this purpose, direct sowing technology using coated rice and corresponding direct seeding machines have been developed (Ito, N., 1987).

A walk-behind direct seeder was constructed in Mie University. The uniformity of sowed seeds and the percentage of damaged seeds range from 7.7 to 10% and 1.3 to 2.4%, respectively, as the rotational speed of the metering roll varied from 40 to 80 rpm (Ito, N. 1987). Uniform plant spacing was most preferred because it can contribute to an increase in crop yield due to more efficient use of soil moisture, nutrients, and light (Donald, 1963). Moreover, Krall, et al (1977) reported that increasing the planting uniformity by decreasing the standard deviation of with-in row variability can increase the yield of corn from 200 to 1 200 kg/ha without changing the planting rates.

Vu, D.P. (1990) and Garcia, P.P. (1993) found that the metering precision of a flat and sliding type metering plate increased and the rate of damaged seeds was reduced by the introduction of an escape canal at the seed cell. Holmes (1985) as cited by S. Shafii and R.G. Holmes (1990) also demonstrated that an air-jet flowing into the apex of a conical cavity captured and retained single seeds of various sizes.

This study was conducted to evaluate the effect of adding escape canal with different slopes at the seed cell and the application of different suction forces on the metering precision and percentage of damaged seeds at different rotational speed of the modified metering roll.

Design of the Modified Metering Roll

The existing metering roll was modified as shown in **Fig. 1**. It has six seed cells in which two 2.4 mm diameter holes were made at the bottom. Sucked air passes through these holes and create a negative force inside the seed cell.

The modified metering roll is hollow. Two air-tight bearings are placed at both ends and a 10 mm diameter pipe with holes on its side and closed at one end, is inserted. Attached to the pipe and placed in between the two bearings, is a 3 mm thick flat rubber, 55 mm in length × 35 mm width. At the downward position of the seed cell, this flat rubber covers the two 2.4 mm diameter air holes and blocks the flow of sucked air. Two pieces of spring were used to keep the rubber always flat against the inside wall of the metering roll. An 84-teeth timing pulley and a timing belt were used to connect it to a 12V, 100 rpm DC motor.

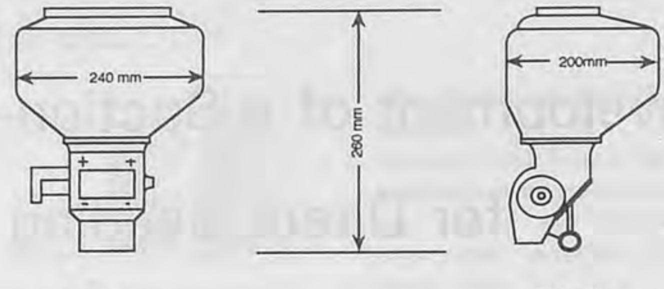


Fig. 1a The seeding unit of the walk-behind type direct seeder.

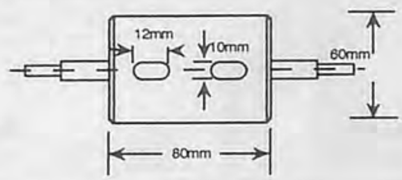


Fig. 1b Detailed view of the existing metering roll.

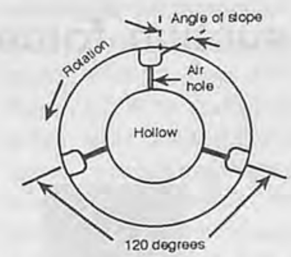


Fig. 1c Detailed view of the modified metering roll.

Experimental Set-up

Figure 2 shows the schematic diagram of the experimental set-up. A vacuum cleaner connected to a variable AC power supply was used to suck the air inside the metering roll and the force is monitored using a Toyoda digital pressure meter (model AA4632). A 12V DC motor connected to a variable 12V DC power supply provided the rotational speed of the metering roll. This was monitored using an OMRON photo-electric sensor (model E3S-DS3E4) that was connected to a digital universal counter. The seed cell picks up seeds from the hopper and extra seeds are scraped off using a brush scraper. The remaining seeds were dropped at the seed outlet and finally to the delivery tube.

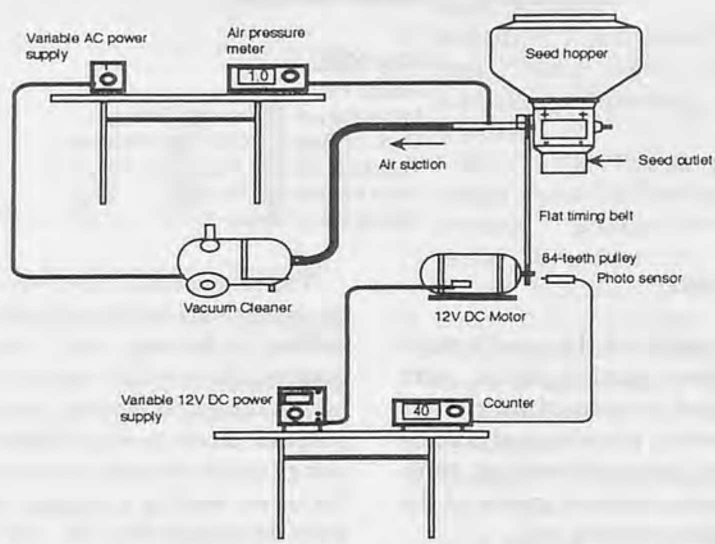


Fig. 2 Schematic diagram of the experimental set-up.

Evaluation Procedure

There were three factors evaluated: a) different angles of slope of the escape canal; b) different suction forces; and, c) different rotational speed of the metering roll. The levels of each factor are shown in **Table 1**.

Rough rice was used in evaluating the metering precision in order to minimize the variation due to uniformity of the test material. Rice coated with calcium peroxide and plaster of Paris mixture (stocked for 3.5 months) was used in evaluating the percentage of damaged seeds. Prior to testing, both rough rice and coated rice were cleaned and screened thoroughly to separate the unusually big and small seeds and other foreign objects. The characteristics of the two materials are shown in **Table 2**.

A. *Metering precision.* The rotational speed and air suction force were adjusted using the variable DC and AC power supply, respectively, until the required

Table 1. Different Levels of Each Factor

Factor A Angle of slope (degrees)	Factor B Rotational speed (rpm)	Factor C Suction force (Kpa)
0°-Existing metering roll	40	0
50°	60	0.5
60°	80	1.0
70°	—	—
80°	—	—
90°	—	—

Table 2. Characteristics of the Coated Rice and Rough Rice

Character	Coated Rice	Rough Rice
Moisture content (%)	5.89	9.59
Length (mm)	7.39±0.38	7.08±0.47
Width (mm)	4.31±0.27	3.17±0.23
Thickness (mm)	3.82±0.33	2.18±0.13
Sphericity*	0.67	0.517

$$\text{*Sphericity} = \frac{(L \times W \times T)^{1/3}}{\text{Largest dimension}}$$

settings were attained. Then the seeding unit was operated continuously and 10 random samples were taken and the number of seeds per sample were counted. This was replicated three times. The standard deviation was used as an index of the metering precision and computed using the equation below:

$$\text{Metering precision} = \frac{\sqrt{\Sigma(Xi)^2 - (\Sigma Xi)^2/n}}{n - 1} \qquad (1)$$

where:

Xi = individual random observations

n = number of observations

B. *Percent damaged seeds.* The same adjustment procedure to get the correct setting of the suction force and rotational speed was used. Then the seeding unit was operated continuously for 50 consecutive passes and the damaged seeds (i.e., at least 15% of the coating material has been detached from the seeds) were counted and the percentage was computed using the equation below:

$$\text{Damaged seed (\%)} = \frac{\text{Total number of damaged seeds}}{\text{Total number of seeds metered}} \times 100 \qquad (2)$$

Results and Discussion

Figures 3 to 5 show the metering precision of the different seed cell types at 40, 60 and 80 rpm and with varying degrees of suction force, from zero, 0.50 and 1.0 Kpa. The relative position of each individual curve along the vertical plane shows their metering precision performance at a given rotational speed and suction force. The lower its position, the higher is its metering precision and vice versa. On the other hand, the slope of the curve shows how the metering precision changes with the application of the suction force.

Comparing the seed cells with and without escape canal it can be observed that as the rotational speed was increased from 40 to 80 rpm, the metering precision of those with escape canal increased but the one without escape canal decreased. Among the seed cells with escape canal, those with higher angle of slope (i.e., 80 and 90 degrees) showed higher metering precision.

The application of suction forces, on the other hand, generally increased the metering precision of all seed cell types. However, comparing the seed cells with and without escape canal, the former showed higher precision, especially at higher rotational speed.

Figures 6 to **8** show the percent damaged seeds of the different seed cell types at 40, 60 and 80 rpm with varying suction forces from zero, 0.50 and 1.0 Kpa. Generally, the percentage of

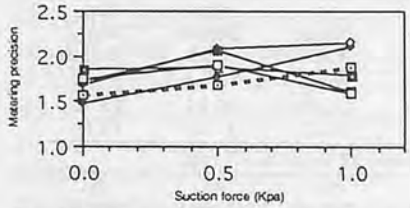


Fig. 3 Metering precision of different seed cell types at 40 rpm.

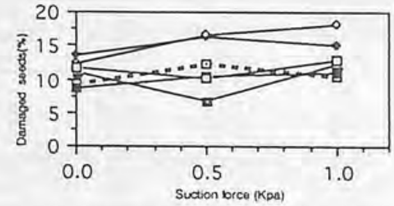


Fig. 6 Seed damage of different seed cell types at 40 rpm.

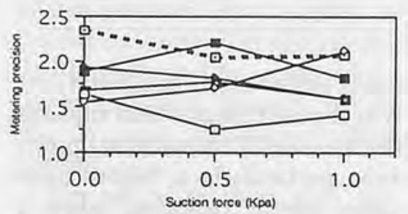


Fig. 4 Metering precision of different seed cell types at 60 rpm.

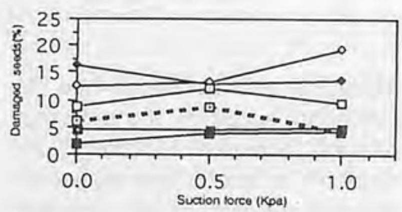


Fig. 7 Seed damage of different seed cell types at 60 rpm.

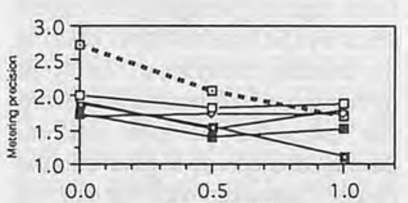


Fig. 5 Metering precision of different seed cell types at 80 rpm.

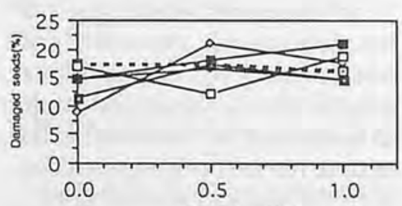


Fig. 8 Seed damage of different seed cell types at 80 rpm.

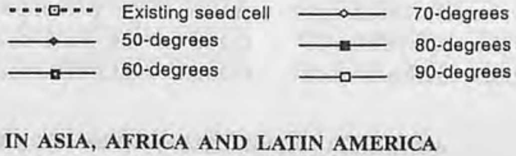


Table 3. Figures 3 to 8 Data

Figure 3 Metering Precision of different seed cell types at 40 rpm

Suction Force (Kpa)	0-Degree Angle	50-Degree Angle	60-Degree Angle	70-Degree Angle	80-Degree Angle	90-Degree Angle
0.0	1.57	1.48	1.86	1.68	1.72	1.75
0.5	1.68	1.77	1.88	2.10	2.07	1.91
1.0	1.88	2.11	1.80	2.17	1.61	1.59

Figure 4 Metering precision of different seed cell types at 60 rpm

Suction Force (Kpa)	0-Degree Angle	50-Degree Angle	60-Degree Angle	70-Degree Angle	80-Degree Angle	90-Degree Angle
0.0	2.34	1.94	1.68	1.54	1.88	1.64
0.5	2.05	1.81	1.78	1.71	2.21	1.25
1.0	2.07	1.60	1.59	2.12	1.81	1.40

Figure 5 Metering precision of different seed cell types at 80 rpm

Suction Force (Kpa)	0-Degree Angle	50-Degree Angle	60-Degree Angle	70-Degree Angle	80-Degree Angle	90-Degree Angle
0.0	2.72	1.92	1.87	1.70	1.72	1.99
0.5	2.05	1.53	1.56	1.74	1.39	1.83
1.0	1.71	1.78	1.11	1.72	1.53	1.88

Figure 6 Damaged seeds (%) of different seed cell types at 40 rpm

Suction Force (Kpa)	0-Degree Angle	50-Degree Angle	60-Degree Angle	70-Degree Angle	80-Degree Angle	90-Degree Angle
0.0	6.17	16.17	4.65	12.55	2.00	8.84
0.5	8.71	12.92	4.58	13.44	3.74	12.30
1.0	4.28	13.60	4.86	19.28	4.22	9.65

Figure 7 Damaged seeds (%) of different seed cell types at 60 rpm

Suction Force (Kpa)	0-Degree Angle	50-Degree Angle	60-Degree Angle	70-Degree Angle	80-Degree Angle	90-Degree Angle
0.0	9.23	13.66	11.04	12.31	8.63	11.58
0.5	12.19	16.28	6.67	16.49	10.33	10.19
1.0	10.35	15.17	12.33	18.23	11.22	12.86

Figure 8 Damaged seeds (%) of different seed cell types at 80 rpm

Suction Force (Kpa)	0-Degree Angle	50-Degree Angle	60-Degree Angle	70-Degree Angle	80-Degree Angle	90-Degree Angle
0.0	17.32	14.86	11.35	8.76	14.86	16.77
0.5	17.15	16.56	17.39	20.86	17.95	12.10
1.0	16.02	14.72	14.63	17.53	21.13	18.83

damaged seeds increased when the rotational speed of the metering roll was increased. Moreover, the slope of the curves also suggested that the percentage of damaged seeds increased at higher suction force.

At higher rotational speed of the metering roll, the centrifugal force created by the peripheral velocity also increased and resulted to either of the following; a) the seeds in the seed cell bounced out, or b) the seed cell was not able to pick-up seeds in the hopper. These explain the decrease of metering precision at higher rotational speed without suction force applied. But with the application of 1 Kpa suction force, the seeds were easily picked up by and held firmly at the seed cell and thus explains the increase of the metering precision, particularly at higher rotational speed. However, when it held the seeds firmly, this suction force also created a resistance force against scraping of excess seeds by the brush scraper causing the coating material of the seeds to be scraped off and thus explains the increase of the percent damaged seeds at higher suction force. Compared with the existing seed cell, generally the seed cells with escape canal were observed to have less percentage of damaged seeds. The presence of escape canal in the seed cell may have created a smooth exit way of the extra seeds and thus the lesser percentage of damaged seeds.

Conclusion and Recommendations

Generally, the metering precision improved significantly with the addition of an escape canal at the rear side of the seed cell and with the application of suction forces. However, the percentage of damaged seeds also increased with an increase in suction force. Based on the result of this experiment, seed cells with 80 to 90 degrees of escape canal's slope and 1 Kpa of suction force are recommended.

LITERATURE CITED

DONALD, C.M. (1963). Competition among crops and pasture plants. Advances in Agronomy. 15:1-113.

GARCIA, P.P. (1993). Participatory development of a corn seeder. Unpublished masters' thesis. University of the Philippines-Los Baños, Laguna, Philippines.

ITO, Nobutaka (1987). Direct seeding of coated rice under submerged paddy. Lecture Text No. 12, Farm Machinery Design Course, Tsukuba International Agricultural Training Center, Tsukuba Japan. pp. 23-49.

KRALL, J.M., H.A. Esechie, R.J. Raney, S. Clark, G. Teneyck, M. Lunquist, N.E. Hamburg, L.S. Axthelm, A.D. Dayton, and R.L. Vanderlip (1979). Influence of within row variability in plant spacing on corn grain field. Agronomy Journal 69; 747-791.

VU Dihn Phien (1990). A low-cost hand-operated seeder for hill seeding pre-germinated rice onto puddled seeds. Unpublished masters' thesis. University of the Philippines, Los Baños, Laguna, Philippines. ■■

Development of a Rolling Punch Planter for Stony Soil Conditions

by
J.P. Molin
Assistant Professor
University of São Paulo - ESALQ
Av. Padua Dias, 11. 13418-900
Piracicaba, SP, Brazil

V. D'Agostini
Extension Agent
EPAGRI - C.P. 791. 89801-970
Chapecó, SC, Brazil

Abstract

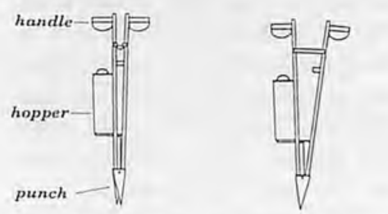
The use of manual planters has been the only solution for farmers' problems in some areas in Southern Brazil where stony soils predominate in steep slopes. Farmers have planted corn and dry beans in these areas since the beginning of this century, using the same kind of equipment. The planters are hand-operated, resulting in limited field capacity and ergonomic problems. A machine using a similar process of dropping the seeds into the holes was designed and constructed. It used 12 spades radially arranged with cam activated doors and a plate seed meter. Preliminary evaluation showed important improvement in the planting operation with reduction in human effort, more accurate stand and high field capacity.

Background

The western part of Santa Catarina State, in Southern Brazil is a region with particular characteristics in terms of topography, land use and farming practices. More than 90% of the farms have less than 50 ha, covering up to 60% of the farmlands (EMPASC /ACARESC, 1983). Similar characteristics are present in the border regions of Rio Grande do Sul and Paraná States. In total, this area covers up to five hundred thousand km^2.

Problems related to soil loss by erosion are common where slopes of 50% to 100% are common in farmland planted to annual crops like corn and beans. No comprehensive studies exist about erosion in these conditions, but it is known that stones take part in the system as soil cover. Recently, the Research and Extension Agencies have been studying and proposing alternative tillage systems for this area, based in the conservation tillage systems already used in mechanized areas. The mechanization limitations like stones, steep slopes and farm finance, persist also in these alternative tillage systems.

The use of planters with furrows is limited to small areas with less stones and slopes. In this case, farmers use both animal and tractor drawn planters. Nevertheless, the use of manual planters is predominant. Local estimate showed that more than 70% of corn and 80% of beans are currently planted with manual planters. Machines like those in **Fig. 1** have been used since the European immigrants occupied the region, in the beginning of this century. These planters are proper for use in stony conditions but fail in ergonomic aspects, field capacity and precision. With the seed hopper full, it weighs from 7 to 10 kg. A man can plant about 0.10 ha/h of corn, producing a dibbling distribution of seeds. Sometimes the operator needs to deviate the row because of stones. The plant population normally used in the region is between 30 000 and 50 000 hills/ha for corn. The space between dibblings is a small step of a walking man, about 0.5 to 0.6 m. For this, the planter is capable of dropping seeds varying between 2 and 5 in each hole.



a. punching position b. seed release position

Fig. 1 Manual planters used today in the region.

Review of Literature

In the past the plant population of corn was an important field of study. Many investigations from the first half of this century are available. More recently, row width and in-row space uniformity have been studied, providing information about their influences yields. Parks et al. (1965), working with hybrid corn, tested different row widths and populations. They concluded that row width has only a small influence upon corn yields, while plant population had a much greater effect, with the highest yields at 44 500 hills/ha, the highest population tested. In Canada, Glenn and Daynard (1974) tested different plant spacing uniformities at the desired population. The reduced variability in spacing resulted in a 5.5% increase in grain yield. Pintér et al. (1978) conducted experiments in Hungary, testing corn plant populations and spacing uniformity and their relationship with grain yield. The highest yields resulted from the best space uniformities.

The planters in use today in the present study area need a comprehensive redesigning. It is possible to improve the seed metering device for putting one seed in each hole, but no farmers would use this method because it requires a hole for each 0.15 or 0.20 m. Therefore, a new design using the knowledge and principle of punching the seeds into the soil, may be the solution. The rolling punch planting method appeared to be an option, but concern about stones was the greatest challenge.

During the last 30 years many researchers tried to employ the punch planting method for solving problems in different situations of modern agriculture. Hunt (1961), developed a punch planter for plastic mulch with four punches around a wheel. They were mechanically activated to open when in the ground for dropping the seeds previously delivered by a horizontal plate seed metering. Jafari and Fornstrom (1972) designed and constructed a punch planter using a wheel with six conical punches, followed by a seed metering device, responsible for putting single sugar beet seeds in each hole in a synchronized action with the wheel. Another prototype was built by Sawant (1972) as a preliminary study for planting in reduced seedbed tillage and with reduced power requirement. Looking for solutions for problems related with crusting surfaces, Heinemann et al. (1973) developed two types of punch planters. One used a pneumatic actuator forcing a cylinder to punch holes in the soil. The other used a belt with eyelets running between two sprocket wheels. Shaw et al. (1978) described a punch planter developed for planting vegetable seeds on plastic mulch. Each punch had a door opened by a cam and closed by a spring in the synchronized time for delivering the seed in the soil. Wilkins et al. (1979) developed a punch planter for vegetables, using magnetic punches around a notched seed shell and seeds coated with iron oxide. A similar magnetic punch planter was patented by Cary and Heinemann (1977) Srivastava and Anibal (1981) designed a punch planter using cones in the periphery of a wheel and an air aided metering device. Kromer (1986), using experience from commercial plastic mulch planters, designed and tested a single bucket wheel for seeding through synthetic and organic mulch.

A manually pulled rolling injection planter is described by Wijewardene (1978). It was developed in Nigeria and is derived from handled planters like those in this paper. This planter consists of six injection points around the periphery of a wheel, each point having its own gravity activated closing mechanism and ground activated opening mechanism. A metering device transfers the seeds into each point as it punches into the soil. The International Rice Research Institute (1979) reports field tests with this machine. Also, Singh et al. (1980) report some field tests where problems were observed like soil sticking to the tip of the injectors and clogging them. The same was reported by Choudhury (1985).

Planter Development

Different sizes of stones, generally present in farmland areas in this region, made the use of the methods described above impossible. The machine would run among stones varying from a few centimeters up to 0.3 m or more in diameter. Also, they would place single seeds in holes like those made by hand machines and working at normal walking speeds with less human effort than with the present manual planters.

A rolling punch planter was proposed with 12 punches spaced 0.2 m in the periphery. The maximum possible free length in individual punches was given for running over small stones and permitting to plant over residue without blocking. The seed metering device developed is a horizontal plate with 6 cells. Its movement is made by a pair of conical gears activated by the planter movement. The external shape of the prototype is schematically presented in **Fig. 2**.

Each spade has a mechanically activated door in the center of the machine where the seed hopper and seed metering device are located. Several options of door commands were studied. The best three options, presented in **Fig. 3**, were constructed and tested. All of them were mechanically activated by a cam. Configuration '*a*' used a push system with an internal frame pushing a deformable steel sheet door. Options '*b*' and '*c*' used a stamped door activated by an internal arm, the first one pulling and the second pushing. Option '*b*' had the best per-

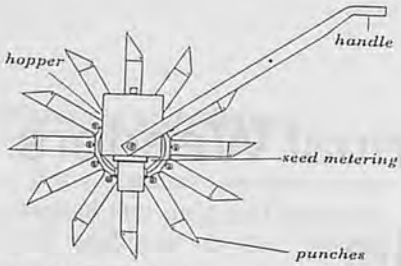


Fig. 2 Schematic side view of the rolling punch planter.

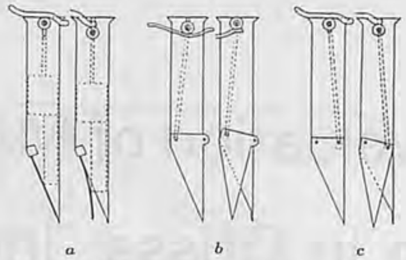


Fig. 3 Different tested options of door commands.

Table 1. Seed Distribution at Two Speeds in Field Tests

Speed	Seed distribution into holes (%)		
	Skips	Singles	Multiples
0.5	17	64	19
0.7	22	61	17

formance.

The first set of tests was conducted in a soil with 69% clay, 16% silt and 15% sand. Seed distribution was evaluated at two speeds. The results are shown in **Table 1**. In these tests the machine produced holes like those made by manual planters. It performed planting with regular spaces between seeds. From the tests it was possible to estimate that the speed, and in consequence, the field capacity, can easily be doubled. In terms of ergonomic aspects, the operator does not carry the machine anymore but only pushes it. Also, the produced stand is compatible with modern concepts of growing corn. Problems related with soil sticking in the doors were observed in wet soil conditions.

Conclusions and Suggestions for Further Development

In a preliminary assessment the configuration discussed here appeared to be helpful in reducing the human effort and producing a more accurate crop stand with the double field capacity. Nevertheless, more investigation need to be made in both engineering and agronomic aspects.

Some tests related to mechanical resistance and use of materials less affected by soil sticking to the punches should be conducted. A mechanical device that allows for changing the space between seeds, permitting different plant populations appear to be a future improvement for this machine. Also necessary are more field evaluations for characterizing the performance of this machine. At the same time, tests are suggested to be made, evaluating this new system in comparison with the present method of planting in dibbles.

REFERENCES

Cary, J.W. and W.H. Heinemann, Jr. 1977. Magnetic delivery autodibble planter. U.S. Patent No. 4,061,094.

Choudhury, M.S.U. 1985. Evaluation of manual planters for selected crops in West African Savana. Agricultural Mechanization in Asia, Africa and Latin America, 16(4): 25-9.

Empresa Catarinense de Pesquisa Agropecuária / Associaçao de Crédito e Assistência Rural do Estado de Santa Catarina. 1983. Plano integrado de pesquisa em sistemas diversificados de produçao para pequenas propriedades. 34p.

Glenn, F.B. and T.B. Daynard. 1974. Effects of genotype, planting pattern, and plant density on plant-to-plant variability and grain yield of corn. Canadian Journal of Plant Science, 54: 323-30.

Heinemann, W.H. Jr,; J.W. Cary and A.E. Dilworth. 1973. Experimental machines for autodibble planting. Transactions of the ASAE, 16(4): 656-9.

Hunt, D. 1961. A vegetable seeder that plants through plastic and paper mulch. Illinois Research, 3(4): 16.

International Rice Research Institute. 1979. Annual Report for 1978, pp 424-5. IRRI, Los Baños, Philippines.

Jafari, J.V. and K.J. Fornstrom. 1972. A precision punch planter for sugar beets. Transactions of the ASAE, 15(3): 569-71.

Kromer, K.H. 1986. A bucket planter for seeding through mulch. Acta Horticulturae - Mechanization of Vegetable Production, 187: 159.

Parks, W.L.; J.A. Odom; J.R. Overton and E.J. Chapman. 1965. Plant population and row spacing for corn. Bulletin 392, The University of Tennessee Agricultural Experiment Station. 16p.

Pintér, L.; J. Nemeth; Z. Pinter and M. Szirbik. 1978. Trend of grain yields in maize (zea mays L.) hybrids as a function of plant number per unit area and sowing uniformity. Acta Agronomica Academiae Scientiarum Hungaricae, 27: 398-404.

Sawant, S.D. 1972. Design and basic studies of a plunger-type planter. PhD Thesis, Pennsylvania State University, University Park, PA.

Shaw, L.N.; R.C. Fluck and H.H. Bryan. 1978. Energy conservation by recropping plastic mulch covered tomato beds. ASAE Paper No. 78-1509, ASAE.

Singh, J.; J.A. Mcmennamy and G. Singh. 1980. Evaluation of selected upland crops establishment techniques. Agricultural Mechanization in Asia, 11(2): 11-6.

Srivastava, A.K. and M.E. Anibal. 1981. A punch planter for conservation tillage. ASAE Paper No. 81-1020, ASAE.

Wijewardene, R. 1978. Systems and energy in tropical farming. ASAE Paper No. 78-1511, ASAE.

Wilkins, D.E.; P.A. Adrian and W.J. Conley. 1979. Punch planting of vegetable seeds - a progress report. Transactions of the ASAE, 22(4): 746-9.

■■

Performance Evaluation of Manual Weeders for Paddy Crop in Orissa, India

by
B.K. Behera
Lecturer
College of Agril. Engg. and Tech.
O.U.A.T., Bhubaneswar
Orissa, India

D. Behera
Lecturer
College of Agril. Engg. and Tech.
O.U.A.T., Bhubaneswar
Orissa, India

S. Swain
Chief Research Engineer
College of Agril. Engg. and Tech.
O.U.A.T., Bhubaneswar
Orissa, India

P.K. Sahoo
Research Assistant
College of Agril. Engg. and Tech.
O.U.A.T., Bhubaneswar
Orissa, India

Abstract

Four manual weeders were evaluated in Kharif Paddy in the Dryland Agricultural Research Project at the Orissa University of Agriculture and Technology, Bhubaneswar. The Central Rice Research Institute (CRRI) weeder was found to be most suitable for the paddy crop with regards to its highest field capacity (0.014 ha/h), highest weeding index (77.2%), highest performance index (1 052.05), less plant damage (2.66%) and lowest cost of weeding (220.16 Rs/ha). It was easy to operate and involved less human drudgery during its operation among all the weeding devices.

Introduction

Weeds are a serious threat to all crops. The weeds instead of harbouring insects, compete with the crop for water, light and plant nutrients and adversely affect the micro-climate around the plant. The weed growth in paddy, particularly in dryland paddy where seeds are drilled, is so profuse that controlling it becomes very troublesome and costly. Weed infestation increases the cost of production and reduces the quality and quantity of the crop.

De Datta (2) reported that the loss of yield due to weeds was 11.8% in Asia. At the International Rice Research Institute in Los Baños, Laguna, Philippines, losses were estimated to be 34% in unweeded plots; in transplanted rice, 45%; in direct seeded rainfed lowland rice; and 67% in upland rice. The weed control experiments conducted at CRRI, Orissa, India reveal that yield losses of 20% and 46% were observed in puddled soil tillage and dry soil tillage, respectively. Gill et al. (3) reported that depending on weed density 20 to 30% loss in grain yield is quite usual which might increase up to 50% if adequate crop management practices were not observed.

Effective land preparation involving primary and secondary tillage, to some extent, destroy the weeds but they are not completely eliminated. The weeds keep on growing with the crop. In India, particularly in the state of Orissa, farmers are still practising the manual uprooting of weeds which is labour intensive and costly. As mechanization is gradually catching up with the farmers and they are aware of the advantages of line sowing popularization and adoption of mechanical weeders have a great potential in this region.

Igbeka (4) indicated that timely weeding is one of the most important agricultural operations for increased rice production and timing rather than the frequency of weeding is a major determinant in effective weed control of rice. Considering the above facts, the performances of the four manual weeders were evaluated to determine the most suitable one for this region.

Acknowledgement: The authors are grateful to Mr. F.C. Das, Senior Scientist, Agricultural Engineering Division, CRRI, Cuttack, Orissa for his technical guidance to carry out the experiment. The CRRI weeder was developed by Mr. Das.

Materials and Method

Four manual weeders were collected and their performances were evaluated in the Kharif Paddy in the Dryland Agricultural Research Project at O.U.A.T., Bhubaneswar. Three of them, i.e., wheel hoe, rotary peg weeder and V-blade hoe are commercially available. The other weeder (**Fig. 1**) was developed at CRRI, Orissa. There were four treatments and each treatment was replicated five times. The experiment was conducted by Randomized Block Design method. The performance index of the weeders was found by calculating the weeding index, field capacity, plant damage percentage and power input of the weeders.

The weeding index was calculated using the formula (1),

Weeding index,

$$e = \frac{w_1 - w_2}{w_1} \times 100$$

where,

w_1 = Number of weeds per unit area before weeding

w_2 = Number of weeds per unit area after weeding

The performance index of the weeders was found using the formula (1),

Performance Index,

$$P.I. = \frac{a \times q \times e}{P}$$

where,

a = Field capacity of the weeder, ha/h

q = 100 − (percent plant damage)

e = Weeding index, percentage

P = Power input, hp

The power input was taken as 0.1 hp for all the weeders. Two weedings were done, one 21 days after sowing and the other, 35 days after sowing. The details of the field and crop conditions during the evaluation is shown in **Table 1**.

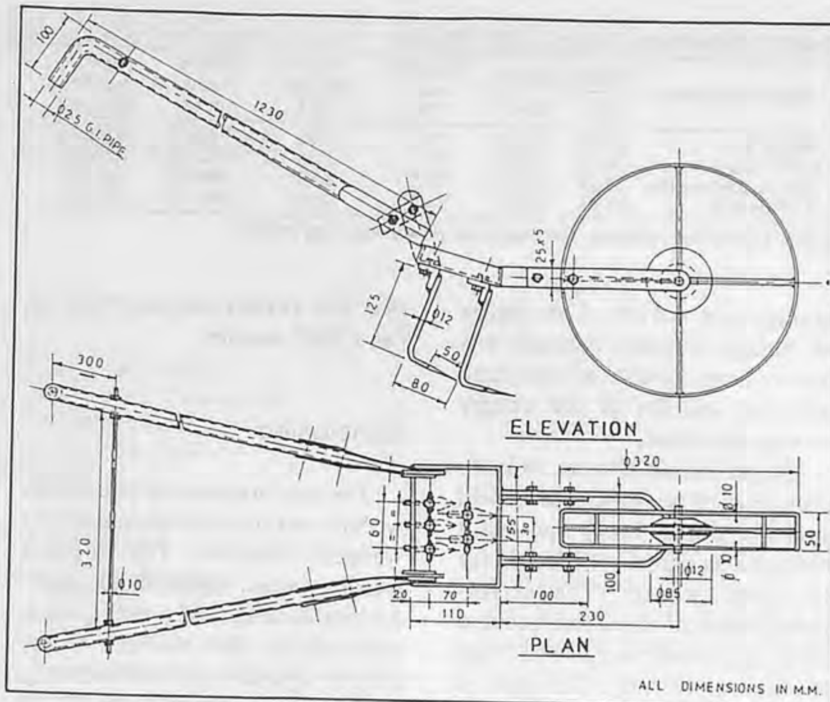


Fig. 1 CRRI weeder used in the experiment.

Results and Discussion

The results of the field evaluation of the weeders are shown in **Table 2**. The field capacity of the CRRI weeder was highest (0.014 ha/h) among all the weeders. It was also observed that compared to other weeders, the CRRI weeder was more comfortable to work with due to the small tynes which made the penetration of the tyne into soil easier. The CRRI weeder had five tynes arranged in two rows - two in the front row and three in the back row. The field capacity of the rotary peg weeder was 0.012 ha/h. The lower field capacity of this weeder was due to the obstruction caused by the weeds in the movement of the blade. Even as the width of coverage of the wheel hoe was good, the field capacity was low compared with CRRI weeder and the rotary peg weeder due to heavier weight and draft which cause the operator to get tired very quickly during its operation. The field capacity of the V-blade hoe was lowest

Table 1. Upland Field and Paddy Crop Conditions During Evaluation of Test Weeders

Name of weeder	Weed density (No. of weeds/m^2)
Wheel hoe	223
CRRI weeder	226
Rotary peg weeder	238
V-blade hoe	231

Note: For all weeders, row spacing was 20 cm; plot size, 400 m^2; number of replications, 5; number of weedings, 2; and the soil type used was sandy loam.

because the operator had to move backward during the operation. Statistical analysis indicated that there was no significant difference in field capacity between the wheel hoe and the rotary peg weeder.

The highest weeding index (77.20%) was observed with the CRRI weeder because the staggered arrangement of the tynes helped in complete uprooting of the weeds. There was no significant difference in weeding index between the wheel hoe and the rotary peg weeder. The plant damage was observed to be within 5% in all the weeders except for the wheel hoe where the plant

Table 2. Experimental Results of Test Weeders

Name of weeder	Field capacity		Weeding index (%)	Plant damage (%)	Performance index	Cost of weeding (Rs./ha)
	h/ha	ha/h				
Wheel hoe	81.67	0.012	71.0	6.81	793.97	255.22
CRRI weeder	70.45	0.014	77.2	2.66	1 052.05	220.16
Rotary Peg weeder	79.39	0.013	70.8	2.39	898.40	248.09
V-blade hoe	91.93	0.010	66.0	1.89	647.52	287.28

Note: For all test weeders, the source of power was one person.

damage was 6.81%. The higher percentage of plant damage was due to larger width of coverage and poor stability of the weeder during operation.

The performance index which is a function of weeding index, field capacity, power input and plant damage was highest (1 052.05) for the CRRI weeder. The performance index of the wheel hoe and rotary peg weeder were 793.97 and 898.40, respectively. The cost of weeding per unit area was calculated for all the weeding devices and the lowest cost of weeding (Rs. 220.16/ha) was observed for the CRRI weeder.

Conclusion

The performance of the CRRI weeder was superior among all the weeders studied. The highest weeding index, highest field capacity and least cost of weeding were achieved by this weeder. It was easy to operate and involves less human drudgery compared to other weeders.

REFERENCES

1. Anonymous; 1981. Testing, Evaluation and Modification of Weeders; Technical Series No. 11. Regional Network for Agricultural Machinery, Philippines.
2. De Datta, S.K. 1981. Principles and Practices of Rice Production. John Willey and Sons, New Jersey, USA.
3. Gill, H.S.; Kollar, J.S. 1981. Weed Control in Rice in Progressive Farming, Vol. XII, No. 10, Punjab Agricultural University, India, pp 6.
4. Igbeka, I.C. 1984. Development in Rice Production Mechanization AMA 10(1): 27-32.
5. Islam, M.S.; Haq, K.A. 1985. Performance of Indigenous Hand Weeders in Bangladesh. AMA. Vol. 16(4): 47-50. ■■

An Appraisal of the Problem of Wheeled Tractors Used in Nigerian Agriculture

by
O.O. Babatunde
Dept. of Agric. Engineering
University of Ilorin
Ilorin, P.M.B. 1515
Nigeria

Abstract

A field survey was conducted to determine the problems causing prolonged breakdown of farm tractors in Nigerian agriculture. The systems of the tractors and the tractor makes were examined in terms of the frequency of breakdown, employing a 2-factor factorial analysis and multiple comparison. Results indicate that the engine and hydraulic problems contributed significantly to prolonged breakdown of farm tractors. The study also indicated aggravation of the situation by the inadequacy of spare parts to service locally assembled tractors in Nigeria.

Introduction

Farm tractors have, in recent times, become very important for large-scale farming in Nigeria. This is probably due to an increasing demand for agricultural products for human consumption and increasing number of agro-based industries. The latter has been increasing in the last two decades as Nigeria developed infrastructure for economic and social development.

However, the high cost of ownership of farm tractors in Nigeria presently militates against the use of tractors by a majority of the farmers. This is further compounded by the fact that the tractors that are available for direct use or hiring services are often grounded due to tractor systems' failure. Various makes of tractors are employed in the Nigerian agriculture but their serviceability is often interrupted by lack of spare parts or high cost of such spare parts.

The growing importance of agricultural mechanization in Nigerian agriculture makes it imperative that the largest group of prime mover in the industry, the farm tractors, should be given considerable attention.

Objectives

The objectives of this study were:

1. To compare the frequency of breakdown of various tractor makes used in Nigerian agriculture;
2. To compare the frequency of breakdown of the tractor sub-systems, viz: - engine, transmission, traction, cooling, electrical, lubrication, fuel and hydraulics; and
3. To provide information for manufacturers and spare parts dealers of tractors in Nigeria.

Literature Review

Wheeled tractors represent a considerable amount of capital investment in agricultural enterprises, but in such developing countries as Nigeria, stocks of immobilized tractors abound, representing a large waste of mechanical power resources. Reasons often given to such phenomenon include shortage and prohibitive cost of spare parts and the use of inexperienced operators (Sheruddin et al, 1988).

The problems associated with reactivating grounded tractors in Nigeria are in part due to the unfavorable foreign exchange situation of the Naira[1]. This problem is compounded by the inability of the local tractor assembly plants to increase the local content of their tractor production. According to Beppler and Hummeida (1985), the accumulated repair costs of tractors may be as high as 1.6 times the purchase price with due

Acknowledgement: The contribution of Engr. A.A. Olowoyile in data gathering effort is acknowledged.

[1] Naira is a denomination for the Nigerian currency.

regards to inflation. The accumulated repair and maintenance cost (C) of tractors and other farm field machineries are given by ASAE Engineering practice, ASAE EP 391.11 (ASAE, 1986) as

$$C = P(RF1(X)^{RF2})(1+i)^{n} \quad ...(1)$$

where factors RF1 and RF2 are given by ASAE Data, ASAE d230.4 (ASAE, 1986); P is the purchase price; i is inflation rate, n is age of tractor or machinery in years; and x is the one-thousandth accumulated hours of usage.

Gene (1983) and Adigun (1987) classified the component system of the tractor into 8 sub-systems, viz: engine, transmission, traction, cooling, electrical, lubrication, fuel and hydraulics.

Oni (1987) attributed some of the reasons for the frequent breakdown of these tractor breakdown sub-systems to poor quality of fuel and lubrications used, seasonal nature of tractor use and lack of proper preventive maintenance.

Survey Methodology

A questionnaire was designed to collect data on such items as: name of establishment that own and/or services farm tractors, year of purchase and purchase price of such tractors; and component(s) or breakdown sub-system failure causing prolonged immobilization of such tractors.

The sub-systems were as given by Gene (1983) and Adigun (1987). A total of 25 organizations responded to the questionnaire. Response from the questionnaires comprised 12 from the Government and 13 from privately-owned establishments from Lagos, Oyo (Oshun and Oyo), Ondo, Kwara and Kaduna States. The distribution of the data is as shown in **Tables 1** and **2**. The purchase prices of the various tractor makes and models showed that up to 1985, the costs of new tractors were generally less than N50 000.00. However, between 1986 and 1991, the tractors generally cost over N200 000.00. The survey was conducted between March and April 1991.

Table 1. Summary of Tractor Breakdown Systems*

Tractor Make	No. of Tractors	Frequency of Breakdown							
		Engine Y1	Trans-mission Y2	Traction Y3	Cooling Y4	Elec-trical Y5	Lubri-cation Y6	Fuel Y7	Hydrau-lics Y8
Fiat	12	7	5	5	4	3	3	2	4
Steyr	16	8	6	5	4	5	4	7	11
Ford	5		2	1		1			2
John Dere	2	2					1	1	2
David Brown	6	3	2	1					5
Massey Ferguson	16	4	2	2	3	2	2	4	5
Gideon	1	1	1	1					
Total	58	25	18	15	11	11	10	14	29

*Data from structured questionnaire.

Table 2. Mean Value Breakdown of Tractors*

Tractor Make	Mean value of frequency of tractor systems breakdown							
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8
Fiat**	0.503	0.417	0.417	0.333	0.250	0.250	0.167	0.333
Steyr**	0.500	0.375	0.312	0.250	0.312	0.250	0.437	0.687
Ford		0.400	0.200	—	0.200	—	—	0.400
John Dere	1.000	—	—	—		0.5Sw	0.500	1.000
David Brown	0.500	0.333	0.167	—	—	—	—	0.833
Massey Ferguson	0.250	0.125	0.125	0.187	0.125	0.250	0.312	
Gideon	1.000	1.000	1.000	—	—	—	—	—

*From Table 1.
**Most frequent data.

Data Analysis

The data in **Table 1** show that Fiat, Steyr and Massey Ferguson tractors were commonly used in the survey area. It is considered that breakdown sub-system failure in the three tractor makes could be projected for the other tractors. **Table 2** shows the reduced values of the results in **Table 1** on unit tractor basis.

Table 3 shows the average age of the tractors. The sub-system failure(s) has been used as a factor for comparing the causes of prolonged breakdown in the tractors as this can provide information to spare parts dealers to stock spare parts for the component of tractors that most frequently cause prolonged breakdown, and for manufacturers to improve on thier designs. The tractor make (TM) is used as another basis of comparison to provoke competition among manufacturers to improve on the component parts of their tractors.

Table 3. Age Distribution of the Tractors

Age (years)	Fiat	Steyr	Massey Ferguson
5	5	8	5
10	6	5	5
15	1	3	4
20	—	—	2
Average age (years)	4.2	4.2	5.5

The data is analyzed using a 2-factor factorial analysis using methods described by Ott (1977). It is assumed that there is no feasibility of interchanging components among tractor makes. By this assumption, any statistical interaction between tractor make and breakdown sub-system resulting from the analysis will not have practical implications. The interaction of the two factors S and TM is used as pooled error in the 2-factor factorial analysis.

The final comparison is to be carried out using Duncan's Multiple Range Test (MRT) as described by Ott (1977) which requires the use of the mean square values obtainable from ANOVA (Analysis of Variance) which, in turn, is obtainable from the 2-factor factorial analysis.

The comparison by the MRT was carried out by ranking the sample means from the sample mean with the smallest, in turn, using the appropriate statistic given by Ott (1977) and Duncan's MRT Table (Duncan, 1955).

Results and Discussions

Tables 4 and **5** show the results of the 2-factor factorial analysis. Results in **Table 5** provide the mean square needed for the computation in the Duncan's MRT. Also, the results in **Table 5** show that the variation of the frequency of breakdown of the tractor sub-systems is not statistically significant. However, the variation of the breakdown among tractor makes is statistically significant.

Tables 6 and **7** show the ranking of the mean values of the frequency of breakdown among tractor makes and breakdown subsystems.

Tables 8 and **9** show the final group ranges of the frequencies of breakdown among tractor makes and the breakdown of subsystems.

The interpretation of the results of the present study is based on the assumption that whatever the cause of breakdown, being nature of duty of the tractor or geographical location of the use, the desire of the tractor owner or service workshop is to put the tractor back to work. Data on **Table 2** show that there is no significant difference in the age of the tractors under investigation. While the Massey Ferguson tractors were purchased between the mid-1970s and 1990, the Fiat and Steyr tractors were purchased between the early 1980s and 1990.

The statistical analysis of the causes of breakdown of tractors was carried out among the Fiat, Steyr and Massey Ferguson tractors. A 2-factor factorial analysis (**Tables 4** and **5**) indicates that tractor make significantly influenced the breakdown under local working conditions they were subjected to.

Results in **Table 8** on comparison among tractor makes indicate that the Massey Ferguson tractors were less prone to prolonged breakdown than the Steyr and Fiat makes. This result is also evident in the consistently lower mean values of breakdown for Massey Ferguson in **Tables 2** and **4**.

Results of the comparative tests shown in **Tables 8** and **9** indicate the relative significance of the components of the 2-factor factorial data as follows:

a) The Massey Ferguson tractor significantly showed the least tendency to prolonged breakdown than Fiat and Steyr tractor makes.

b) Lubrication, electrical and cooling breakdown systems significantly had less effect on tractor breakdown than hydraulics and engine systems. Lubrication particularly showed to be significantly less of a cause for tractor breakdown compared with fuel, traction and transmission systems. However, the hydraulics and engine systems significantly

Table 4. 2-Factor Factorial Analysis of Tractor Breakdown Frequency as a Function of Tractor Make and Breakdown System*

Tractor Make	Breakdown Systems								
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Total
Fiat	0.583	0.417	0.417	0.333	0.250	0.250	0.147	0.333	2.75
Steyr	0.500	0.375	0.312	0.250	0.312	0.250	0.437	0.607	3.123
Massey Ferguson	0.250	0.125	0.125	0.187	0.125	0.125	0.250	0.312	1.499
Total	1.333	0.917	0.854	0.770	0.687	0.625	0.854	1.232	7.372 = Grand Total

*From Table 2.

Table 5. Analysis of Variance (Anova)*

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F-ratio	Level of Significance
Breakdown System(s)	0.0855	7	0.0122	0.762	NS**
Tractor make	0.1809	2	0.0904	5.639	5%
Error	0.2245	14	0.01603	—	—
Total	0.4909		—	—	—

*From Table 3.
**NS = not significant.

Table 6. Ranking of Mean Values of Frequency of Tractor Breakdown*

Tractor Sample Mean	MF	Fiat	Steyr
Item	1.400	2.750	3.123

*From Table 3.

Table 7. Ranking of Mean Values of Frequency of Breakdown of Tractor Sub-systems

Break-down	Lubri-cation	Electrical	Cooling	Traction/ Fuel	Trans-mission	Hydraulic	Engine
Systems	Y6	Y5	Y4	Y3/Y7	Y2	Y8	Y1
Sample Mean	0.625	0.697	0.770	0.854	0.917	1.232	1.333

Table 8. Comparison of the Frequency of Breakdown

Comparison	Conclusion	Remarks
Steyr MF = 1.624	>2.647	Significant
Fiat MF = 11.251	>0.647	Significant
Steyr Fiat = 0.373	<0.647	Not Significant

Result MF. Fiat Steyr
Values of MF is less significant than that of Fiat and Steyr.

Table 9. Comparative Frequency of Tractor Sub-system Breakdowns

Comparison	Conclusion	Remarks
Y1-Y6 = 0.708	>0.230	Proceed
Y8-Y6 = 0.607	>0.229	Proceed
Y2-Y6 = 0.228	>0.228	Proceed
Y7-Y6 = 0.229	>0.226	Proceed
Y4-Y6 = 0.145	<0.221	Stop
Y1-Y5 = 0.646	>0.229	Proceed
Y9-Y5 = 0.515	>0.228	Proceed
Y2-Y5 = 0.230	>0.228	Proceed
Y7-Y5 = 0.167	<0.221	Stop
Y1-Y4 = 0.563	>0.228	Proceed
Y8-Y4 = 0.162	<0.226	Proceed
Y2-Y4 = 0.147	>0.221	Stop
Y1-Y3,Y7 = 0.479	>0.226	Proceed
Y8-Y3,Y7 = 0.378	>0.221	Proceed
Y2-Y3,Y7 = 0.063	<0.214	Stop
Y1-Y2 = 0.416	>0.221	Proceed
Y8-Y2 = 0.315	>0.214	Proceed
Y1-Y8 = 0.101	<0.214	Stop
Results of group ranges	Y6 Y5 Y4 Y3 Y7 Y2 Y8 Y1	

The multiple comparison indicates that Y6, Y5 and Y4 are significantly less than Y8 and Y1; Y6 is significantly less than Y3, Y7, and Y2, while Y8 and Y1 are both significantly higher than Y2, Y3, and Y7.

showed the highest tendency to tractor breakdown as shown in **Table 9**.

Experience has shown that lubrication, electrical, fuel and traction systems are frequent sources of tractor breakdown, but their problems are not always serious enough to cause tractor grounding.

The comparative tests were carried out at 0.05% C.I. probability, (Duncan, 1955). The data in **Table 3** showed that Massey Ferguson consistently gave the least mean values for breakdown on most of the breakdown systems. The relatively high tendency of the engine, hydraulic and transmission systems to breakdown is explained by the agglomeration of moving parts with reliability falling with increasing number of component parts breakdown (Shigley, 1963). The difference between breakdown tendency of transmission system between the Massey Ferguson tractor, on the one hand, Fiat and Steyr, on the other, may be due to the grade of oils used in the transmission. For while Massey Ferguson uses SAE90, the others use SAE30 or SAE40 grades. The absence of cooling system for externally mounted hydraulic pumps in Steyr is another source of problem for the hydraulic system.

However, as Fiat and Steyr have assembly plants in Nigeria, the implication of the findings of this study is to direct the attention of manufacturers and spare parts dealers to areas of importance in the business of servicing available tractors. Also, for tractors that are being imported, this study directs, attention to critical issues of durability and relative supply of spare parts to bring along.

Conclusion

The study conducted an investigation into the causes of tractor breakdown or grounding in this work showed during the strong presence of the locally assembled tractors in the Nigerian Agriculture. However, the results of analysis of data obtained on the tractors indicated the inadequacy of the locally assembled tractors in providing reliable and sufficient spare parts to service the tractor engines, hydraulics and transmission. In particular, the results of the study reveal, that engines and hydraulics showed outstanding significance in being responsible for tractor grounding or prolonged breakdown.

REFERENCES

Adigun, Y.J. 1987. Maintainability of agricultural machinery in Kwara State of Nigeria. Unpublished B.Eng. (Agric) Project Report. University of Ilorin.

ASAE, 1986. American Society of Agricultural Engineering Standards. Am. Soc. of Agric. Engrs. Michigan. 159-165, 300-303pp.

Beppler, D.C. and M.A. Hummeida. 1985. Maintaining and repairing agricultural equipment in developing nations. Trans. of ASAE, 66(12): 11-13.

Duncan, D.B. 1955. Multiple range and Multiple F-tests. Biometrics. 111: 11-42. In: an introduction to statistical methods and data analysis by L. Ott. 1977. Duxburry Press. Massachusetts. 696 pp.

Gene, L.D. 1983. Agricultural and automotive diesel mechanics. Prentice Hall Inc. New York 212-2 pp.

Oni, K.C. 1987. Agricultural Tractor reliability in integrated farm mechanization. Conference paper at the 2nd National Conference on Technological Development and Nigerian Industries. Engineering Section of Science Association of Nigeria (ESSAN). At the University of Ilorin between 4th-6th November.

Ott, L. 1977. An introduction to statistical methods and data analysis. Duxbury press. Massachusetts. 378-396, 430-443, 696 pp.

Sheruddin, B.B., M.B. Jan and H.N. Saadat, 1988. Cost of operating tractors on Quetta Farms. Pakistan. AMA 19(1): 114-120.

Shigley, J.E. 1963. Mechanical engineering design. McGraw-Hill Bk. Co. London. 214-218 pp. ■■

The Role, Shortcomings and Future Strategy of Agricultural Machinery Testing in Kenya

by

P.M.O. Owende
Graduate Student
Dept. of Agricultural and Food Engineering
University College Dublin
Earlsfort Terrace Dublin 2
Republic of Ireland

P.G. Kaumbutho
Lecturer
Dept. of Agricultural Engineering
University of Nairobi
P.O. Box 30197
Nairobi, Kenya

Abstract

Appropriate agricultural mechanization should be based on rational acquisition, utilization and maintenance of machinery units and systems to minimize operation costs and optimize performance in respective operations. Consequently, machinery testing is the best basis for selection, utilization and sustainance of appropriate machinery. This paper outlines the status of agricultural machinery testing in Kenya, with emphasis on the deficiency in its role in encouraging efficient selection and utilization, local innovation and manufacture, and in technology transfer as a whole. The revitalization of agricultural machinery testing as part of a strategy for self-sufficiency in agricultural production, and the necessary infrastructural support required for development of National Testing Standards are proposed. While strategy for agricultural machinery technology development and transfer for Kenya is presented, the same may apply to most developing countries.

Acknowledgement: The authors thank the Netherlands Project of the Department of Agricultural Engineering, University of Nairobi for the financial assistance in organizing this paper. They are also grateful to the Agricultural Engineering Division of the MoALDM for valuable information Mr. P.K. Ndethi for useful discussions on the subject.

Introduction

Kenya lies astride the equator between latitudes 5°N and 5°S and longitudes 34°E and 42°E on the eastern part of Africa. The total land area is 580 000 km^2 with an unevenly distributed population of 25.4 million (Central Bureau of Statistics, 1995). Agriculture in Kenya employs approximately 70% of the population and earns 30% of GNP, and over 60% of the foreign exchange. Food processing, beverages and textiles which represent over 75% of the country's industrial output are processed from agricultural raw materials (MoALDM, 1992). There are about 10 million ha of high and medium potential land for rainfed agricultural production and a potential of 0.5 million ha for irrigation (Central Bureau of Statistics, 1991). Currently, only 5.2 million ha of the high and medium potential land are under cultivation and only 11 000 ha are irrigated for crop production.

Although the majority of the population is involved in agriculture, production levels for food and fibre has remained inadequate and, consequently, Kenya is a net importer of food and fibre. Failure to meet the demand for food and fibre in spite of the large area of cultivated land is an indication of the low efficiency in the utilization of land and labour. Kenya has the potential of growing up to surplus levels of these commodities provided an appropriate mechanization strategy is adopted to address the fundamental problems of low labour productivity. The apparent low productivity of labour is a major justification for appropriate mechanization. Appropriate mechanization is the application of human, animal and mechanical equipment in agriculture with regard to technical, socioeconomic and cultural constraints. It is arguable, therefore, that the deficit in food and fibre production may be offset by raising the productivity of labour through appropriate mechanization using aids from local innovations and transferred technology. Instituting a well coordinated agricultural machinery testing system within the mechanization policy may be one of the best means of achieving this.

Machinery testing is to determine by measurement and observation, whether a machine component, a system of components, or a system of machines, meet the performance standards set by manufacturers and users (Mbugua, 1990). In this context, agricultural machinery testing may be used to:

(a) set standards of performance of agricultural machines;
(b) to ascertain the level of performance of the machines in use;
(c) provide machinery manufacturers with guideline on design and construction for specific conditions; and
(d) to provide the criteria for adaptive design in technology transfer.

Through machinery testing, farmers can be assisted in making wise selection and application of improved hand, animal drawn and motorized units of production. They may also be offered suitable options for overcoming traditional constraints and elimination of bottlenecks as these develop in their production systems. Agricultural machinery testing, therefore, is arguably the best basis for selection and sustainance of appropriate agricultural machinery in Kenya.

The objectives of this paper were;

(1) to report on the status of agricultural machinery testing in Kenya with emphasis on the shortcomings and their negative impacts, and
(2) to propose an appropriate strategy for its revitalization.

Status of Agricultural Machinery Testing

Background

Testing of agricultural machinery in Kenya was started in 1956 under the East African Machinery Testing Unit (EAMTU). The main duties of EAMTU were:

(i) To test all imported agricultural machinery and ascertain their performance;
(ii) To advice the government as to which of the tested machinery was appropriate to Kenyan conditions; and
(iii) To protect the interest of farmers from any unscrupulous dealers.

It mainly catered for the large-scale colonial farmers in the 'White Highlands' of Kenya (Shiribwa and Mwanda, 1992), with services offered to other East African countries of Tanzania and Uganda. In 1962, EAMTU's operations were decentralized to individual countries with Kenya retaining the formerly EAMTU as Agricultural Machinery Testing Unit (AMTU). Up to 1977, AMTU concentrated mainly on machinery used by large-scale farmers. In 1977, the Agricultural Equipment Improvement Project (AEIP) was started with the assistance of the Food and Agricultural Organization (FAO) of the United Nations. The main objectives of AEIP under its four year project period was to test and modify equipment for small scale farmers. A new project, the Small Farm Mechanization Programme (SFMP) was started within AMTU in 1982, with the objective of multiplying suitable equipment identified under AEIP. In 1983, AMTU was restructured and renamed Rural Technology Development Centre (RTDC) with regional units established in selected locations within the country, while the original centre in Nakuru maintained the role of co-ordinating operations for all the centres. A World Bank funded Farm Equipment Use for Small Holder Agriculture (FEUSHA) programme whose tenure covered the years 1990-1993, had similar objectives to the AEIP.

All these projects have left little in the form of innovative equipment adaptable by small-holder farmers which can be witnessed from the many prototypes that have been produced and abandoned at RTDC's. Similarly, the machinery bought by the projects for both large- and small-scale operations may also be seen in unserviceable condition at RTDC (**Fig. 1**). Currently, the mandate to carry out agricultural machinery testing in Kenya is with the Agricultural Engineering Division of the Ministry of Agriculture and Livestock Development and Marketing (MoALDM) with the RTDCs as the test agents.

Fig. 1 A common result from poorly managed machinery acquisition and management in Kenya.

Current Situation

Although the mandate of carrying out agricultural machinery testing on behalf of the Kenya Government is with the Agricultural Engineering Division of MoALDM, different bodies have contributed to the objective of machinery testing. The agencies, institutions and organizations currently undertaking some form of agricultural machinery testing may be distinguished as follows:

Government bodies — Under the Ministry of Agriculture, machinery testing is carried out by the RTDCs. There is the national machinery testing centre in Nakuru, with regional centres in the eight provinces of Kenya, meant to conduct localized machinery design, development, testing and extension. The tests carried out have mainly been on small farm implements (indigenous and adopted designs) during the FEUSHA programme and on imported farm tractors. Parastatals including the regional development bodies such as Lake Basin Development Authority and Kerio Valley Development Authority, and sugar companies also engage in machinery testing. However, these are generally focused on customized applications and the results are never disseminated to the public.

Institutions of higher learning — Contributions to the tests by the MoALDM have been realized from the Department of Agricultural Engineering (University of Nairobi) and the Department of Agricultural Engineering (Egerton University). The contribution from Egerton University has been in the form of facilities (test equipment and site) to the RTDC for conducting on-farm test of tractors and accompanying ploughs. A limited number of tractor engine power performance tests have also been conducted on imported tractors by the University of Nairobi under request from the MoALDM. Currently, the University of Nairobi has embarked on setting up a Design and Test Centre to address the design and development of agricultural machinery to cover both animal and mechanical aids to mechanization.

Farm machinery production industries and repair shops — Agents of established farm tractors and motorized machinery such as the Farm Machinery Distributors (SAME tractors and equipment), CMC Holdings (Ford tractors and equipment) and Gailey and Roberts (Caterpillar, John Deere and Kubota tractors and equipment), have set workshops in which tests on motorized units are performed mainly for applications in large-scale farming. These tests are confined to engine power performance after repair or reconditioning while no tests are carried out on accompanying implements. The results are confidential to the machinery dealers.

Non-governmental organizations (NGOs) — Several NGOs that are involved in technology development such as Action-aid, Approtec and Intermediate Technology Development Group are also involved in promoting tillage and rural transport technologies using animal traction, crop processing, and water pumping and treatment techniques mainly for subsistence farming. The tests on these equipment and techniques are devoid of standard procedures although the achievement in their extension to the target groups is commendable.

Table 1. Land Preparation Costs for Sugarcane Farming in Kenya

Sugar company	Operation	Field capacity (ha/h)	Cost (US$/h)	Cost (US$/ha)
Nzoia sugar Co.	Ploughing	0.67	12.97	19.46
	Harrowing	1.2	12.97	10.78
	Furrowing	0.67	10.37	15.47
	Total	—	36.31	45.71
Mumias Sugar Co.	Ploughing	0.22	9.70	44.09
	Harrowing	1.05	6.42	6.11
	Furrowing	0.94	10.95	11.63
	Total	—	27.07	61.83
Chemelil Sugar Co.	Ploughing	0.35	13.26	37.87
	Harrowing	0.55	14.48	26.33
	Furrowing	0.63	6.53	10.37
	Total	—	34.27	74.57
Muhoroni Sugar Co.	Ploughing	0.6	32.46	54.10
	Harrowing	0.8	32.46	40.58
	Furrowing	0.9	12.62	14.03
	Total	—	77.54	108.71

Source: MoALDM, 1994.
1 US$ = KSh 55.45 (September, 1995).

Problems

Kenya relies on imported agricultural machines from developed countries. However, any imported equipment designs must meet local needs for acceptance. Machinery testing under Kenyan condition should offer basis of decision on the types suited to local condition and which should be encouraged for import, production or popularization. However, the money allocated to the RTDCs is not adequate to finance the appropriate machinery tests and lack of appropriate instrumentation aggravates the situation. Currently, imported machines are tested against manufacturers' specifications only at the introduction to the Kenyan market which offers little more than what is available in the accompanying brochures for the respective equipment.

Inappropriate selection and poor management has contributed significantly to high costs in utilization, maintenance and repair of agricultural machinery in many agro-based industries in Kenya. **Table 1** provides an illustration from the sugar industry. For similar selection of machinery, Chemelil Sugar Co. achieved about 31% less cost when compared to Muhoroni, under similar soil condition. The cost of machinery use for Mumias Sugar Co. was about 43% less than that of Muhoroni, not entirely because of lighter soils in the former areas but largely because of combination of appropriate selection as well as good management (MoALDM, 1994). Although the data here are specific to the sugar industry, homogeneity of land preparation operations for crop production in Kenya as reflected by the limited makes and capacities of prime movers and implements used implies that the same may apply to most agro-based industries in Kenya.

Effective application of research and development in agricultural machinery can only be realized from the commercial production, i.e., there should be a transition from technically viable innovations to commercially successful ventures. The major problems facing agricultural machinery manufacture in Kenya are: absence of appropriate vetting for machinery imports (transferred technology) and the inability to control the build-up of an innovation system. Dealers' preference for imported implements and auxiliary equipment to match imported tractors has been imposed on the farming community to the exclusion of locally made versions even when quality difference is not significant (MoALDM, 1994). This may be due to the lack of information on comparative performance evaluation in structural and functional capabilities of the available options. On the other hand, a lot of resources have been directed towards development of new technology in the informal (*Jua Kali*) sector but very little effort has been made to develop markets for them. Concurrently, novel solutions to some immediate problems facing small- and large-scale farming in land productivity, efficient crop management and post-harvest handling of farm products have been generated at local universities as purely academic exercises, with no serious consideration to commercial production.

Machines have to render reliable service under varying conditions of operation. Easy operation, maintenance, availability of spares and interchangeability of critical components assume special significance where basic infrastructural facilities for repair and maintenance are lacking. Currently, in Kenya, reliable network for service and repair of agricultural machines only serve major towns, including Nairobi, Mombasa, Kisumu and Nakuru, and smaller towns in predominantly large-scale farming areas such as Eldoret and Kitale. There are no vetting procedures in place to ascertain the availability or facilitation of the critical back-up service for all machinery imports. A common consequence is illustrated in **Fig. 2**. The Kenya Standard Specification for agricultural tractors is KS 06-1066/1-6 (KBS, 1992) which was adopted from ISO 789 (parts 1 to 6). The standard covers procedures for test and reporting for both laboratory and field tests of wheeled and track-laying tractors. The RTDC performs the PTO test to determine the power transmission efficiency (Mbugua, 1990; Shiribwa and Mwanda, 1992 and RTDC, 1985). The University of Nairobi (UoN) performs the PTO tests and the hydraulic power test (Owende, 1991). RTDC also does field tests to determine indicative durability, the rate of work (ha/h), the fuel consumption, the slip and cost-benefit analysis of the machine. On completion of tractor test, the RTDC prepares the report in triplicate of which one copy is sent to the Ministry of Agriculture headquarters, a second copy is offered to the dealer/applicant and the third is filed at the test station. Results from test by UoN which are mainly academic exercises, appear as student dissertations.

For tillage equipment, Kenya Standard KS 06-252 (KBS, 1982) and KS 06490 (KBS, 1985) are specifications for animal-drawn mouldboard plough and discs for tractor-drawn ploughs, respectively. Material specification for manufacture are covered in both the referred documents. It is notable that standard test procedures on evaluating performance in the intended applications are not offered. There are no specifications for tractor-drawn mouldboard ploughs and, disc or tined harrows despite significant utilization of this group of tillage implements in Kenya. However, the RTDC conducts tests on submitted tillage equipment with

Fig. 2 Illustration of lack of appropriate back-up service and lack of standardization in manufacture. The tractor on the foreground became redundant from lack of spares. Poor workmanship on mass produced punch-planters on the back ground-left led to rejection by the intended users. Such may be avoided by user survey and standardization in manufacture processes and for quality control.

parameters measured as width of cut, depth of cut, draught force, travel speed and work capacity. Soil type, surface relief and vegetative cover are recorded as test condition (MoALDM, 1994). The tests are based on one soil type and in all cases one soil condition thereby limiting the applicability of the results to the entire range of operation conditions in Kenya. Supplementary to parameters measured in test by RTDC, UoN tests includes surface roughness, soil moisture status, soil physical and mechanical characteristics, and statistical analysis of data (Maobe, 1990). There are currently no specification and test codes developed for seeders.

The national machinery test centre in Nakuru is poorly equipped for tractor testing as it does not have functional basic equipment such as, a dynamometer, fuel flow monitor, a loading car or a test track for tractor drawbar power tests. The test currently performed are deficient for Standard KS 06-1066 and only comparative reporting can be made (i.e., test confirmation of manufacturers specification) as there are no set criteria for Kenya on the performance of agricultural tractors probably due to the lack of primary data on requirements of local conditions. Although the machinery test reports from the RTDCs are prepared in triplicate, poor keeping or insufficient number of these reports has led to their loss or unavailability for reference. Neither the cumulative records of tractors that have been tested nor the eventual action taken based on the tests conducted to-date are readily available (Oduor, 1992). Agricultural hand tools and crop processing machines such as manually operated and mechanically powered oil presses and grain milling equipment that are developed by the informal sector and other light industries in Kenya are not subjected to any testing. There is virtually no control on equipment such as stationary engines, irrigation pump sets and water dispensers, and plant protection equipment. Consequently, consumers with limited resources evade risk undertaking in mechanizing production with their use. In general, tests on agricultural machines and auxiliary equipment as currently conducted is sporadic and are limited in number each year, thereby raising queries about the rationale of investing on test equipment and personnel attached to government test units. The limited number of tests done on agricultural tractors and accompanying implements compared to sale of tractors (Githua, 1992) and implements (Gumbe et al., 1991) spell lack of clear guiding policy for agricultural technology transfer in Kenya.

On reporting of machinery test results, current tests do not offer criteria of performance, making it difficult if not impossible to qualify machines based on test reports. The data reported are based on average values and variability is not indicated. This is probably due to limitations in the test equipment and methods of analyzing test results. The method of reporting is of little use to those without basic engineering background who make the bulk of farm machinery users in Kenya.

From the foregoing, it is clear that machinery testing currently conducted by the mandated arm of the Kenya Government is not sufficient in scope and lacks support systems for long term impact in mechanization of agriculture in Kenya. There is will for comprehensive machinery testing, as outlined, say, in the recommended test procedure for tractors. What lacks is a coordinated approach to develop capacity and priorities in testing, and to link these with standard enforcement for the benefit of machinery users. The major components that are lacking to allow the establishment of appropriate machinery testing system in Kenya can be identified as:

(1) Lack of funds to conduct comprehensive agricultural machinery testing and to include all options for mechanizing the different scales of agricultural production in Kenya;
(2) Lack of appropriate agricultural machinery test equipment and facilities, and adequately trained and research-oriented personnel to man the test centres;
(3) Uncoordinated research and development of agricultural machinery;
(4) Lack of policy on controlling transfer of technology;
(5) Lack of policy to promote local innovations and local machinery manufacture;
(6) Poor extension service on the use and management of agricultural machinery;
(7) Deficient standardization on agricultural machinery to serve the whole spectrum in scale of production, i.e., small to large-scale farmers; and
(8) Lack of or unco-ordinated/poor management of data-base on agricultural machinery use.

Strategy for Revitalization of the Role of Machinery Testing

In order to establish a machinery testing programme with the aim of developing an appropriate support system for self sufficiency in agricultural production, the schematic components, procedure and linkages as in **Fig. 3** are suggested. Under this programme, the RTDC is the official machinery test agency in the MoALDM, and with the main station in Nakuru, acting as the co-ordinating body for machinery tests in Kenya. Institutions of higher learning are suggested as test centres/agencies with the aim of a National Agricultural Machinery Test Centre (NAMTC) culminating in one of them. The purely research institutions and research and development sections of parastatals and private companies will cover specific needs from the industry. Statutory organizations such as the Kenya Bureau of Standards (KBS) are to ensure the enforcement of 'Kenya Standards', while NGOs and farmers are participants in extension.

In this proposal, a sample of machinery to be introduced into the Kenyan market is submitted to the RTDC/NAMTC for classification and assessment of need with consideration of history of performance elsewhere where applicable. The sample is then delivered to the most appropriate test agency to undergo standardized laboratory and field tests as per the procedures and codes in operation. Failure to qualify in the two tests may lead to rejection with an opportunity for modification after a technical appraisal for minor deficiencies. Satisfactory performance at all test stages qualifies the machine or equipment for expert recommendation

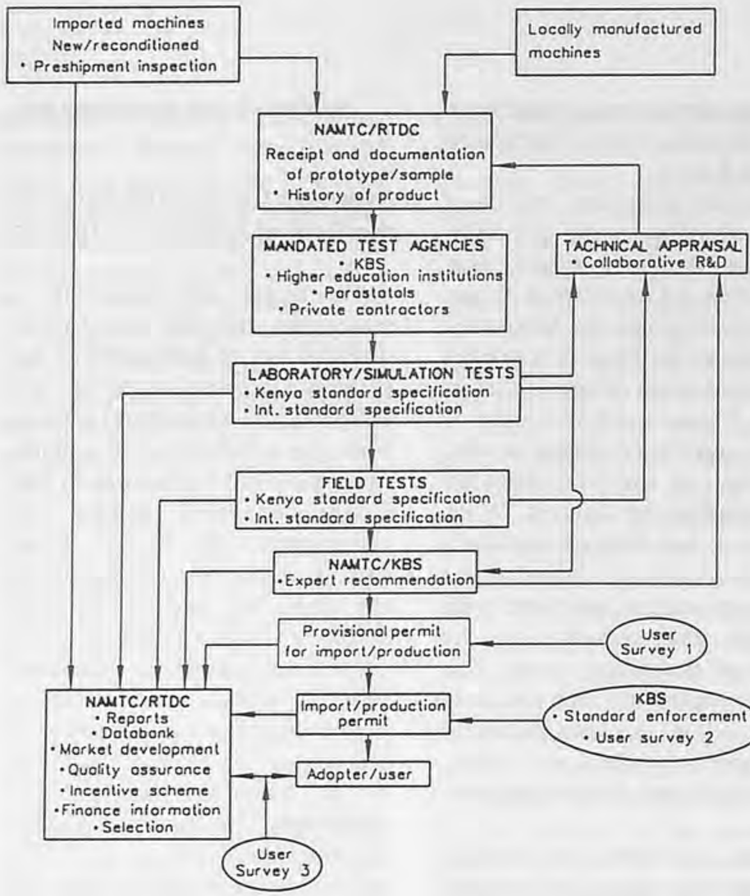


Fig. 3 The proposed components and procedure in agricultural machinery testing for Kenya.

on appropriate utilization under local conditions and the initiation of developing standards of performance. A provisional permit for import or production is then issued with a pilot survey (**User Survey 1**) on the implementation of support services, training on use and initial durability assessments over a defined period. Subject to satisfactory performance, a full import/production permit is issued with strict standard enforcement by inspection of random samples to ensure compliance. **User Survey 2** is enforced to gauge user response or criticisms. **User Survey 3** is used to acquire data on use and gauge long term performance indices, to provide selection and financial information to the market and development of support systems to cover all areas of significant utilization. A demand oriented development through shows and demonstrations can then be undertaken fully by the manufacturers and sales representatives with the assistance of the government and privately managed Mechanization Information and Advisory Services. The objectives and feasibility of these proposals are discussed in the subsequent sections.

Testing in Local Machinery Manufacture

Agricultural machinery testing in Kenya should act as an link between machinery production or supply represented by the inventors or entrepreneurs, and the demand represented by users of products and services. The above link should be developed to quality assurance for the users and as a consequence, the production may benefit from ensuing increase in scale of production required by the demand of proven technology or innovation, and to some extent protection from unfair competition from substandard imports.

The proposed co-ordination role of RTDC can make immense contribution in identifying prototype machines that have potential for commercial production. To attract the commercial use of the test facilities, test reports should be made in strict confidence in deserving situations such as tests on prototypes prior to manufacture. A clear guiding policy on objectives of such tests to run concurrently with the academic programmes in the NAMTC institutions will ensure sustainability of testing program. Follow up in the form of user survey would be an essential component of a testing programme for durability and general performance records of machines in use.

Testing in Technology Transfer

Appropriate service facilities are important for successful implementation of mechanization programs (Sarker and Sarker, 1979). With appropriate back-up service, one machine is as good as another intended for the same application. This argument should be used in regards to short term donor projects whose machines by-pass test regulations and are unserviceable at the end of the project period. A service package should be negotiated in the donor funded projects to enable the sustainance of the machines during their economic life. Supply of spares and provision of service facilities and expertise should establish themselves within the project periods at strictly commercial rates to ensure their survival after the project period expires and the capital investment are privatized or turned over to the government.

It is suggested that local testing should emphasize on areas of peculiar interests such as ease of utilization, comfort and safety for the user with due regard to human factors in design (anthropometric dimensions), and noise and vibration levels. While these are notable omissions in Kenya Standards for agricultural equipment that are already in place, the number of accidents on farms in Kenya are on the increase (Nyakiba, 1989). The tests on agricultural equipment, in general, and tractors, in particular, should possibly specify suitability of performance to specific operations such as tillage, haulage or stationary jobs. Since it has been noted that particular makes of agricultural machines are highly sensitive to abuse through poor maintenance and operation (Gumbe et al., 1991), assessment of influence of age and maintenance service through periodic re-appraisals of machines in use, seem to be a better basis for vetting in technology transfer. This approach is most important since short term assessments have become obsolete as a result of quality production/assembly by manufacturers as in the case of agricultural tractors. A consequence of reliance on short term assessments is illustrated in **Fig. 4**.

Extension as Means of Relaying Machinery Test Results

The role of extension service should be to assist prospective users with reliable information in a comparative format on machine quality, technical performance, costs and benefits of use, user friendliness and technical and financial arrangements available to support sustainable use (Inns, 1995). With the increasing multi-farm use of animal-powered and motorized machinery through custom hiring, there is need for data on cost estimates for common agricultural operations. These are necessary for planning and managing agricultural operations. The NAMTC should process data accrued from the regional centres and user surveys (**Fig. 3**) to prepare standards including estimates for efficiency levels of different important operations for its extension programs. The extension service system should develop mechanization information flow and machinery introduction to farmers through a series of regular field demonstrations. The latter is currently undertaken (Shiribwa and Mwanda, 1992), but should be more elaborate than a day's demonstration of the hardware, i.e., there should be more flexibility in frequency, timing and location of such demonstrations.

User surveys as a component of machinery test procedure should be designed to asses operator performance and durability of machines in use. In Kenya, it should also be used to provide information on standard and number of after sales service facilities provided by the manufacturer and dealer network. This could be the mainstay of sustainable mechanization in agriculture. The concept of machinery testing should be used in the machinery management system to show benefits of good management. Good management may be used to reduce agricultural production and processing costs, which in turn may lead to lowering of commodity prices to allow fair competition between imports and locally produced commodities as the secondary effects. There is need, therefore, to set up a mechanization information and advise service to operate within an institutionalized agricultural machinery testing in Kenya.

Collaboration in Technology Generation, Research and Development and Management of Data on Machinery Use

Local and international collaboration in testing and in research and development should aim at spreading the costs of activities undertaken over all participants in the program. Collaborative research and development should be geared towards developing and testing prototypes, and modification of viable imported machines to meet Kenyan conditions. In addition to the technical evaluations, social impact and economic analyses should be evaluated. Institutions of higher learning in Kenya as in most developing countries in general (Nääs, 1984), are geared towards education and training with minimum attention to commercial ventures. However, technology generation and product development require risk capital which the predominantly small scale industries in Kenya cannot afford. Since funds for research or the capacity to raise such funds are available to these institutions, it should be their responsibility to cater for technology generation (creative and adaptive) and the product development need of small scale agricultural machinery industries. Provision of incentives to private entrepreneurs to support research, probably in reduced taxes or otherwise, should be considered.

Through collaboration with foreign institutions, institutions of higher learning in Kenya are able to acquire and develop equipment and expertise necessary for research specific to local conditions. The present set-up of RTDC units in the different agro-climatic conditions sets an exhaustive spectra of expected conditions to which machines would be used. In this respect, the Department of Agricultural Engineering at the University of Nairobi has developed instrumentation for tillage research in the areas of animal and tractor-powered tillage equipment through collaboration with the Swedish University of Agricultural Sciences and University College Dublin in Ireland. Locally, the firms that produce or use

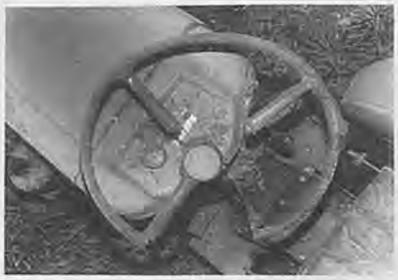


Fig. 4 An illustration of failure of machine components (broken steering wheel) after an extended period of use. Such weaknesses in design or quality can only be apparent in the long-term user survey (durability assessment) as a component of agricultural machinery testing.

agricultural machinery should be encouraged to offer research schemes or grants to graduate schools in the local universities in areas specific to their applications. Apart from providing vital training for the graduate engineers enrolled in these schools, this may speed up their research programmes. This approach has been successfully applied in the developed countries. In 1990, the Department of Agricultural Engineering at the University of Nairobi initiated a collaboration program with the Mumias Sugar Company (Kenya) in the area of design and development of tillage and crop management equipment specific to sugarcane production in this respect. Owende et al (1994) and Owende et al (1995) have reported on an initial study in the collaboration.

There should be a government policy on documentation of performance data on machinery use in large agricultural establishments, which should assist in building a database desired for the formulation of test criteria for respective machines and machine operations under Kenya conditions. Local professional bodies such as the Kenya Society of Agricultural Engineers should lobby for such policies. As the economy in the private sector calls for operation of machines under most severe circumstances, data from notable organizations should be used as guide for machinery selection for farms and the agro-based industry in general, and eventually for the development of 'Kenya Standards' of performance for the respective machines. From experience with multi-functional use of agricultural machinery, it is realized that different machinery manufacturers excel in specific functional components of these machines Gumbe et al., 1991). Through experience, the ease of repair and maintenance of different machines should be comparatively evaluated to identify the better options.

Field vs Rig (simulation) Testing of Agricultural Machines

There is no substitute for field experience with the use of agricultural machinery, but once it has been gained there is an advantage in comparative rig testing. In rig testing, test conditions are reproducible and comparison can be rapidly made between different materials, processes, tools and tool configurations independent of the weather, and which can, subsequently, be used for quality control purposes. Modified or re-designed components can be conveniently tested against those which have previously proved in use by simulated test conditions in the laboratory. This approach requires a wide database to be realistic. Predictive methods where applicable may also be appropriate for widening the scope of the tests currently performed and in situation where necessary equipment is lacking. In this perspective, a sand bin has been built at the University of Nairobi, as a good ground for producing standardized tests with tillage tools. The current facility, however, has limitation in variability of the test medium (soil). Damping and excavation during change of the media is not only inconvenient but also beyond the financial capabilities of on-going research. Soil preparation tools are limited to a tractor mounted disc harrow and a light hand-drawn roller and water and electricity are still not conveniently available. With appropriate financial support, however, the use of potable/interchangeable soil media and installation of the necessary facilities can be effected. On utilization of animal traction, there is on-going research on developing a loading car for simulated studies on draught-ability of work animals. On completion it is expected that this facility will be an accurate, convenient and economical means of matching different tillage tools to intended sources of power.

Formulation of Standard Test Procedures

In order to analyze and compile laboratory and field test observations in a meaningful and comparative manner, standard test procedures and codes are necessary. Where there are no Kenya Standards in place, relevant sections of codes in use by other organizations in developed and developing countries such as the American Society of Agricultural Engineer (ASAE) and the Regional Network of Agricultural Machinery (RNAM) in Asia, should be adopted at the initial stages with a view to modifying or upgrading them with changing techniques in testing and as local operating conditions dictate. It is suggested that after prior assessment of a need for standards for specific machines or components, experts drawn from the machinery manufacture industry, technologists, research and test organizations and consumer bodies with interest in the elements of mechanization programme should be engaged to formulate standards for conditions in Kenya. It is duly noted that this is currently practised by the KBS and should be strengthened for agricultural machinery. In drawing standards for Kenya, the presence of capacity for executing the procedures, with accompanying statutes to enforce them should be considered. For instance, there is no need to conduct measurement of exhaust smoke as required in Kenya Standard KS 061066 if no acceptable levels of emission has been set by law. It is proposed that because of the numerous power and machine models with corresponding items of special or optional equipment, the scope of Kenya Standards on machines should be limited to obtaining and reporting only the most significant and widely used performance data for Kenya. There is need to include non-destructive material test procedures as part of specification for both imported and locally manufactured agricultural equipment that are intended for small scale farm applications, as this is one area that has been worst affected by unscrupulous dealership.

Engineering education in Kenya is currently expanding. The introduction of standardization in the current syllabi would help graduate engineers to appreciate its principles and advantages and, therefore, make contribution in their application, once they get to practice. Since standardization is a process in which attempt is made to seek advise and help from all professionals concerned, active participation in their formulation and enforcement will provide a will for implementation of standards in Kenya in the long term.

Documentation of Machinery Test Reports

Documentation of cumulative data on operation and cost parameters on machines over different work conditions, may ease the selection or evaluation of these systems (efficiency assessment) specific to Kenyan conditions. Specific formats for report of test results vis-à-vis the objectives of testing should be included in the machinery test procedures. The use of standard data sheets for raw data with provision for stochastic occurrences for future reference is highly desirable. With the objectives of specific tests defined, test reports could be categorized into:

(a) Technical reports which would include detailed results and methods used in evaluation, including a basis for suitable or adverse decisions; and
(b) Summary reports highlighting only important parameters with regard to intended application and in a form attractive to the target users.

This approach may reduce overheads incurred where situations may demand mass circulation of test results as in an extension program. The publication of periodical farming journals which includes information on selection and management, with advise on sources of finance requires urgent attention.

Conclusions

The testing and research and development of agricultural machinery in Kenya lacks capacity, funding, clear guiding policies and support systems to enable them to make an impact in regulating local machinery innovations and control of technology transfer as a whole. Important institutional and infrastructural support systems are still uncoordinated, hence their scope do not envisage long term benefits to local machinery manufacture and mechanization for self sufficiency in food and fibre production.

There is need for a central coordinating body for proper management of agricultural machinery testing in Kenya. A National Agricultural Machinery Test Centre is suggested. Institutions of higher learning have potential capacities to be utilized as test agencies and to develop agricultural machinery data banks through their academic programmes. This can be possible through clearly set procedures for machinery testing and reporting, with a rigorous review procedures of test results. The test centres should aim for self sustenance as this may be the only means of all year round testing of equipment.

There is need to develop test codes and standard test procedures for the entire range of agricultural machines in use, based on their importance to the farming community in Kenya. Apart from ensuring that only suitable equipment is introduced to the market, there arises an opportunity for improved efficiency in utilization through proper management and by research and development. The test codes should be periodically reviewed to update them according to changing techniques in experimentation. For multipurpose equipment, the requirements from different farm enterprises should be used to develop the standards.

The introduction of policy, making it mandatory for locally produced and imported machinery to obtain certification would allow for quality assurance as protection of the farmers. Apart from carrying out tests with the objective of vetting imported and locally manufactured machines, the test agencies should be geared towards providing technical assistance in machine design and analysis for the manufacturers and assistance in selection for the farmers.

In capacity building, there is need to develop or import complete ranges of test equipment and auxiliary calibration equipment, as the use of uncalibrated equipment obviously leads to erroneous observations. In research and development, tests over short periods are now obsolete within the technological world and there should be programs of users survey after commissioning of equipment for long term and more reliable data.

Although the illustrations of equipment and expertise that have been acquired as a way of capacity building for machinery testing has been limited to that available at the Department of Agricultural Engineering in the University of Nairobi, what is currently available in other universities in Kenya may make a significant contribution as the basic structure around which to build a more comprehensive machinery test programme. The proposed role of co-ordinating RTDC can be effectively used to prevent duplication in current and possible areas of excellence for all institutions contributing to machinery test programmes. Elevation of one of the institutions of higher learning to a NAMTC should be based on excellence in facilities and expertise endowed in training, research and development, commercial ventures and in collaboration with the industry. This recognition should be spontaneously gained through appropriate capacity building.

REFERENCES

Central Bureau of Statistics. 1991. Statistical abstracts, 1991. Ministry of Planning and National Development. Government Printer, Nairobi Kenya.

Central Bureau of Statistics. 1995. Economic Survey, 1995. Ministry of Planning and National Development. Government Printer, Nairobi-Kenya.

Githua S.K. 1992. Agricultural machinery marketing in Kenya. Proceedings of Workshop on National Agricultural Mechanization Strategy (NAMS), Masinga Kenya. pp. 30-33. Agric. Engineering Division, MoALDM.

Gumbe, L.O.; Odhiambo M.O.; Kamasara V. and Owende P.M.O. 1991. Modalities for the Project Tractor Hire Unit for West Kenya Rainfed Rice Development Programme (WKRRDP), Chapter 5: Identification of necessary machinery. African Development Bank (ADB) funded study for Lake Basin Development Authority (LBDA), Kenya (Unpublished).

Inns, F.M. 1995. Selection, testing and evaluation of agricultural machines and equipment. FAO Agricultural Services Bulletin 115. FAO, Rome.

Johnson, I.M. 1980. Agricultural machinery manufacture in developing countries. The Agricultural Engineer, 35(4):86-87.

Kenya Bureau of Standards (KBS). 1982a. Kenya standard KS 06-252: Specification for animal-drawn mouldboard plough, fixed type.

Kenya Bureau of Standards (KBS). 1982b. Kenya standard KS 06-490: Specification for discs for agricultural tractors.

Kenya Bureau of Standards (KBS). 1992. Kenya standard KS 06-1066 (Part 1 to part 6): Specification for agricultural tractors.

Maobe, W.O. 1990. Measurement of draught force required by five different animal-drawn ploughs under several field and soil conditions. Unpublished B.Sc. Final Year Dissertation, 1990. Dept. of Agric. Engineering, University of Nairobi.

Mbugua, J.K. 1990. Tractor testing. Proceedings of Kenya Society of Agricultural Engineers (KSAE) Conference, 1990: 38-47.

MoALDM. 1992. Agricultural mechanization strategy with special reference to crop production. Agric. Engineering Division, Ministry of Agriculture and Livestock Development, Kenya (Unpublished). 28 pp.

MoALDM. 1994. National agricultural mechanization strategy formulation for Kenya. Chapter 4: Status of mechanization for sugarcane production, pp. 37-38 and Chapter 5: Local supply for agricultural machinery, implements and tools, pp 41-42. MoALD (Unpublished).

Muchiri, G. 1981. Production and use of agricultural machinery in Kenya. In: Industry and Development, No. 9ILO. pp. 13-38.

Nääs, I.A. 1984. Process of technology generation. AMA 15(1): 43-46.

Nyakiba, J.M. 1989. Accidents on the Kenyan farms and methods of prevention. Proceedings of the Kenya Society of Agricultural Engineers, 1989, pp. 49-52.

Oduor, J.K. 1992. A review of status of agricultural machinery testing in Kenya. Unpublished B.Sc. Final Year Dissertation. Department of Agricultural Engineering, University of Nairobi.

Owende, P.M.O. 1991. Test on Universal Model U850. Unpublished Tractor test report. Department of Agricultural Engineering, University of Nairobi.

Owende, P.M.O., P.G. Kaumbutho and J.N. Kamau. 1994. Mounted implement for sugarcane stool destruction, AMA 25(2): 47-53.

Owende, P.M.O., P.G. Kaumbutho, C.M. Maende and J.N. Kamau. 1995. Comparison of options for sugarcane (Saccharum Officinarum L.) stool destruction. Soil and Tillage Research 33(3-4): 185-195.

RTDC. 1985. Tractor test report-Kubota tractor (Unpublished). Agric. Engineering Division, MoALDM. 17 pp.

Sarker, R.I. and N.N. Sarker. 1979. Agricultural mechanization strategies in Bangladesh. AMA 10(2): 20-28.

Shiribwa, M. and C.O. Mwanda. 1992. The role of machinery testing and selection in Kenyan agriculture. Paper presented at Workshop on National Agricultural mechanization Strategy, Masinga Kenya. Agric. Engineering Division, MoALDM (Unpublished). 5 pp.

■■

Improving the Rice Post-harvest Technology in Bangladesh

by
Akhter Ahmed
Senior Agricultural Engineer
bangladesh Rice Research Institute
Gazipur-1701, Bangladesh

M.A. Mazed
Director
Bangladesh Agricultural Research Institute
Gazipur-1701, Bangladesh

Abstract

The post-harvest activities in Bangladesh are traditional and labour intensive. The main activities are manual harvesting, manual threshing, animal or mechanical treading, sun drying, traditional parboiling and milling in huller mills or traditional devices. The milling recovery and quality of milled rice depends on the milling machinery, pre-milling treatments and the paddy variety. Many of the post-harvest activities in the rural area are done by women. These activities are mainly threshing, cleaning, drying, parboiling, milling and grading.

The post-harvest losses in paddy was estimated at about 13% of which the processing losses were very high. The losses are due to delay harvesting, improper handling, incomplete threshing, scattering, bird and domestic animals eating the grains, improper soaking, parboiling and drying, use of inefficient steel huller for both husking and polishing etc. There is no organized rice marketing system in the country. As a result, the farmers receive low prices for their paddy. Millers, traders or enterprises are not accountable for the quality of the polished rice in the market.

Improved methods for loss prevention are suggested in this paper. The practice of steam parboiling in all the rice mills will produce uniform parboiled paddy. The rubber-roll huller for husking may be incorporated to the existing machinery which can be used as a polisher. The owners of automatic rice mills can take loan to run the mills. For adoption of the appropriate post-harvest technology and the improvement of rice processing and marketing, some action programmes are also suggested.

Introduction

Bangladesh is an agricultural country. The main crop is rice. The climate is hot and humid during summer (April to September) but cool and dry during winter (October to March). The climatic and weather factors like rainfall, flood, drought, temperature and humidity which vary in different parts of the country and contribute to the development of agriculture enable farmers to produce one to three crops a year. The adoption of modern variety of rice is increasing day by day. About 78% of the total land area is used for rice cultivation, which produces over 19 million t of milled rice (28 million t of paddy) annually (BBS 1992). The rice area is not increasing but the production is comparatively increasing due to introduction of modern high yielding rice varieties as it can be seen in **Fig. 1**.

The rice crop is harvested during 'Boro' (April to June); 'Aus' (July and August) and 'Aman' (November and December) seasons depending on the cropping pattern and intensity. More than 80% of the population live in the rural areas and agriculture is their major occupation. The post-harvest practices in rice are primitive, traditional and labour intensive, which vary according to localities depending on the existing physical, topographical and climatic condition of the area.

Choudhury (1984) mentioned from the preliminary results that the farm level rice post-harvest losses from harvest to milling operations did not exceed 15%. Greeley (1981) reported that the total physical losses in the operation from harvesting to sun drying did not exceed 7%. In the same study Greeley and Rahman (1980) reported that the physical losses for storage of paddy for about 3 months was 2.6%. Bala (1978) reported that total losses in drying ranges from 1.56% to 5% and that in storage ranged from 3.05%

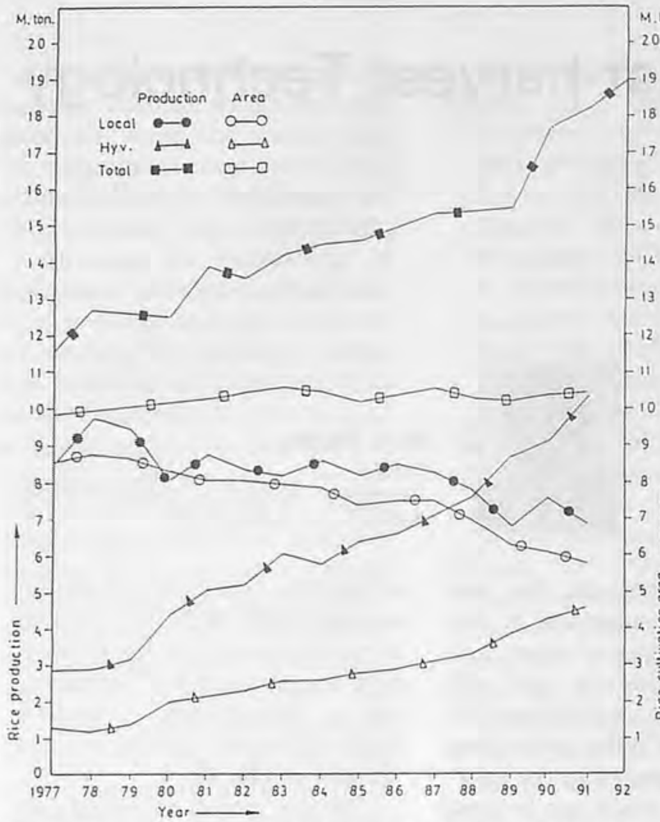


Fig. 1 Rice production vis-à-vis rice area for local and high yield varieties.

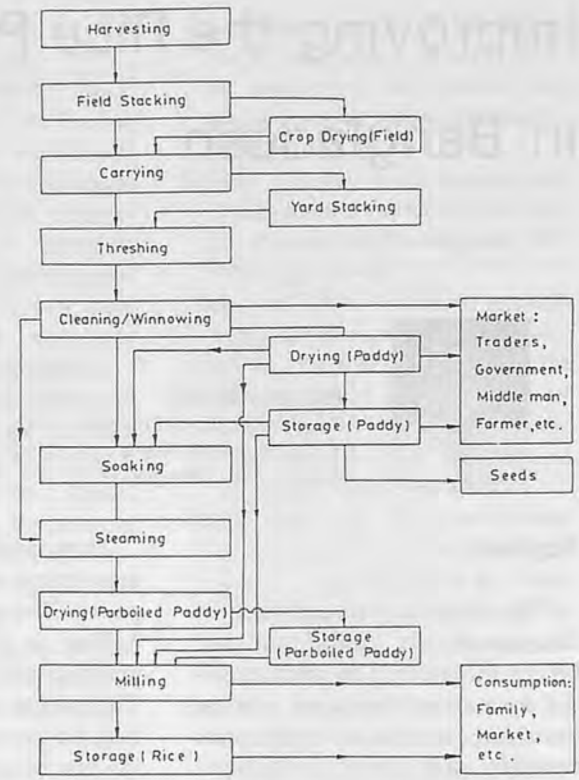


Fig. 2 Flow chart in post-harvest operations at farm and village levels.

to 5% in Bangladesh.

Whereas de Padua (1978) reported that the estimated post-harvest losses in drying, storage and milling ranges from 2 to 5%, 2 to 6% and 2 to 10%, respectively, for South-East Asia. Kumar (1984) stated from the post-harvest study in Nepal that the total losses in storage and milling was 4.6% and 4.15%, respectively. Gaiser (1981) mentioned from a survey in Indonesia that the average post-harvest losses in paddy during drying, milling and storage was 2%, 5% and 5%, respectively. Lee (1984) mentioned from Korean experience that the losses in farm storage was 7%, commercial storage was 3% and milling was 1.5% from local machine for paddy.

With the adoption of modern varieties and improved management practices, the problems of delay harvesting and threshing have been identified due to the large amount of crop handling within a limited time. There are some surplus labour during the slack period of the year, whereas labour shortage usually occurs during the harvesting-threshing season. Women play a key role in post-harvest activities, especially in processing. BRRI/FAO (1985) reported that the total paddy losses from harvest to milling were about 13%. At present, the total production of milled rice is about 19 million t. This means that about 2 million t rice is lost annually.

Objectives

The objective of this study were:

To review the rice post-harvest practices in Bangladesh;

To study the women's involvement in post-harvest operations;

To review the rice post-harvest losses; and

To suggest how to reduce the losses.

Post-harvest Practices

Paddy grains from the field undergo a series of operations before it is sold, consumed or used as seeds. The flow chart of the post-harvest operations practiced at farm and village levels in Bangladesh is shown in **Fig. 2**.

Harvesting and Threshing

Ruiz (1965) showed that the average grain losses at different harvesting times were: 1 week before maturity 0.77%, at maturity 3.35%, and 1, 2, 3 and 4 weeks after maturity were 5.63%, 8.64%, 40.70% and 60.46%, respectively. In Bangladesh paddy is harvested manually by sickle and are left in the field for drying if the weather is favorable. Harvesting losses are due to the shattering and handling. Duff and Toquero (1975) reported that depending upon the number of times the harvested stalks are handled from the field to the threshing yard, shattering loss was up to 7%. Afterwards the stalks of paddy plant are carried to the threshing yard for stacking. The paddy stalks are stacked in the yard for threshing later on. But sometimes the farmers directly thresh the paddy. The common threshing methods are traditional animal treading, beating and mechanical threshing by pedal thresher. The threshing losses are due to unthreshed paddy, scattering and lack of threshing facilities in the rainy season. Mechanical threshing may reduce losses. But the farmers are not interested in mechanical threshing due to lack of capital, adherence to traditional methods and poor mechanical aptitude.

Drying and Cleaning

Sun drying of paddy is the most common practice in Bangladesh. Sun dryng includes spreading of wet paddy over the hard, leveled and mud plastered dry floor with a thickness of 10 to 15 mm. The grain is usually stirred by foot. The thickness is irregular over the drying floor due to ridges formed during stirring. During the rainy season, sun drying on ground yard is not possible. Generally, sun drying on road, roof and elevated ground is done. Much of the losses are due to birds and scattering. Drying losses are high in the rainy season. Mechanical drying can reduce losses as well as human drudgery. Miah et al. (1987) showed that artificial drying below 52°C does not affect the germination of paddy.

The separation of chaffs and unfilled grain from the threshed paddy is done by women in traditional methods. Only light weight foreign materials are separated. There is no system for separating heavy materials like stone, broken metal, etc. which may damage the machinery during milling.

Parboiling

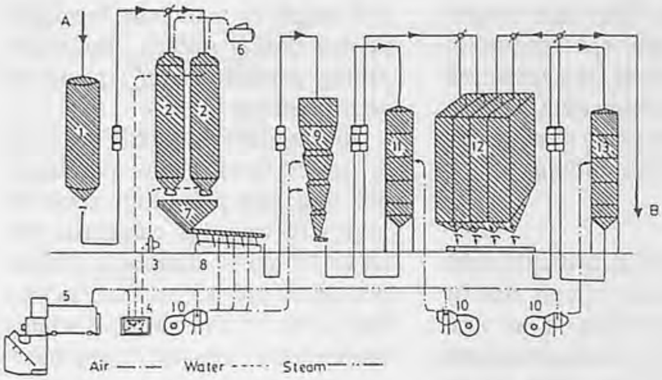
Parboiling is a hydrothermal process applied to rough rice or paddy. Raghavendra Rao and Juliano (1970) stated that the most notable change that occurs during parboiling is the gelatinization of starch and the disintegration of protein bodies in the endosperm. As a result, the starch and protein expand and fill the internal air spaces. Both fissures and cracks present in the endosperm are sealed, making the grain translucent and hard and tough enough to withstand milling stresses, which increases the yield of edible rice. They also cited that less protein and starch are lost from parboiled rice into the cooking water. Mattews et al. (1982) stated that parboiling can reduce breakage in milling to essentially zero percent. Parboiling of paddy is done in three steps: soaking or steeping, steaming and drying.

In the soaking process, the void in the hull and rice kernel are filled with water and the grain swell, which causes an increase in the volume of the grains. During steaming, soaked paddy is exposed to steam heat treatment for 15-20 min and the starch present in the rice kernel is gelatinized. Subsequently, the paddy is dried again to 18% moisture content. Bhattacharya and Indudharaswamy (1967) showed that the cracks and fissures begin to appear when the moisture content falls below 18%. To prevent this, the drying process is stopped for a while called 'tempering' and resumed using appropriate temperature and drying time. Ramo Rao and Bal (1973) reported that the drying of parboiled paddy should be done in two stages to avoid the breakage of rice during milling. Improper drying conditions may result in high breakage.

In Bangladesh, paddy is usually soaked in clay pot, aluminum pot, large clay pot, drum, concrete tank with variable capacities for 24 to 48 hours. Soaked paddy is placed in the pot in such a way that 20% of the paddy remains under water. The pot is then heated inthe oven, fired by wood or straw. The hot water boils the paddy at the bottom and steam parboil the rest. Usually 25 to 30 min is required to complete the steaming process. In this system, a portion of paddy is under boiled another portion is cooked (over boiled). As a result, a heterogeneouos mixture of parboiled paddy is produced causing high breakage in milling. In some areas, farmers also practice double parboiling to reduce soaking time and increase hardness of grain. In some rice mills, parboiling is done by steaming. A modern parboiling plant's flow diagram is shown in **Fig. 3**, where steam and pressure parboiling system is practiced. This system will save time and energy and produce uniform parboiled paddy, which will, in turn, reduce breakage during milling and improve nutritional and eating quality of rice.

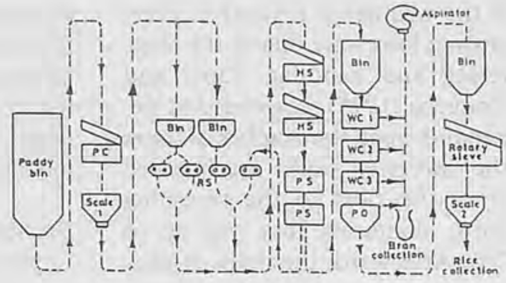
Milling

Milling includes the operations of hulling, whitening and polishing. Hulling is to remove the husk from the paddy grain with a minimum of damage to the bran layer and if possible without breaking the brown layer of the grain. In the processes of whitening, the skins stick and the bran layers of the brown rice are removed. In the process of polishing the whitened rice, the bran particles still sticking to the surface of the rice is



A. Raw paddy
B. Parboiled paddy
1. Feeding bin
2. Parboiling pressure tanks
3. Preheated water pump
4. Water heater
5. Steam boiler
6. Air compressor
7. Hopper
8. Vibratory conveyor
9. Predryer
10. Air heater and blower
11. Column dryer
12. Tempering bins
13. Column dryer

Fig. 3 Flow diagram of a modern rice parboiling system.



PC – Paddy cleaner
RS – Rubber roller
HS – Husk separator
PS – Paddy separator
WC – Whitening cone
PO – Polishing cone

Fig. 4 Flow diagram of a modern rice mill.

slightly polished to give it a shinier appearance.

Traditional *dheki* and Engelberg huller rice mills are the main devices for milling paddy in Bangladesh. The *dheki* was the popular milling device before the introduction of huller in the villages. High capacity and low cost of milling compared to *dheki* makes the huller more popular to the farmers. About 80% paddy is milled by the huller. Some quantity of paddy is milled in *dheki* for cake preparation at home. The *dheki* milled rice is always less polished and has low proportion of breakage than huller milled rice. In huller rice mills, hulling and polishing is done at the same time and as a result husk and bran mix together and break the rice kernels. The milled rice, bran, husk mixture is separated manually. In some mills simple cleaner is used for separation.

The milling losses were very high due to over polishing, processing machinery, pre-milling treatments and unskilled operator. Araullo et al. (1976) reported that the milling recovery of rice is 63%, 67% and 70% from Engelberg, disc huller and rubber-roll huller rice mills, respectively. Maramba (1953) observed that a rubber-roll huller combined with an Engelberg huller which is used as a whitener, gave a low milling recovery but higher than the Engelberg alone. In a separate study using the same machine combination, Obungen et al. (1960) found that one % of grain was broken in the rubber-roll huller while 14% was broken in the Engelberg machine. Wimberly (1972) reported that modern mills using rubber-roll hullers combined with abrasive and friction whiteners gave an average over-all increase in total rice recovery of 2.5% over a disc-huller and 6.6% over the Engelberg huller. But for reducing the rice milling losses, the adoption of rubber roll huller with polisher in the rural area and modern automatic rice mills in the commercial areas are essential. The flow diagram of a modern automatic rice mill is shown in **Fig. 4**. This type of mills can produce uniform quality of polished rice.

Storage

Much of the paddy seed is being preserved by rural women from harvest until the next sowing season. They store seeds in sealed containers, sacks, locally made *motka*, *gola*, *dole*, *khuti*, and even on floors of their houses. Mandal et al. (1984) reported from a storage study at Mymenshingh that the average loss for government goodown was 1.5% and that for farm level structures was 2.8% for a period of 4 months.

The principal agents of seeds deterioration in storage are fungi and insects and their development is influenced by the temperature and humidity. The limiting relative humidity is 65% and the corresponding equilibrium moisture content is 13% (wet basis) for paddy. Women usually use dry neem leaf, tobacco dust, etc. to prevent the onset of insects in the store. If insects get in, they can be controlled by redrying and cleaning the paddy. If needed, insecticide like Sevin dust or Phosphine can be applied.

Women's Participation in Farm Operations

The gender division of labour in Bangladesh agriculture is rigidly demarcated; women are responsible for most agricultural works within the farmyard but rarely undertake field or market work. Traditionally, their major economic contribution to agricultural output is in rice processing. Halim and McCarthy (1983) indicated that 55% of the rural women in Bangladesh spend about

50% (5-6h/day) of their time in rice processing activities. Ahmed (1983) showed that labour for post-harvest processing by traditional methods represents 30-33% of the total labour requirement for rice and women provided 86% of this. Abdullah (1983) reported that even when a farmer intends to sow seed in his field, his wife determines the quality of seeds to be sown by a germination test. Hye (1984) reported that the tribal women are responsible for a major share of field crop cultural activities as well as post-harvest and domestic work. Boserup (1970) made two important points with respect to its impact upon women: male rather than female tasks get modernized first, and when female tasks do get modernized, they are likely to be taken over by men. The above statement indicates that women are victims rather than beneficiaries of economic change.

Rural women in Bangladesh are an integral part of rice processing event. In addition to taking care of their children, preparing and serving food for other members of the family, rural women are accomplishing many agricultural and non-agricultural activities daily. This includes processing of crops, caring for livestock, producing vegetables and fruits in the kitchen garden, maintaining and repairing of house and household equipment, collecting and preparing cowdung and other fuels, fetching water, etc. In other words, without their participation a farmer cannot think of completing the daily household jobs, including rice processing. The gender involvement in different post-harvest operations are shown in **Table 1**. Usually harvesting and transportion/carrying are performed by male and 85% of the post-harvest activities are done by women. The women play key roles to prepare the courtyard with a fresh layer of mud and cowdung; supervising the threshing of paddy by bullocks, drying the straw for cattle feed; winnowing and sieving paddy several times; parboiling and usually soaking, drying, husking, supervision of storage and periodic redrying.

Table 1. Comparative Share in Rice Post-harvest Chores by Gender

Operation	Chore	Gender involved	Involvement of women (%)
Harvesting and handling	Cutting	male	—
	Bundling	male	—
	Handling	male	—
	Carrying	male	—
	Stacking in		
	field	male	—
	yard	female/male	60
Threshing	Beating	female/male	70
	Foot treading	female/male	80
	Animal treading	male/female	30
	Pedal thresher	male/female	10
Cleaning	Traditional	female	100
	Manual winnower	male/female	5
Drying	Sun drying on road/pavement	female/male	90
	Yard	female	100
Storage	Domestic	female	100
	Market	male/female	20
Parboiling	Conventional	female	100
	Improved	male/female	50
Milling	Traditional	female	100
	Huller mills	male/female	40
Separation and grading	Traditional	female	100
	Winnower	male/female	40

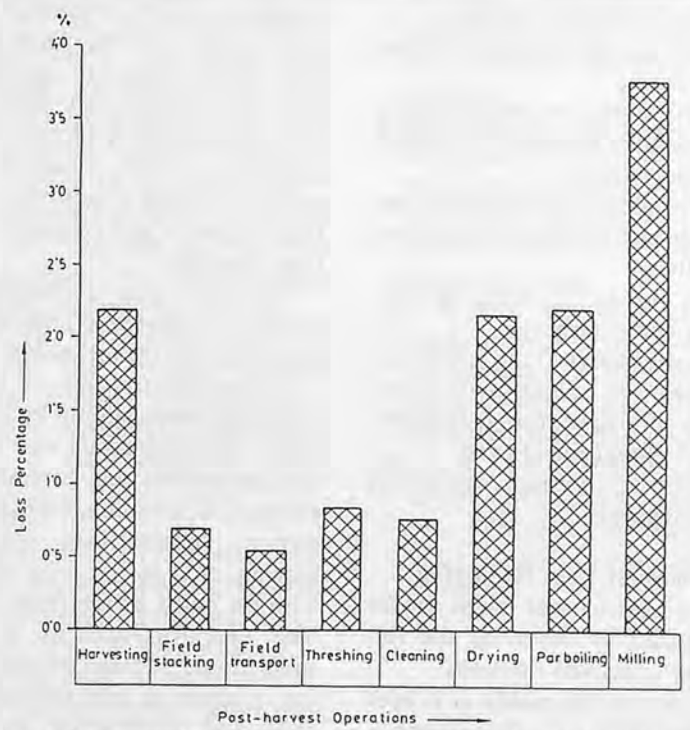


Fig. 5 Comparative percentage of losses, by Chore post harvest operations.

Rice Post-harvest Losses

The total paddy losses from harvest to milling are shown in **Fig. 5**. The parboiling, drying and milling losses were very high at 2.16%, 2.22% and 2.78%, respectively (FAO/BRRI 1985). The drying loss was due to domestic animals and birds eating and scattering. Farmers believe that the grain eaten by domestic animals are not considered losses because they gain benefit indirectly from them. The parboiling loss was due to over- or partly-parboiling, incomplete soaking and drying. The milling loss was due to over polishing and high quantities of brokens.

Causes of Losses

The following are the main causes of rice losses in post-harvest operations:

- Delayed harvesting;
- Delayed threshing;
- Traditional threshing practices;
- Lack of mechanical thresher;
- Heavy rainfall during Boro and Aus harvesting seasons;
- Lack of mechanical drying facilities;
- Over-boiling or under-boiling instead of steaming the paddy in parboiling;
- Both hulling and polishing are done by a single inefficient steel huller;
- High broken percentage in hulling and polishing;
- Over-polishing of the milled rice (degree of milling is 10-15%);
- Lack of proper storage facilities and management; and
- Lack of proper technical knowledge.

Post-harvest Loss Reduction

The post-harvest losses can be minimized by observing the following improved methods:

- To harvest the paddy at proper time (80% of grains ripen);
- To thresh the paddy by pedal or mechanical thresher;
- To dry clean paddy in steps drying (tempering) system;
- To use improved parboiling equipment for steaming paddy;
- To practice two-stage milling system by modern huller and polisher;
- To use less polished rice for cooking and eating;
- To put a coating inside the traditional storage structures (*motka*, *dole*, *gola*, etc.);
- To use preventives (dry neem leaf, tobacco dust, etc.) in stored grains;
- To dry and clean the stored paddy/rice when needed;
- To apply proper insecticide (like Sevin dust, phosphine, malathine, etc.) when needed.

Improvement in Post-harvest Activities

In order to minimize the rice post-harvest losses the government should give more emphasis on proper farm planning, execution and efficient marketing system. The price of polished rice in the market is higher compared to the paddy price. On the other hand, the middle men are exploiting both the farmers and ultimately the consumers. Therefore, the marketing system should be organized in such a way that both the producers and consumers get their benefits.

The following recommendations are suggested to improve the rice post-harvest technology:

Technology transfer — A special programme should be undertaken to demonstrate and adopt the appropriate post-harvest technology (like cleaning, drying, tempering, parboiling, milling, storing, etc.) to the rural women who do much of the farm work. The operators/workers of rice mills should undergo proper training in order to gain the required skill and knowledge for rice processing.

Marketing system — In order to supply fair, uniform quality of polished rice in the market, rice bags should be leveled by the rice millers for identification of necessary information. The government should allot short term loan at low interest rate to rice millers for paddy procurement only from the farmers during harvest season.

Action programme — Harvesting the paddy crop at about 80% ripe should reduce shuttering and handling losses. Popularization of pedal thresher for threshing paddy should be undertaken. Installation of rubber-roll huller for hulling paddy to the existing custom rice mills and polishing by the existing machinery. Steam treatment parboiling should be practised in the rice mill, in order to guard against over/under boiled paddy. Installation of mechanical dryer to those rice mills where only sun drying is practised to save the paddy in the rainy season. Two stage drying, i.e., tempering between initial and final drying should be practiced to minimize breakage during milling. The degree of milling should be restricted to within 6-8% for maximum milling recovery.

REFERENCES

Abdullah, T. 1983. Women in rice farming system in Bangladesh and how technology programme reach them. Women in rice farming, IRRI. Los Banos, Philippines. pp 209-219.

Ahmed, J.U. 1983. Labor use patterns and mechanization of rice post-harvest processing in Bangladesh. In consequences of Small-Farm Mechanization, IRRI, Los Banos, Philippines.

Araullo, E.V.; D.B. De Padua and M. Graham. 1976. Rice post-harvest technology, IDRC, Ottawa, Canada,: 294-295.

Bala, B.K. 1978. Post-harvest losses of paddy in Bangladesh. Agricultural Mechanization of Asia, Africa and Latin America. Tokyo, Japan. 9(4): 54-56.

BBS. 1992. Statistical year book of Bangladesh. Bangladesh Buro of Statistics, Share-Bangla Nagar, Dhaka, Bangladesh.

Bhattacharya; K.R. and Y.M. Indudharaswamy. 1967. Condition of parboiling paddy for optimum milling quality. Cereal Chemistry J. India. 44(6): 492-600.

BRRI/FAO. 1985. Study on farm and village level post-harvest rice loss assessment in Bangladesh, Field document No. 8, BRRI, Gazipur, Bangladesh.

Boserup, Ester. 1970. Women's role in economic Development, New York, St. Martin Press.

Choudhury,, N.H. 1984. Rice post-harvest practices in Bangladesh. Proceeding of the FAO/UNDP regional Workshop on Rice post-harvest technology, RAS/81/086, Cabanatuan City and Santiago, Isabela, Philippines.: 244-246.

Duff, B. and Z. Toquero. 1975. Factors affecting the efficiency of mechanization in farm level post-production systems. Paper No. 75-04 Agric. Eng. Dept. IRRI. Los Banos, Philippines.

Gaiser, D. 1981. A brief summary of paddy loss in Indonesian rice post-harvest system, Proceedings of the 4th Annual Workshop on Grain Post-harvest Technology, South-east Asia cooperative post-harvest research and development programme, SEARCA College, Laguna, Philippines.: 33-48.

Greeley, M. 1981. Farm level rice processing in Bangladesh: Food loss, technical change and the implications for future research. Proceeding of the 4th Annual Workshop on Grain Post-harvest Technology, South-east Asia cooperative post-harvest research and development programme, SEARCA college, Laguna, Philippines.: 33-48.

Greeley, M. and S. Rahman. 1980. Wet season post-harvest food losses. Paper presented at the post-production workshop on food grain. Food science and technology division, BCSIR. Dhaka, Bangladesh

Halim, A. and F. McCarthy. 1983. Women labors in rice producing villages in Bangladesh. Women in rice farming, IRRI. Los Banos, Philippines.: 247-248.

Hye, H.A. 1984. Mechanization in agriculture and women in Bangladesh. Unpublished paper, Bangladesh Academy for Rural Development, Comilla, Bangladesh.

Kumar, K.C.G. 1984. Paddy post-harvest loss assessment study in Nepal. Proceeding of the FAO/UNDP Regional Workshop on rice post-harvest technology, RAS/81/086, Cabanatuan and Santiago, Philippines.: 253-255.

Lee, N.W. 1984. Korean experience in post-harvest technology (paddy). Proceeding of the FAO/UNDP Regional Workshop on rice post-harvest technology, RAS/81/086, Cabanatuan City and Santiago, Isabela, Philippines.: 259-262.

Mandal, G., J.N. Samajpati and M.A. Rashid, 1984. Studies on grain storage structure in Mymenshingh district. Agricultural Mechanization of Asia, Africa and Latin America J. Tokyo, Japan. 15(4): 50-54.

Maramba, F.D., 1953. Rice mill recoveries, Philippines Agricultural Engineering J. Philippines. 4: 2-3.

Mattews, J., J.I. Wordsworth and J.J. Spadaro. 1982. Characteristics of the thin rice kernels before and after parboiling. Transaction of ASAE. 25(3): 818-819.

Miah, M.A.K.; M.A. Quasem and K.A. Haq. 1987. A comparative study on the effects of four drying methods on germination of paddy. Agricultural Mechanization of Asia, Africa and Latin America. 18(2): 74-76.

Obungen, S.S.; A.B. Catambay and D.B. de Padua. 1960. A study on the operation and performance of the Japanese made rubber-roll huller rice mill. B S Thesis, UPLB, Los Banos, Philippines.

Padua, D.B. De. 1978. Post-harvest food losses in developing countries. National Academy of Science, Washington D.C. USA.: 38.

Raghavendra Rao, S.N. and O.B. Juliano. 1970. Effect of parboiling on some comparative milling properties of raw and parboiled rice. J. Food sci. Technology 4(4): 150-155.

Rama Rao, V.V. and S. Bal. 1973. Design and lay out of a modern parboiling and drying plant. Rice Processing Engineering Center, Indian Institute of Technology, Kharagpur, India.

Ruiz, E. 1965. Harvesting losses of paddy grain of BPI-121 low land rice varieties at different levels of moisture content, Central Luzon State University, Sci. J. 1(2).

Wimberly, J.E. 1972. Review of storage and processing of rice in Asia, Mimeographed paper No. 72-01, IRRI, Los Banos, Philippines. ■■

An Approach to Developing a Peanut Sheller

by
I. Deniz Akcali
Department of Mechanical Engineering
Cukurova University
01330 Balcali
Adana-Turkey

Abstract

A set-up comprising of a conical auger and a surrounding conical grate to shell peanuts has been designed based on a mathematical model associating physico-mechanical properties of peanut with the design parameters and by the use of an algorithm resulting therefrom. At the end of experiments performed on a manufactured model, a capacity of approximately 80 kg/h and an efficiency of 86% kernel without breakage have been obtained.

Introduction

Peanut is an important crop with economic potential. It has basically kernel and hull which can be evaluated on an economic basis. Its kernel is a valuable food resource, containing 25% protein and 50% fat[1]. Its hull can be utilized as printing and insulation material as well as in the production of plywood, fuel, animal feeding stuff and fertilizers[2].

In order that the economic value of raw peanut multiplied, it is necessary that it be processed. This is evidenced by a review of peanut world trade figures[3]. For instance, 90% of all the peanut imported by the EC countries is in the form of kernel.

Acknowledgement: This work was supported by the Turkish Science and Research Council (TUBITAK, Ankara) under grant No. TOAG-580.

A major step in the processing of peanut is shelling. Without shelling, it is impossible to make use of its kernel and hull in other further technological processes such as in oil extraction or in hull briquetting.

Several methods of shelling and the associated machinery are reported in the literature[4-10]. Neverthelsss, within accessible publications, it appears that design and operation of such machinery are based upon an empirical approach.

Here in this work, an attempt is made to handle the shelling of peanut on quantitative grounds so that the design of shelling machinery can be derived from a mathematical model combining physico-mechanical properties of peanut with the machine characteristics.

Materials and Methods

Consistent with the quantitative approach chosen, the shelling properties have been thoroughly investigated. Peanut material used in this process has been of those species, the so-called Anamur, Antalya, Osmaniye, Silifke types, mentioned in the Turkish Standards No. 310 (TS-310)[11]. Moisture content is about 5%.

Behaviour Under Static Loading

One way of peanut shelling is to apply compressive forces in certain directions. Two cases have been distinguished here, single and bulk loading.

Single Behaviour

First the loading directions have been defined. The mid-fiber joining the two halves of the hull has been accepted to describe the reference plane. Thus the axes of an orthogonal system coincident with the long axis of the peanut on the reference plane have been selected as the loading directions.

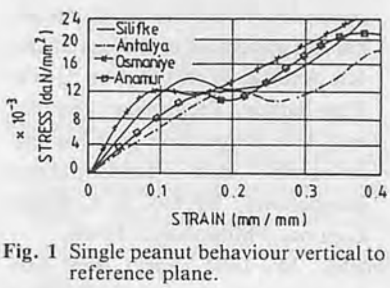


Fig. 1 Single peanut behaviour vertical to reference plane.

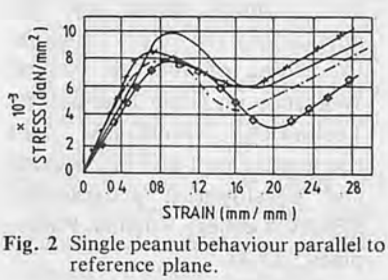


Fig. 2 Single peanut behaviour parallel to reference plane.

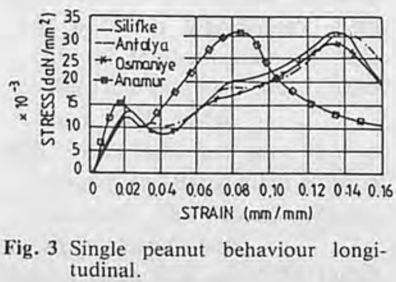


Fig. 3 Single peanut behaviour longitudinal.

Table 1. Mean Stiffness Coefficients of Hulled Peanut

Variety	Stiffness Coefficient, k (daN/mm) Vert. to Ref. Plane	Parallel to Ref. Plane	Longitudinal
Anamur	2.92	3.18	5.83
Antalya	2.56	4.15	7.50
Osmaniye	4.06	3.45	5.50
Silifke	3.50	3.88	3.17

After measuring the length, diameter, mass and cross-sectional areas, 15 mid-sized[12] peanuts of each species have been loaded in defined directions by means of a free compression soil-test apparatus until they have collapsed. Meanwhile applied forces (F) as well as the resulting deformations (δ) have been recorded. Loading speed has been kept constant during all the experiments.

Of the recorded data, two things need to be noted here, regarding the behaviour of peanut. One of them is the set of stress-strain curves reflecting typical single behaviour as shown in **Figs. 1** to **3**. The other is stiffness coefficient along certain directions, calculated from linear domain of load-deformation curves, **Table 1**.

Bulk Behaviour

If the peanuts are to be shelled via pressure on a lot, then a rational approach requires that its bulk behaviour be known. Observations on preliminary testing have shown that too many variables are involved in this process. Therefore, it has been decided to perform the experiments under carefully controlled conditions.

Mid-sized peanuts of TS-310 types were placed inside an iron cylinder of 90 mm diameter and 70 mm height, fitted with a wooden piston, forming one, two and three homogeneous layers. Then these layers of peanuts, each at one time, have been subjected to compression in a universal 20-t test machine under constant loading speed. After having a record of applied pressure forces (F) versus corresponding deformations (δh), these data were transformed

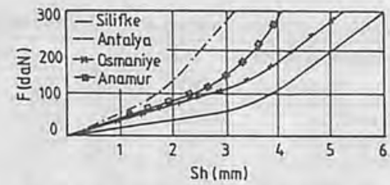


Fig. 4 One layer of bulk peanut behaviour.

into polynomials of fifth degree using least-squares technique. The curves thus found are exhibited in **Figs. 4** to **6**.

What is observed commonly in curves, **Figs. 4** to **6**, is that in the beginning and at ends of loading there appears to be linear behaviours, whereas in between there is a non-linear behaviour. It can be said that hulls begin to deform in the linear region and break in the non-linear region and then kernels start deforming in the final linear region.

Now that the area of cylinder cross-section (A), initial height (h_0), mass (m), items of layer together with forces (F) and deformations (δh) have been measured, applied pressure ($P = F/A$), strain ($\epsilon = \delta h/h_0$), volume ($V = A\ h$), density ($\varrho = m/V$) have been calculated. By entering all these data into a computer program written in accordance with the least-squares method, F-δh, P-V, P-ϱ, P-ϵ relationships have been expressed in the following linear form, valid only for the region up to start of shelling:

$$y = a_0 + a_1 x \qquad (1)$$

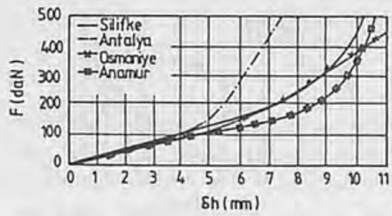


Fig. 5 Two layers of bulk peanut behaviour.

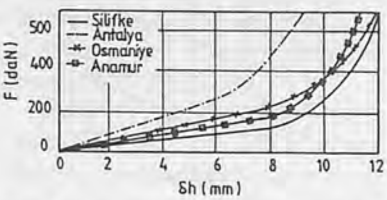


Fig. 6 Three layers of bulk peanut behaviour.

Relevant a_0, a_1 coefficients were collected in **Table 2**.

Departing from the observations on bulk behaviour, one, two and three layers of peanut have been loaded in the non-linear region in order to study the shelling effects of pressure. Upon visually examining the peanuts one by one, the numbers of peanuts with hulls broken, not broken and kernels damaged, have been determined. Shelling percentage (KY) has been defined as the ratio of numbers of broken and total peanuts times one hundred. Damaged percentage (ZY) is the number of damaged kernels multiplied by 100 and divided by the total number of kernels. By calculating the average values over TS-310 types, curves signifying KY and ZY against pressure are

Table 2. Coefficients of Eq'n (1) for F-δh, P-ϵ, P-ϱ Relationships

Variety	Layer No.	F-δh daN-mm		P-ε daN/mm² -mm/mm		P-V daN/mm² -mm³		P-m/V daN/mm² -kg/mm³	
		a_0	a_1	a_0	a_1	a_0	$a_1 \times 10^{-7}$	a_0	$a_1 \times 10^{-7}$
Anamur	1	−2.20	44.60	−0.035	0.216	0.126	−1.10	−0.111	7.30
	2	0.00	20.23	0.000	0.114	0.115	−5.00	−0.098	5.80
	3	2.40	10.10	0.037	0.080	0.076	2.50	−0.060	3.10
Antalya	1	0.00	54.97	0.000	0.159	0.160	−1.35	−0.147	8.60
	2	0.00	33.23	0.000	0.162	0.162	−8.21	−0.149	6.43
	3	−1.00	47.14	−0.080	0.170	0.310	−1.16	−0.280	1.16
Osmaniye	1	2.60	36.50	0.041	0.103	0.104	−9.01	−0.085	4.45
	2	1.58	26.00	0.024	0.126	0.127	−6.42	−0.101	4.70
	3	0.20	23.70	0.098	0.156	0.157	−5.80	−0.114	5.50
Silifke	1	−2.08	20.24	−0.004	0.102	0.047	−5.00	−0.038	1.87
	2	−1.10	20.56	−0.000	0.113	0.112	−5.08	−0.080	4.31
	3	−0.53	17.51	−0.000	0.123	0.124	−4.32	−0.089	4.45

Movable-motionless Surface	Anamur SDD[1]	Anamur SDP[2]	Antalya SDD	Antalya SDP	Osmaniye SDD	Osmaniye SDP	Silifke SDD	Silifke SDP
Iron-iron	0.0325	0.0325	0.0350	0.0375	0.0500	0.0450	0.0460	0.0400
Wood-iron	0.0425	0.0365	0.0374	0.0350	0.0425	0.0425	0.0425	0.0400
Rubber-iron	0.0430	0.0430	0.0370	0.0400	0.0550	0.0570	0.0545	0.0580
Iron-grate (cp)[3]	0.0300	0.0380	0.0450	0.0450	0.0500	0.0480	0.0630	0.0600
Iron-grate (cd)[4]	0.0370	0.0370	0.0420	0.0550	0.0530	0.0370	0.0430	0.0430
Rubber-grate (cp)	0.0440	0.0420	0.0500	0.0480	0.0500	0.0550	0.0670	0.0650
Rubber-grate (cd)	0.0380	0.0420	0.0440	0.0430	0.0450	0.0440	0.0450	0.0580
Wood-grate (cp)	0.0430	0.0380	0.0450	0.0440	0.0540	0.0520	0.0530	0.0600
Wood-grate (cd)	0.0430	0.0480	0.0440	0.0540	0.0440	0.0430	0.0430	0.0420

Table 3. Peanut Shelling Pressure for Several Surface Pairs (p, daN/mm²)

[1] SDD: Vertical to ref. plane [2] SDP: Parallel to ref. plane
[3] (cp): Parallel to bars [4] (cd): Vertical to bars

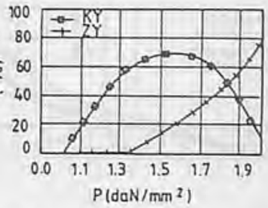


Fig. 7 Shelling effects of pressure for 1-layer peanut.

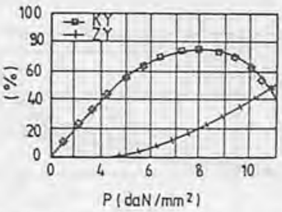


Fig. 8 Shelling effects of pressure for 2-layer peanut.

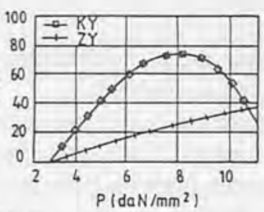


Fig. 9 Shelling effects of pressure for 3-layer peanut.

drawn in **Figs. 7** to **9**.

Shelling pressure (P_k) is then defined to be that pressure where damaged percentage starts assuming a non-zero value. From the curves of **Figs. 7** to **9**, P_k's for different number of layers have been found as such:

1-layer : P_k = 0.0103 daN/mm², KY = 3.33%, ZY = 0.00%

2-layer : P_k = 0.0230 daN/mm², KY = 7.03%, ZY = 0.00%

3-layer : P_k = 0.0284 daN/mm², KY = 4.45%, ZY = 0.00%

Impact Strength of Peanut

Review of literature indicates that the impact may be another method of shelling, as has been applied for pistachio nuts[13], and for sunflower seeds[14]. Thus investigation of the resistance of peanuts to sudden loads was undertaken.

Slay[15] and Turner[16] have worked on the impact properties of peanut from the viewpoint of transportation. Therefore, for the purpose of shelling, another road has been taken. Here the problem of exerting sudden forces has been solved through a design of an apparatus whereby masses of known weights are dropped onto resting peanuts from certain heights. Movable impact surfaces have been selected out of wood, rubber and iron materials while the surfaces on which peanut rests are made of iron material and grate formed by rectangular beams of 10 × 10 mm cross-section with 10 mm spacing in between. After performing experiments with mid-sized peanut material of the 4 TS-310 types having measured dimensions and projected areas in three directions, experimental data were evaluated as to whether kernels are damaged or whether they can be taken out of the hull or not.

In computing the pressure (p) effective at impact, the following formula[17-18] was implemented:

$$P = \frac{W(1 + 2hk/w)^{1/2}}{A} \qquad (2)$$

Here, w and h are drop weight and height, respectively; k and A are stiffness coefficients and projected areas in defined directions, respectively.

In evaluating the collected data, the curves involving shelling and damaged percentage versus pressure were drawn, similar to **Figs. 7** to **9**. Then the pressure yielding maximum shelling percentage was determined for each peanut type and material pair (**Table 3**).

From the impact tests, in the longitudinal direction, the effective shelling pressure was seen to vary between 0.12 and 0.14 daN/mm², very large values as compared to those for the other two directions.

With regard to the results, it has been found that the impact medium that caused least damage to the kernel while maintaining a large shelling percentage should include grate.

Fatigue Strength of Peanut

Analysis of the existing shelling machinery, such as that[9], reveals that fatigue behaviour of peanut may form another basis for shelling peanut. In general, fatigue results when a point of a material is subjected to variable stress[18]. Here, collapse of the peanut hull has been investigated under isolated fatigue conditions.

First, an experimental set-up, whereby controllable pressure can be applied while peanut sample is rolled between a surface movable with constant velocity and another surface at rest, was developed. Then mid-sized peanut samples of each TS-310 type, with measured diameter, length, mass and projected areas were prepared. Pressure applying surfaces, movable and motionless, were chosen as sheet iron, iron grate, wood, rubber and wire screen. The approximate shelling pressure, determined through preliminary tests, were exerted on samples until collapse and the corresponding number of revolutions of the drive-arm was recorded.

The relation between the dynamic shelling pressure,

Table 4. Coefficients of Linear Peanut Fatique Model

Surface Pairs	Anamur		Antalya		Osmaniye		Silifke	
	b_0	b_1	b_0	b_1	b_0	b_1	b_0	b_1
Wood-wood	6.998	−0.0179	6.769	−0.0040	7.543	−0.0776	6.066	−0.0134
Iron-grate (cd)-Iron-grate (cd)	5.931	−0.0075	6.016	−0.2834	5.943	−0.2068	5.577	−0.1726
Rubber-rubber	10.350	−0.0035	9.646	−0.0051	10.430	−0.0078	9.990	−0.0138
Wire screen-Wire screen	4.967	−0.0028	5.123	−0.0064	4.920	−0.0135	5.062	−0.0053
Wire screen-Iron grate (cd)	4.579	−0.6151	3.736	−0.0279	3.717	−0.0515	3.725	−0.2021
Iron grate (cd)-rubber	4.362	−0.0177	4.172	−0.0127	5.570	−0.0305	4.490	−0.0319
Iron grate (cp)-Iron grate (cp)	4.316	−0.0034	4.170	−0.0070	4.643	−0.0071	4.998	−0.0306
Iron grate (cp)-Wire screen	4.970	−0.0436	5.360	−0.0490	5.000	−0.0185	4.410	−0.0137
Galvanized sheet-Galvanized sheet	7.935	−0.0083	—	—	11.360	−0.4972	7.305	−0.0180
Sheet iron-Sheet iron	8.498	−0.615	6.707	−0.0177	—	—	6.444	−0.0016

($P, N/cm^2$) and equivalent load cycle (N) was searched for each surface pair, taking into consideration the linear and logarithmic models expressed as follows:

$$P = b_0 + b_1 N \qquad (3)$$

$$\log P = b_0 + b_1 \log N \qquad (4)$$

From the experimental data, b_0, b_1 were calculated through the least-squares technique for both models. Coefficients b_0, b_1 pertaining to the linear model are shown in **Table 4**.

The results indicate that as the pressure is increased, the number of load cycles required for shelling decreases. Then it is deduced that the pressure assumes its largest value when the load cycle is zero. For this reason, the linear model is conveniently used to estimate the maximum shelling pressure although the logarithmic model has been found to reflect the peanut fatigue behaviour more closely.

With regard to the medium causing fatigue, it has been observed that all mentioned materials except rubber are suitable and that the most convenient surface requiring the least pressure for shelling is iron grate.

Peanut Sheller

Proposed System

The system that is to apply shelling pressures on bulk peanuts through compression, impact and fatigue is essentially made up of a conical auger and a surrounding grate. As the auger rotates with constant speed inside the grate, it will exert controlled pressures along the rotation axis. This will then cause the shelling of peanuts and thus the resulting mixture of hulls and kernels will drop from the openings of grate.

Analysis and Design

What has been done in the analysis of the system at first, is the derivation of the pressure distribution along the axis of the cone. To this end, equilibrium equations were written and solved for an infinitesimal cone element assuming that control volume is homogeneously filled with bulk peanut, that pressure gradient perpendicular to cone axis is negligible, that peanuts move with constant velocity in the axial direction and that weight of the peanuts is neglected. This has finally led to an equation which relates pressure at ith point P_{zi} to that at (i + 1) st point $P_{z(i+1)}$ (See Appendix):

$$P_{z(i+1)} = A_{zi} P_{zi} / A_{z(i+1)} (4Z_{i+1}^2 \tan^2\alpha - 4Z_{i+1} \tan\alpha \; d_0 + d_0^2 + d_s^2 / 4Z_i^2 \tan^2\alpha - 4Z_i \tan\alpha \; d_0 + d_0^2 - d_s^2)^{K\frac{1+\tan\alpha}{\tan\alpha}\left(\frac{\mu+\tan\alpha}{1-\mu-\tan\alpha}\right)} \qquad (5)$$

Here, Z_{i+1}, Z_i are the axial distances of the (i + 1) st and ith points from the circular plane with largest diameter (d_0); $A_{z(i+1)}$ and A_{zi} are the areas of the cone cross-sections at (i + 1) st and ith stations, respectively; d_s is the diameter of the pipe around which sheet metal helix is wound; K is the lateral-to-axial pressure ratio; α is the half of the cone angle; μ is the coefficient of friction between peanut and iron grate.

If continuity equation is written with the assumption that shelling has occured n times at n stations and joined with the peanut pressure-density relationship, eqn (1), then this yields peanut pressure (P_z^s) expression at distance z:

$$P_z^s = a_0 + a_1 (1 - KY)^n \varrho_0 \frac{A_0}{A_z} \qquad (6)$$

Here a_0, a_1 are coefficients found in **Table 2**; ϱ_0 is the initial density of bulk peanut at the cone entrance; A_0, A_z are cone cross-sectional areas at the start and at distance z, respectively; KY is the shelled ratio at a corresponding shelling pressure.

In order that shelling take place, pressure provided on the part of the machine, given by equation (5), should be equal to that required by peanut, expressed in (6), at a suitable value. If shelling has been realized n times discretely, then after the nth station the total shelling ratio (K′) is to be estimated as follows:

$$K' = 1 - (1 - KY)^n \qquad (7)$$

Peanut flow at the machine entrance (q_0) will be the following:

$$q_0 = \varrho_0 A_0 \frac{dz}{dt} \qquad (8)$$

Velocity of peanuts along the cone axis dz/dt is related to the rotational speed (NN,rpm) and pitch (Pt) of the auger:

$$\frac{dz}{dt} = \frac{Pt}{60} NN \qquad (9)$$

The length of the cone (L) will

consist of N_c pitches:

$$L = N_c Pt \quad (10)$$

Besides, the time (t) during which peanuts may remain in the cone is calculated as such:

$$t = \frac{L}{(dz/dt)} \quad (11)$$

Finally, the largest (d_0) and the smallest (d_n) cone diameters are correlated through half of the cone angle (α) in the following manner:

$$\tan\alpha = \frac{(d_0 - d_n)}{2L} \quad (12)$$

$$d_0 = d_s + 2a, \; a = d_k J \quad (13)$$

$$d_n = d_s + 2d_i \quad (14)$$

Above d_k, d_i signify the largest hulled peanut and kernel diameters, respectively, and J is the number of peanut layers.

In a rational design, the dimensions of the conical sheller are selected under the light of parameter interaction deduced from the mathematical formulation combining machine and peanut characteristics. After investigating the effects of parameters, the following algorithm has come out as a reasonable approach to the design of the sheller:

1. Physical properties of peanut are entered. Among these, peanut dimensions, density, coefficients of friction, lateral-to-axial pressure ratio, shelling pressures, shelling percentages under certain shelling pressures, and pressure-density relationship can be noted.
2. Duration of peanut transport through the conical shelling medium (t,s) is predicted, subject to subsequent checking.
3. Cone length (L,cm) is selected.
4. Peanut transport velocity (dz/dt,cm/s) is calculated by eq'n (11).
5. Subject to checking later, auger pitch (Pt,cm) is guessed.
6. Rotational speed of the auger (NN,rpm) is found from eq'n (9).
7. Number of pitches (N_c) on the auger is computed by eq'n (10).
8. Pipe diameter (d_s) is selected out of the standard values (d_s = 4.2; 5.7; 7.6; 8.9; 12.7 cm).
9. By specifying the number of peanut layers (J), radial spacing (a) at the entrance is determined by eq'n (13).
10. The ratio of outer cone diameter at the entrance (d_0) to that of pipe (d_s) is calculated by eq'n (13). If this ratio (d_0/d_s) is not between 2 and 6, then steps are repeated from the 9th.
11. Peanut flow rate at the entrance (q_0) is determined from eqn (8).
12. Cone angle (α) is computed through eq'ns (12)-(14).
13. Using relation (6), for $n=0$ the axial distance (z) at which shelling pressure (P_k) is obtained is found with the dimensions determined and checked up until this step.
14. Machine pressure at distance z is calculated by means of eq'n (5). If this pressure is not equal to that required for shelling the peanuts, steps are repeated from the second.
15. Number n is determined through simultaneous use of eq'ns (5) and (6) for the process whereby pressure is lowered because of the drop of peanut at a shelling rate of (KY) and due to the friction from cone walls and raised again to the shelling level through cross-sectional effects.
16. Resultantly, what amount of peanuts is shelled is theoretically estimated by eq'n (7). If this amount (K') is below a desired value (say 80%), iterations are carried out starting at step No.2, until the required results is achieved.

Experimental Set-up

After implementing the design algorithm on a computer, the dimensions of the sheller are obtained as follows:

$d_0 = 23.95$ cm, $d_s = 7.6$ cm,
$d_n = 10.6$ cm, $L = 75$ cm
$N = 10$, $P_t = 7.5$ cm,
$\alpha = 5.08°$, $NN = 5$ rpm.

In addition to the design dimensons above, cylindrical parts of 4-pitch and 2-pitch lengths are added to the conical auger at the entrance and at the exit with the purposes of feeding and increasing shelling effectiveness, respectively. Besides, in order to achieve full volume and impact effects inside the conical medium, intermediary plates were inserted around the auger at every 90° interval, consistent with the theoretical assumptions. Helicoid of the auger is made up of 2.5 mm-thick sheet metal.

The surrounding grate is manufactured such that it complies with the auger dimensions and that it has 11 mm-wide openings.

The feeding unit is composed of 4-pitch cylindrical auger rotating inside a suitable bin of 2-mm sheet metal holding approximately 14 kg of peanut.

Thus the whole shelling set-up consists of a frame made up of 60 × 60 mm box beam, a feeding and shelling unit placed on it, together with a pulley-belt system driven by an electric motor (**Fig. 10**). Other than this, a gearbox is provided to change auger speeds.

Experimental Results

Shelling experiments were carried out with four different

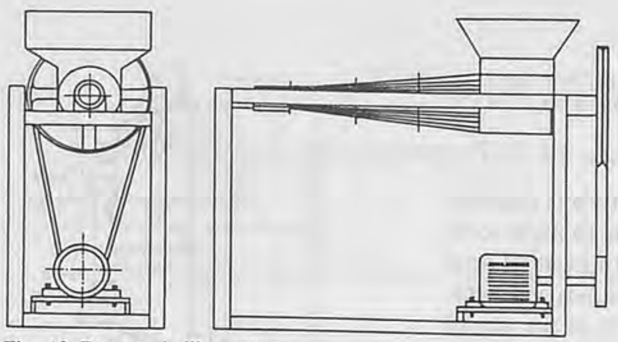


Fig. 10 Peanut shelling set-up.

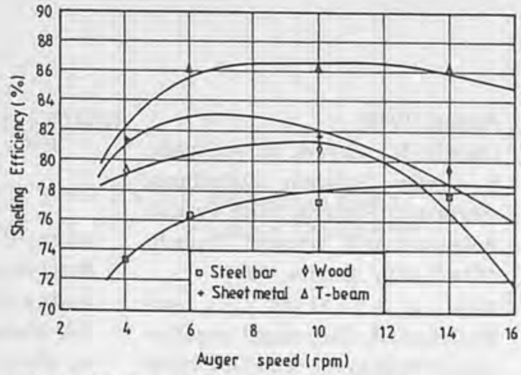


Fig. 11 Shelling efficiency vs auger speed.

grates made of sheet metal, metal bar, wood and T-beam and with four different auger speeds ranging from 4 rpm through 6 and 10 to 14 rpm, using 1 000-gr. hulled peanuts. Peanut parts coming out of the machine in the form of hull, integral kernel and broken kernel have been weighed and recorded. Since it has been observed that all of the peanuts satisfying dimensional requirements have been shelled out, it was necessary to refer to a shelling efficiency (%) which is defined as the weight of integral kernels multiplied by 100, divided by the total weight of the kernels, in order to assess the experimental data.

For each grate, experimental data were transformed into curves representing shelling efficiency versus auger speed (**Fig. 11**).

Accordingly, the best results are achieved for the arrangement involving T-beam grate, 6 rpm auger speed producing 86% shelling efficiency with a capacity of approximately 80 kg/h.

Conclusions

A quantitative approach is shown in this work leading to the development of a peanut shelling machine. The following basic steps were involved in this process:

1. Determining physico-mechanical properties of peanut;
2. Proposing a machine model fitting with the above properties and devising a mathematical model for it;
3. Setting up an algorithm based on investigations with the mathematical model;
4. Obtaining a design using the above algorithm;
5. Manufacturing the design thus obtained; and
6. Experimentally testing the machine.

As a result a machine with 86% shelling efficiency under 80 kg/h capacity was obtained in the laboratory.

REFERENCES

[1] Burns, E.E.; Huffman, V.L. Food Quality of Peanut Products, Peanut Production in Texas, January RM3, 1975, 126-131.

[2] Lilliston Implement Company, Why Grow Peanut? Georgia Commodity Commission for Peanuts, Oppenheimer International Corporation Brochures.

[3] Carley, D.H. World Production and Trade in Peanuts Edited by Woodroof J.G., Peanuts, Production, Processing and Products, 3rd. Ed., AVI Publishing, Westport, 1983, 33-41.

[4] Davidson, J.I.; Whitaker, T.B. and Dickens, J.W. Grading, Cleaning, Storage, Shelling and Marketing of Peanuts in the United States, Peanut Science and Technology edited by H.E. Pattee and C.T. Young, American Peanut Research and Education Society, Texas, 1982, 571-623.

[5] Davidson, J.I. Mechanical Cleanout Devices for Commercial-type Peanut Shellers, Summer Meeting of American Society of Agricultural Engineers, Canadian Society of Agricultural Engineers, University of Manitoba, Winnipeg, Canada, June, 1979, 24-27.

[6] Kadayifci, S. ve Uslu, M. Yerfistigi Hasat ve Harman Makinalari, (Peanut Harvesting and Threshing Machinery) TZDK Mesleki Yayinlari, (Turkish Institute of Agricultural Supplies, Professional Publications), Ankara 1981.

[7] Incekara, F.; Mutaf, E.; Emiroglu, S.H.; Onal, I.; Oktay, E.; Ogutcu, Z., Ege Bolgesinde Yerfistigi Tariminin Mekanizasyonu ve en Uygun Toprak ve Cesitlerinin Saptanmasi, (Determinationof the most suitable soil and type in peanut Mechanization in the Aegean Region), Turkish Research and Science Council, TOAG-329, Izmir, 1980.

[8] Person, N.K. Grading Procedures, Peanut Production in Texas, January RM3, 1975, 96-104.

[9] Singh, G and Thongsawatwong, P. Evaluation and Modification of two Peanut Shellers, Agricultural Mechanization in Asia, Africa and Latin America, 1983, 14(3), 33-40.

[10] Woodroof, J.G. Peanuts: Production, Processing, Products, 2nd. Ed., AVI Publishing, Westport, 1973.

[11] Turk Standartlari Enstitusu (Turkish Institute of Standards), Peanut, TS-310, 1972.

[12] Akcali, I.D. Yerfistiginin Siniflandirilmasi ve Ic Fistigin Cikarilmasi, (Grading and Decortication of Peanut), Turkish Research and Science Council, TOAG-580,

Adana, 1989.
13 Ozcelik, E.; Akyurt, M. ve Sipahi, S. Antep fistiginin Citlatilmasi (Shelling of Pistachio Nut), Turkish Research and Science Council, TOAG-229, Ankara, 1977.
14 Nag. K.N.; Singh, P. and Bhandani, R. Centrifugal Impeller-type of Sunflower Seed Decortication, Agricultural Mechanization in Asia and Latin America, 14, (1), 1983, 55-58.
15 Slay, W.O. Damage to Peanuts from Free Fall Impact, Agricultural Research Service ARS-S-123, United States Department of Agriculture, 1-12 June, 1976.
16 Turner, W.K.; Suggs, C.W. and Dickens, J.W. Damage to Peanuts and its Effects on Germination, Seedling Development and Milling Quality, Transactions of American Society of Agricultural Engineers, 1967, 248-251.
17 Popov, E.P. Mechanics of Materials, Prentice-Hall, Englewood Cliffs, 1952.
18 Shigley, J.E. Mechanical Engineering Design, McGraw-Hill, New York, 1963.

Appendix

Derivation of Equation (5):

In **Fig. 12**, the free-body diagram of an infinitesimal element of the conical sheller is drawn with primary pressure and frictional forces acting upon it. Assuming that the control volume is homogeneously filled with bulk peanut, that pressure gradient perpendicular to the cone axis as well as the weight of peanuts are neglected and that peanuts move with constant velocity in the axial direction, the static equilibrium conditions will be written: First, by considering forces perpendicular to the cone axis, the following is written:

$$P_n'\delta A - (P_n \frac{\delta A}{Cos\alpha})Cos\alpha + \mu(P_n \frac{\delta A}{Cos\alpha A})Sin\alpha = 0 \quad (15)$$

Here, P_n' is the fictitious (equivalent) lateral pressure thought to be acting upon an infinitesimal area δA whose normal is perpendicular to the cone axis, P_n is the actual pressure on the outer surface of the infinitesimal cone element, α is the half of the cone angle and μ is the coefficient of friction between conical grate and peanuts. The fictitious pressure P_n' makes it possible to write down the following relationship:

$$K = \frac{P_n'}{P_z} \quad (16)$$

Here, K is the lateral-to-axial pressure ratio and P_z is the axial pressure. If the equilibrium of forces in the axial direction is taken into account, the following can be written:

$$P_zA_z - P_{z+\delta z}A_{z+\delta z} - P_n\pi(\frac{d_z + d_{z+\delta z}}{2})\delta zSin\alpha - \mu P_n\pi(\frac{d_z + d_{z+\delta z}}{2})\delta zCos\alpha = 0 \quad (17)$$

Here, diameter, area and pressure associated with the left-hand surface, **Fig. 12**, whose normal is along the cone axis are denoted by d_z, A_z, P_z, respectively, and those for the rigth-hand surface away from the other one by an infinitesimal axial distance δz, are designated by $d_{z+\delta z}$, $A_{z+\delta z}$, $P_{z+\delta z}$, respectively.

Now, Taylor's series expansions are considered:

$$(PA)_{z+\delta z} = (PA)_z + \frac{\partial (PA)_z}{\partial z}\delta z + \frac{1}{2!}\frac{\partial_2 (PA)_z}{\partial z^2}\delta z^2 + \ldots \quad (18)$$

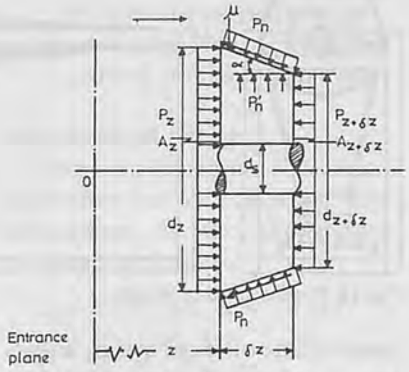


Fig. 12 Free-body diagram of an infinitesimal cone element.

$$d_{z+\delta z} = d_z + \frac{\partial d_a}{\partial z}\delta z + \frac{1}{2!}\frac{\partial^2 d_z}{\partial z^2}\delta z^2 + \ldots \quad (19)$$

After substituting (18), (19) in (17), using (16) and (15), and neglecting second- and higher-order terms, the following is obtained:

$$\frac{\partial (PA)_z}{\partial z}\delta z + \frac{KP_z}{1-\mu\tan\alpha}\pi d_z \cos\alpha(\mu + \tan\alpha)\delta z = 0 \quad (20)$$

Now the following geometrical relations can be written:

$$d_z = d_0 - 2z\tan\alpha \quad (21)$$

$$A_z = \frac{\pi}{4}(d^2_z - d^2_s) \quad (22)$$

Since $(PA)_z$ depends only on z, partial differentials in (20) become ordinary differentials leading to the followig integral equation:

$$\int_{z_i}^{z_{i+1}} \frac{d(PA)_z}{(PA)_z} = -K\pi\cos\alpha\frac{\mu+\tan\alpha}{1-\mu\tan\alpha}\int_{z_i}^{z_{i+1}} \frac{d_z}{A_z}dz \quad (23)$$

Substituting (21), (22) in (23) and carrying out integrations between axial distances from z_i to z_{i+1} and rearranging will finally yield equation (5). ■■

ADVERTISED PRODUCTS INQUIRY

Product	Advertiser	Vol., No., Page

EDITORIAL REQUEST TO AMA

Your Name :

Address :

Occupation :

SUBSCRIPTION/ORDER FORM

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (AMA)

Issued Quarterly

Subscription Rate (includes surface mail postage)

Annual (4 issues) ------------ ¥.6,000
Single copy ------------ ¥.1,700

Back Issues (1971－75, ¥.2,000 per copy)
(1976－77, ¥.1,200 per copy)
(1978－80, ¥.1,500 per copy)

★Spring, 1971	□Vol.7 No.2, Spring, 1976	★Vol.9 No.4, Autumn, 1978
★Vol.2 Autumn, 1971	□Vol.7 No.3, Summer, 1976	□Vol.10 No.1, Winter, 1979
□Vol.3 No.1, 1972	□Vol.7 No.4, Autumn, 1976	□Vol.10 No.2, Spring, 1979
□Vol.3 No.2, Summer, 1972	□Vol.8 No.1, Winter, 1977	□Vol.10 No.3, Summer, 1979
★Vol.4 No.1, Spring, 1973	□Vol.8 No.2, Spring, 1977	□Vol.10 No.4, Autumn, 1979
□Vol.4 No.2, Autumn, 1973	□Vol.8 No.3, Summer, 1977	★Vol.11 No.1, Winter, 1980
★Vol.5 No.1, Summer, 1974	□Vol.8 No.4, Autumn, 1977	★Vol.11 No.2, Spring, 1980
□Vol.6 No.1, Spring, 1975	□Vol.9 No.1, Winter, 1978	□Vol.11 No.3, Summer, 1980
★Vol.6 No.2, Autumn, 1975	□Vol.9 No.2, Spring, 1978	□Vol.11 No.4, Autumn, 1980
□Vol.7 No.1, Winter, 1976	★Vol.9 No.3, Summer, 1978	★: Indicates issues out of stock.

□ **Abstract and Index, 1971-80 (Special Issue, 1983)**

(Check issues and number of copies you wish to order)

Back Issues from 1981, ¥.1,700 per copy (Vol. 12 No. 1 and No. 4 are out of stock)
Abstract and Index, Special Issue, 1983, ¥2,000 per copy.

Vol.____ No.____, ____ 19____, ____ copy/copies

(check one)

□ Please invoice me/us

□ I/We enclose remittance for ¥________

****

Name: ________________

Firm: ________________

Position: ________________

Address: ________________

(block letters)

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

7, 2-chome, Kanda Nishikicho, Chiyoda-ku,
Tokyo 101 Japan
Tel. (03)－3291－3671～4, 5718

STAMP

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

7, 2-CHOME, KANDA NISHIKICHO, CHIYODA-KU

TOKYO, 101 JAPAN

1st FOLD HERE

2nd FOLD HERE

Design Parameters for Stripping Fresh Oil Palm Fruitlets

by
Hadi Suryanto
Graduate Student
Dept. of Power and Machinery Engineering
Faculty of Engineering
Universiti Pertanian Malaysia
43400 UPM Serdang, Selangor
Malaysia

Mohd. Zohadie Bardaie
Professor
Dept. of Power and Machinery Engineering
Faculty of Engineering
Universiti Pertanian Malaysia
43400 UPM Serdang, Selangor
Malaysia

Abstract

An attempt was made in this study to separate oil palm fruitlets mechanically from cut spikelets prior to transportation to the mill. An experimental drum thresher was developed and the effects of various technical conditions on threshability, bruise index, and threshing power requirement were identified.

The percentage of stripped fruitlets could be increased by increasing the rotational speed, decreasing inclination angle and diameter of the inner drum. The threshability of fruitlets with a feeding rate of 600 kg/h, inner drum speed of about 300 rpm and diameter of 16, 22, and 28 cm were about 98%, 95%, and 94% for each drum diameter, respectively.

Increasing the inner drum speed and diameter would increase the threshing power requirement. The relationship between drum speed and bruise index for each diameter was not significant. The bruise indexes in the threshing drum of 16, 22, and 28 cm diameter approached their average value of 2.4, 3.9, and 4.0, respectively. Fruitlets with these indexes would produce free fatty acid of less than 5% within 12 hours.

Acknowledgment: The authors wish to express great appreciation to Dr. Desa Ahmad (Associate Professor) and Dr. Azmi Yahya, Universiti Pertanian Malaysia, for their cooperation in undertaking the study.

Introduction

In the present harvesting system, the fresh fruit bunch (FFB) is usually transported to the mill as a whole material instead of fruitlets only. In the mill, the bunches are then sterilized and stripped mechanically to remove fruitlets from the stalk. The fruitlets are processed to provide oil and kernel while the rejected empty fruit bunch is brought back to the field for mulching.

The implementation of this system breeds some problems such as additional cost to transport and to heat the stalk, difficulty to heat the heavy and compact bunch, and oil loss absorbed by the empty fruit bunch.

To overcome these problems, it is worth considering a new harvesting system for separating fresh fruitlets from the stalk in the field such that only fruitlets will be transported to the mill, while their stalks may be left in the field as mulch.

The main hindrances to this proposal were the high strength of fruit stem joint and the structure of fruitlets densely packed in a bunch. To reduce the removal force of fruitlets, the bunch was then applied with ethephon and stored in the field for variable time. This compound can release ethylene which may accelerate the ripening of fruits. Hadi and Zohadie (1993) reported that 4 gram ethephon of 20-30% concentration which was brushed on cut stalk would hasten the fruitlet abscission and reduce the removal force from about 300 N to less than 20 N after storing for 24 hours. Another study showed that the application of ethephon on FFB would not affect the development of free fatty acid.

To ease the separation of loose fruitlets, the bunch should be cut to provide spikelets as threshing material. This operation may be accomplished using a knife blade or circular saw. The design parameters for cutting the spikelets from the treated bunch have been studied by Hadi et al. (1993a).

In order to provide necessary design data for the development of in-field stripping system, this study was carried out by developing an experimental drum thresher and investigating the effect of various technical conditions on threshability, bruise index, and threshing power requirement. Its

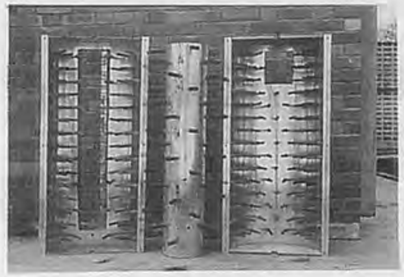


Fig. 1 Rubber beaters on the inner and outer drums.

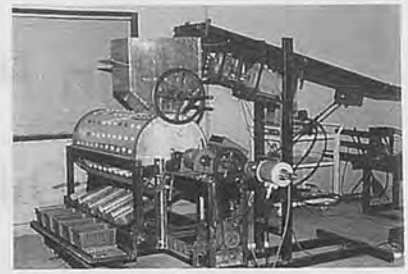


Fig. 2 Experimental drum thresher representing threshing drum unit and feeder.

performance was evaluated by varying the threshing drum speed, drum angle, drum diameter, configuration of beaters, length of spikelet, and feeding rate.

A drum type thresher has been widely developed to thresh agricultural products such as maize (Vasilew and Le, 1991), groundnut (Krishnapa, 1990; and Gol and Nanda, 1991), and rice (Umeda, 1992).

Experimental Drum Thresher

The experimental drum thresher consisted of a threshing unit and a feeder. This threshing unit was made up of an inner drum equipped with beaters distributed along three helical lines at a distance of 10 cm apart, and an outer drum furnished with several rows of teeth **(Fig. 1)**. In order to reduce mechanical damage, the teeth were made of rubber material. The inner drum can be rotated about the shaft at various speeds by 1 hp motor which is equipped with the speed controller (Model: MD100).

There were three interchangeable inner cylinders with diameters of 16, 22, and 28 cm. The lengths were 110 cm. The diameter and length of the outer drum were fixed at 50 cm and 120 cm, respectively. It was equipped with rubber teeth arranged at 10 cm × 10 cm or 5 cm × 10 cm. The bottom of the outer drum was opened to 15 cm wide. This opening was covered partially with the slit of 88 cm long. This slit was made of transverse bars at a distance of 4 cm apart to enable the stripped fruitlets to be sifted through this slit easily. The other materials are released at the end of the opening. The outlet of threshed material was divided into five zones. Each zone was provided with the pan having a capacity of about 7 000 grams oil palm fruitlets.

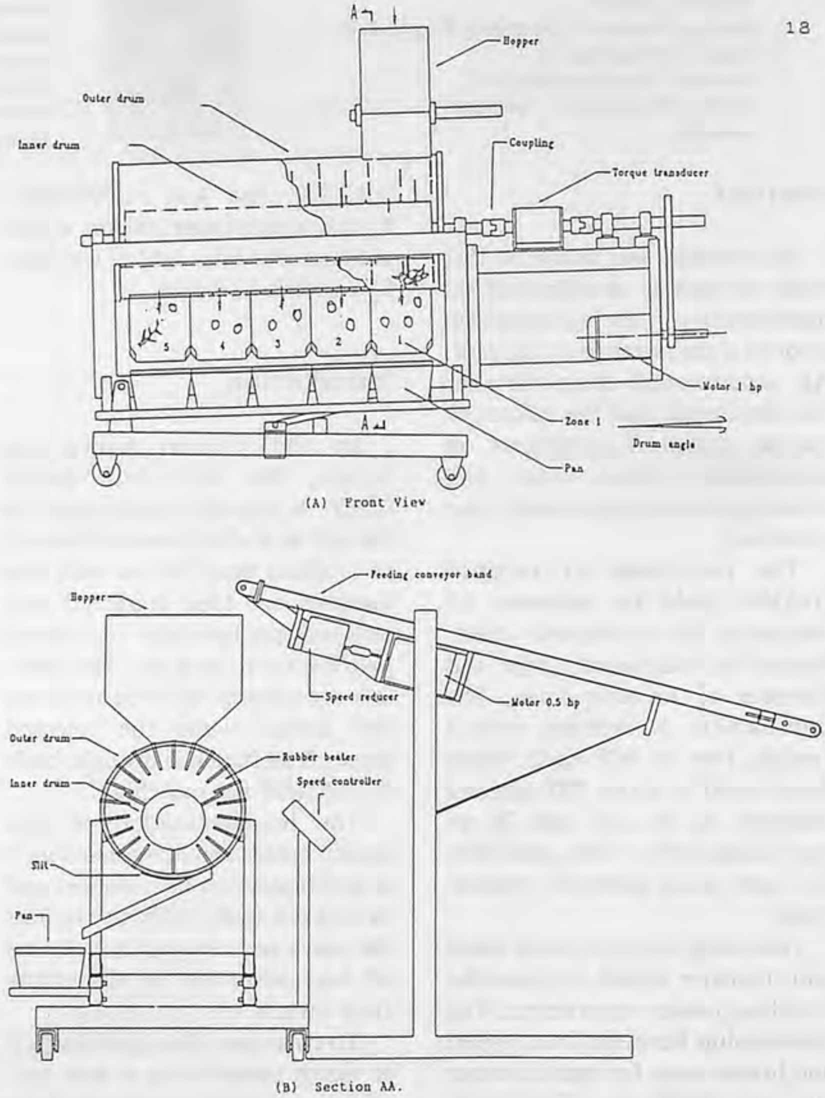


Fig. 3 Experimental drum thresher setup. (A) Front View, (B) Section AA.

Each inner drum was positioned within the outer cylinder such that the clearance of the bottom part was fixed at 10 cm; but that of upper part would be varied from 10 to 22 cm depending on the diameter of the inner drum.

The threshing unit could be positioned at different angles by turning this unit around the hinged joint which is fixed at the end of the frame.

A belt conveyor was fabricated

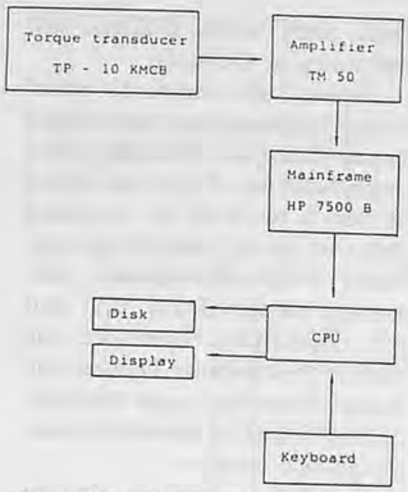


Fig. 4 Block diagram of instrumentation system to measure torque and rotational speed.

to feed the spikelets into the thresher at different rates. The conveyor can be set at various heights and angles. **Figure 2** shows a test rig set up representing the experimental drum thresher and conveyor.

During the operation, the spikelets which are fed into the threshing unit by a belt conveyor will move through the gap between the two drums. The fruitlets are threshed due to the continuous impact of the rubber beaters, friction between the threshed materials and the rubber teeth, and friction among the spikelets. When threshed, the fruitlets will pass through the slits and fall on the inclined plate. Finally, these fruitlets are collected in the pan, and other materials are released at the end of the outer drum (**Fig. 3**).

A torque transducer (Kyowa Model TP-10KMCB) required to measure torque and speed was mounted between the drum thresher and pulley using two flexible couplings. The output signals were amplified using indicator (type TM 52) and sent to a personal computer through the main frame HP 7500 series B (Hewlett Packard, 1991). Digital signals representing the torque and drum rotational speed were recorded in a floppy disk. The Labtech software was used to provide the interface between a user and instrumentation system (Laboratory Technology Corporation, 1991). A composite drawing of the instrumentation system is shown in **Fig. 4**.

For the calibration, this instrument was subjected to known torque and rotational speed shown on a digital hand tachometer. The multiplying factor for torque and rotational speed were 100 Nm/volt and 1000 rpm/volt, respectively.

Experimental Procedures

Tenera oil palms of 15 years old were selected as source of fresh fruit bunch (FFB). In order to facilitate separation of the fruitlets, 4 gram ethephon of 30% concentration was brushed on the cut stalks of every bunch sample. The bunch was then stored in the plantation area for 24 hours. A previous study showed that this treatment could promote the loosening of fruitlets without any significant effect of FFA development. The treated bunches were then cut to give the spikelet samples for the threshing experiments. During the tests, the spikelets were fed into the thresher using a belt conveyor.

For each experimental set, the machine would be operated under predetermined working conditions. A factor being studied was varied, and the remaining factors were kept constant approximately at the middle of the range. The description of working conditions for this study is shown in **Table 1**. During the operation, rotational speed and torque transmitted to the drum shaft were recorded for 180 seconds. The average of total threshing power and no-load power were determined for each drum speed level.

At the end of the experiment, threshability was determined by comparing the weight of stripped fruitlets with the total fruits. Bruise index (BI) was determined by evaluating a sample of 750 grams stripped fruitlets and dividing them into the following categories:

A = Sound fruitlet, no skin break, corresponding to BI of 1.

B = Minor bruised fruitlet with total bruise area less than 1 cm^2, corresponding to BI of 2.5.

Table 1. Descriptions of Working Conditions for the Study on the Performance of Experimental Drum Thresher

Expt	Variable	Range	Constants
1	Inner drum dia.	16, 22, 28 cm	Feed rate = 10 kg/min Drum angle = 2.5° Teeth = 10 cm × 10 cm
	Inner drum speed	100-400 Rpm	Feed rate = 10 kg/min Drum angle = 2.5° Teeth = 10 cm × 10 cm
2	Drum angle	0-15 degree	Drum diameter = 16 cm Feed rate = 10 kg/min Drum speed = 300 Rpm Teeth = 10 cm × 10 cm
3	Feed rate	5, 10, 15 kg/min	Drum diameter = 22 cm Drum angle = 2.5° Drum speed = 300 Rpm Teeth = 10 cm × 10 cm
4	Teeth arrangement	5 cm × 10 cm 10 cm × 10 cm	Drum diameter = 16 cm Drum angle = 2.5° Drum speed = 300 Rpm Feed rate = 10 kg/min
5	Length of spikelets	7.5 and 12.5 cm	Drum diameter = 16 cm Drum angle = 2.5° Drum speed = 300 Rpm Feed rate = 10 kg/min

Note: The length of spikelet for experiment 1-4 was about 12.5 cm.

C = Moderate bruised fruitlet with total bruise area of 1-2 cm^2, corresponding to BI of 5.5

D = Major bruised fruitlet with total bruise area more than 2 cm^2, corresponding to BI of 10.

The index was then determined by the following equation:

$$BI = (1*X1 + 2.5X2 + 5.5*X3 + 10*X4) / 100 \quad [1]$$

where X1, X2, X3 and X4 were the percentage weight of fruitlets with category A, B, C, and D, respectively.

This bruise index would be 1.0 if the whole lot consists of sound fruitlets only, and it would be 10 if this lot is constituted of fruitlets with major damage. Hadi et al. (1993b) reported that the relationship between BI and FFA (%) which was developed by just ripe fruits at 12 hours after the bruising could be represented by the following equation:

$$FFA = 0.122 + 0.502\ BI; \quad r = 0.823 \quad [2]$$

where the range of bruise index is about 1-5. Further study showed that just ripe fruitlets with the bruise index of 10 would produce FFA of 5.547% for 12 hours delay.

Results and Discussion

Effect of Drum Speed

The cut spikelets required as threshed material is shown in **Fig. 5**. The stripped fruitlets produced by the experimental drum thresher is shown in **Fig. 6**.

Figure 7 shows the effects of threshing drum speed (DSPEED) of various drum diameters on threshability (TA). Their relationships are represented by the following regression equations:

$$TA16 = 63.171 + 0.109\ DSPEED; \quad r = 0.845 \quad [3]$$

$$TA22 = 62.580 + 0.102\ DSPEED; \quad r = 0.838 \quad [4]$$

$$TA28 = 87.929 + 0.017\ DSPEED; \quad r = 0.825 \quad [5]$$

where TA16, TA22, and TA28 represent threshability (%) using the inner drum of 16, 22, and 28 cm diameters, respectively. The range of drum speed was 100-400 RPM.

The p-value for drum with diameter of 16, 22, and 28 cm were 0.072, 0.037, and 0.175, respectively. Generally, an increase of threshing drum speed caused higher striking force and the frequency of encounter between rubber beaters of inner and outer drums. As a result, the percentage weight of stripped fruitlets would also increase. However, for the same rotational speed, threshability decreased with an increase of the inner drum diameter. As an illustration, the percentage of stripped fruitlets for the inner drum of 16, 22, and 28 cm diameter at about 300 rpm were 98%, 95%, and 94%, respectively. The longer diameter of the inner drum results in a shorter gap between the inner and outer drums. Consequently, the spikelets could not move around in this gap easily and would leave at the bottom with less rubbing. Finally, when the spikelet was thrown out at the end of the drum, there were some fruitlets still remaining at the stalk.

Figure 7 also shows the effect of the threshing drum speed on the bruise index for different inner drum diameters. The bruise indexes were a result of the threshing drum of 16, 22, and 28 cm diameter which approached their average values of 2.4, 3.9, and 4.0, respectively. Therefore, the shorter the clearance between the drums due to the longer diameter of threshing drum resulted in more mechanical damage.

Correlation analysis showed that the relationship between the inner drum speed and bruise index for each diameter was very poor. The correlation coefficient for drum of 16, 22, and 28 cm were 0.29, 0.73, and 0.06, respectively.

The relationship between drum rotational speed (DSPEED) and power requirement for different drum diameter are shown in **Fig. 8**. The total power included no-load power required to overcome idle resistance and that for threshing operation. Idle resistance is caused by friction in the bearings and ventilating effect of drum. Threshing resistance is due to the acceleration of spikelet mass, rubbing among threshed materials and that between spikelet and concave. The power utilized to thresh the fruitlets was strongly affected by rotational speed and the diameter of the inner drum. The relationship between DSPEED (rpm) and power requirement P (watt) was

Fig. 5 Cut spikelets as threshing materials.

Fig. 6 Threshed fruitlets produced by an experimental drum thresher.

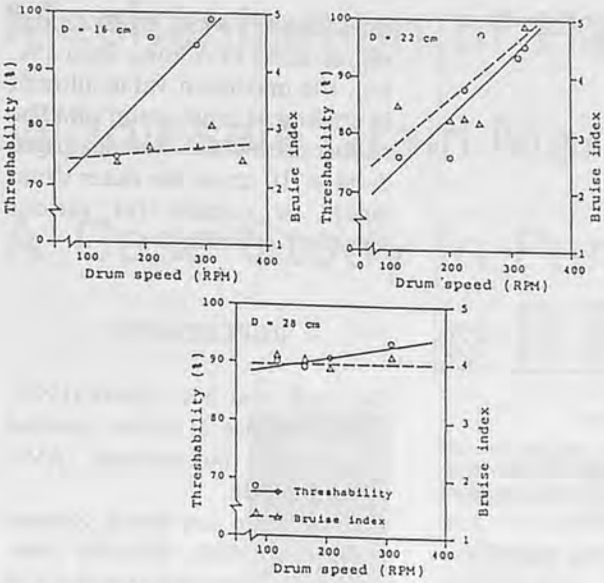


Fig. 7 Effect of drum speed on threshability and bruise index for different threshing drum diameters.

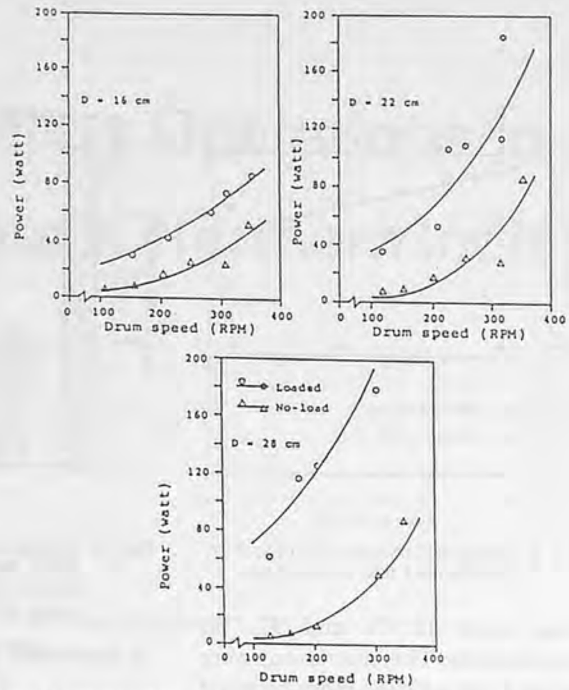


Fig. 8 Relationship of inner drum speed and no-load and total threshing power requirement with different drum diameters.

given by the following common equation:

$$P = BO\ e^{(B1.DSPEED)} \qquad [6]$$

where the range of DSPEED is 100-400 rpm. The values of the constant B0 and B1 are shown in **Table 2**.

Increasing drum diameter or rotational speed resulted in greater threshing power requirement. As an illustration, the power required to thresh fruitlets for 16, 22, and 28 cm drum diameters at 300 rpm were 65.64, 116.69, and 195.54 watt; and that at the speed of 400 rpm were 108.22, 212.64, and 322.40 watt, respectively. Increasing the speed by more than 400 rpm caused high vibration which can damage the machine setup.

Effect of Drum Angle

Figure 9 shows the effect of inclination drum angle DA (degree) on threshability TA (%). Their relationship can be represented by the following regression equation:

$$TA = 99 - 0.777\ DA;$$

Table 2. Coefficient and Asymptotic Standard Error for No-load and Total Power Requirement for Threshing (Feed Rate = 10 kg/min)

Power	Parameter		Asymptotic standard error for coefficient	
	B0	B1	B0	B1
Drum diameter = 16 cm				
No load	1.434	0.010	0.903	0.002
Total	14.646	0.005	1.380	0.0003
Drum diameter = 22 cm				
No load	0.734	0.013	0.637	0.003
Total	19.290	0.006	12.290	0.002
Drum diameter = 28 cm				
No load	0.756	0.013	0.056	0.0002
Total	43.632	0.005	12.389	0.001

$$r = 0.713 \qquad [8]$$

where the range of drum angle is 0°-15°. The p-value for its slope is 0.11. Correlation analysis shows that the relationship between drum angle and threshability is not so significant.

The higher the angle between the drum axis and horizontal line, the shorter will be the time of beating action on individual spikelets. Consequently, it might reduce the amount of stripped fruitlets. An increase in the angle from 2.5 to 15 degree would reduce the percentage weight of stripped fruitlets by 7.8%.

Figure 9 also shows that the bruise index was not influenced by the drum angle, and their values were almost constant at about 2.87.

Effect of Feeding Rate

Total power required to thresh fruitlets was directly proportional to the material mass and stripping resistance. Increasing threshed material from 10 to 15 kg/min would double the amount of power requirement from 89.36 to 174.66 watt, but the threshability decreased from 97.2% to 85.6%.

Effect of Beater Arrangement

The rubber teeth of the outer drum arranged at 10 cm × 10 cm was used to thresh spikelets of different lengths. The result shows that the average threshability for spikelets of 7.5 cm and 12.5 cm

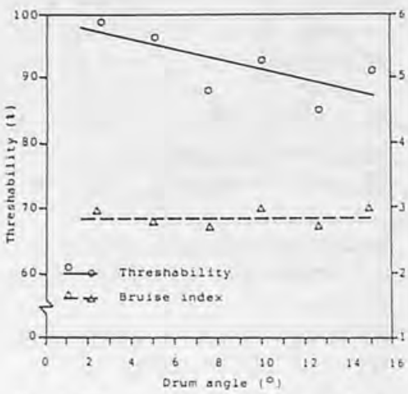


Fig. 9 Effect of threshing drum angle on threshability and bruise index.

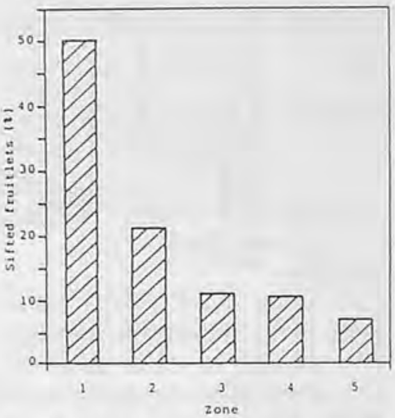


Fig. 10 Sifting capacity through five slit zones for the threshing with inner drum of 22 cm diameter and drum speed of 300 rpm.

long were 88.5% and 97.7%, respectively. This operations were carried out with the inner drum of 22 cm diameter, 2.5 degree drum angle, and about 300 rpm drum speed.

In order to increase the threshability of the short spikelets, the teeth of the outer drum were then set at 5 cm × 10 cm. This arrangement could improve the threshability of short spikelets from 88.5% to 96.5%. The threshability for spikelets with 12.5 cm long was 97.1% almost equal to that produced by the first arrangement.

An experiment with the teeth of 5 cm × 10 cm arrangement and the threshing drum speed of about 300 rpm shows that the power requirement to thresh 12.5 cm spikelets was 156.15 watt. It was almost three times as much as that to thresh 7.5 cm spikelets, i.e., 61.93 watt. In this case, the threshing resistance increased with the spikelet length.

To determine the sifting capacity along the threshing drum, the opening of the outer drum was then spaced equally into five zones (**Fig. 3**). After the threshing, the percentage of sifted fruitlets was recorded for every zone. An example of sifting capacity for the thresher is shown in **Fig. 10**. The result indicates that starting from the first zone this shifting capacity decreased with the distance.

Conclusion

There are three steps required to accomplish the stripping of oil palm fruitlets in the field. The first step is to reduce the strength of fruit-stem joint by applying ethephon on fresh fruit bunch just after harvest. The second step is to prepare threshed materials by producing spikelets from the bunch stalk. The third step is to detach loose fruitlets from cut spikelets using a drum thresher. Its technical specifications should be set optimally to obtain not only a high threshability but also low power requirement and bruise level.

Tests on the performance of the experimental drum thresher showed that the threshability was influenced by threshing drum speed, drum angle, feeding rate, and beater arrangement. Threshing power requirement decreased with the decreasing inner drum diameter and rotational speed.

It is recommended that the threshing process should be conducted with the small drum diameter (16 cm), high rotational speed (about 300 rpm), and the drum angle of 2.5°-5°. This condition would result in about 98% threshability with bruise index representing FFA lower than 5%, i.e., the maximum value allowed in trading of crude palm oil. The rubber teeth which were arranged 5 cm × 10 cm at the outer drum would be suitable for various length of spikelets.

REFERENCES

Gol, A.K. and S.K. Nanda (1991). Performance of power operated groundnut pod stripper. AMA 22(3): 25-28.

Hadi Suryanto and Mohd. Zohadie Bardaie (1993). Effective treatments to hasten the loosening of oil palm fruitlets. AMA (under review).

Hadi Suryanto, Mohd. Zohadie Bardaie, Desa Ahmad, and Azmi Yahya (1993a). Force and energy requirement for cutting oil palm fresh fruit bunch. The Planter 69: 399-407.

Hadi Suryanto, Mohd. Zohadie Bardaie, Desa Ahmad, and Azmi Yahya (1993b). Bruise index as a criteria for use in the desing of oil palm fruitlets stripper. The Planter (under review).

Hewlett-Packard (1991). HP 7500 Series B Mainframes HP E1300A and E1301A User Manual. California: Hewlett-ackard Company.

Krishnappa, C., K.C. Krishnamurthy, and A.P. Vishwanath (1990). Evaluation of variuos groundnut pod stripper. Mysore Journal of agricultural Science 22(4): 505-508.

Laboratory Technologies Cooperation (1991). Labtech Notebook Family of Products Notebook/xe Notebook users manual. Wilmington: Laboratory Technologies Corporation.

Umeda, M. (1992). Analysis of threshing mechanism of head feeding thresher; Part 3; analysis of detaching process. Journal of the Japanese Society of Agricultural Machinery 54(3): 43-52. ■■

Mechanization of Handling Operations in Wholesale Grain Markets in Northern India: A Case Study in Punjab

by
Rajinder Singh
Professor and Head
Dept. of Processing and Agricultural Structures
Punjab Agricultural University
Ludhiana, India 141004

Abstract

A sudden increase in foodgrain production in the early 1970s as a result of the Green Revolution in Northern India caused near-collapse of the traditional marketing system. The number and size of the markets were sharply increased but the glut situations persisted. Based on extensive surveys the concept of phased mechanization was introduced in the early 1970s and first adopted on a limited scale in 1980. Three medium-sized markets were partially mechanized. The number of mechanical handling units (MHU) increased from 6 in 1980 to 22 in 1986, to 34 in 1991, to 64 in 1992 and 88 in 1993. Small markets are also being mechanized in phases from 1992 onwards. Mechanization of large markets has yet to be started by the trade. After initial opposition the concept is gradually being accepted by all concerned.

Introduction

After the partition of India in 1947, free India was forced to import foodgrains. Several national campaigns such as 'Grow More Food' and 'Save Foodgrains' followed by opening of a number of State Agricultural Universities in the country, resulted into the so-called Green Revolution. The increased production also increased the marketable surplus **(Table 1)**. To avoid crash in prices and encourage the farmers to keep up the production tempo, the Government launched a vigorous price support program, especially for wheat and paddy during 1970-71 which continues to this day.

During the pre-Green Revolution days, the arrivals of foodgrains in *mandis* or wholesale grain markets were meagre and spread over long marketing seasons of 3-4 months for each crop. Under these conditions the age-old

Table 1. Production, Marketable Surplus and Support Price of Wheat and Paddy, 1967-91

Year	Wheat				Paddy			
	Support price (Rs./qtl)	Production (000 t)	Marketable (000 t)	surplus (percent)	Support price (Rs./qtl)	Production (000 t)	Marketable (000 t)	surplus (percent)
1967-68	—	24.51	8.52	34.8	—	6.12	3.71	60.6
1970-71	76	51.43	31.21	60.7	51	10.32	8.46	82.0
1975-76	105	58.09	35.45	52.4	76	21.71	18.36	84.4
1980-81	117	76.74	39.24	51.1	105	48.50	44.32	91.4
1985-86	162	110.00	67.79	61.6	142	82.28	71.06	86.4
1986-87	162	94.47	29.42	52.3	146	89.24	75.65	84.8
1987-88	166	110.84	55.18	49.8	150	81.63	70.99	87.0
1988-89	173	115.76	63.26	54.6	160	74.13	56.47	76.2
1989-90	183	116.81	70.55	60.4	175	100.46	83.20	82.8
1990-91	215	121.55	61.03	50.2	205	98.07	78.82	80.4

Fig. 1 Congestion in grain mandi.

Fig. 2 Grain unloaded on road sides.

marketing technology had done very well. However, in the post-Green Revolution days, the marketing season steadily shrank to the present duration of just about a month each for paddy and wheat crops. The use of reapers, power threshers, combines, faster modes of transportation, fixed support price system throughout the year and lack of incentives to the farmer to hold back his product for sometime, resulted in unprecedented flow of foodgrains into the wholesale markets causing glut, confusion and congestion in the markets (**Figs. 1** and **2**). This resulted into malpractices and the traditional system seemed to be collapsing under the unexpected load. Several new markets were opened and the existing ones shifted to new spacious sites as an immediate solution. In Punjab the number of markets increased from 255 in 1970-71 to 626 in 1980-81 and 663 in 1991-92. Hollman (1969) and Gill (1971) after a thorough study of the market behaviour, recommended mechanization of the grain markets and Singh *et al.* (1972 and 1975) recommended phased mechanization of grain markets as a solution to the problems of labour and glut.

Traditional Handling System and Its Limitations

The traditional system of handling foodgrains in wholesale markets is slow, inefficient, space consuming and labour intensive. According to Singh (1989), each of the four operations of the traditional system (**Fig. 3**) is preceded by a delay period which may vary from a few minutes to a few hours. As a result of this delay the farmer has to stay in the market for the whole day alongwith his bullock cart or the tractor-trolley causing avoidable congestion and pollution in the market, under utilization of space and wastage of farmer's time.

Singh *et al.* (1975) conducted time-motion studies for various operations in six markets and concluded that maximum time-labour of 45.07% (**Table 2**) was required for sieving and cleaning operation (**Fig. 4**). This was followed by bagging, weighing and stacking operation with 37.52% and stitching 9.00%. Minimum time-labour (8.41%) was required for unloading operation. Grover *et al.* (1989) also conducted time-motion studies of the traditional system for both paddy and wheat marketing (**Table 3**). They observed that time-labour requirements on per tonne basis are much more for paddy processing as compared to wheat processing. Further, a comparison of **Tables 2** and **3** reveals that the requirement of time-labour for processing one t of wheat using the same traditional technique required a total of 191.1 man minutes in 1989 against 110.62 man minutes in 1971. This shows a decline in labour productivity index from 100 (base) in 1971 to 57.89 in 1989. Thus, keeping in view the above facts, introducing phased mechanization of the marketing operations in wholesale markets of Punjab is inevitable.

For mechanization purposes, markets handling more than 20 000 t of foodgrains per season were termed as large markets whereas those handling 5 000 to 20 000 t were termed as medium-

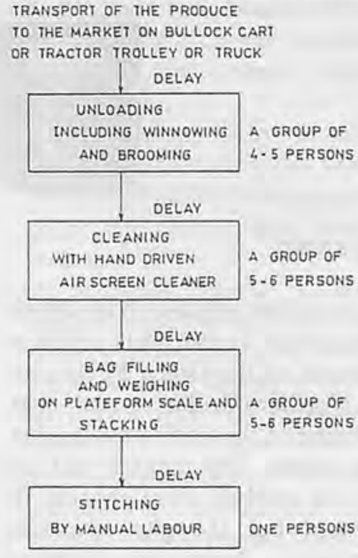


Fig. 3 Flow chart of conventional manual handling system.

Fig. 4 Conventional Cleaning System.

Table 2. Time and Labour Requirements in 1971 to Process a Cart-load (1.5 t), a Tractor Trailer Load (3.0 t) and a Truck Load (7.0 t) of Wheat

Operation	Man minutes to process one unit of				Percentage of total man minutes required
	Bullock cart load	Tractor trailer load	Truck load	Per ton	
Unloading	13.55	30.12	61.32	9.3	8.41
Cleaning	84.00	137.40	337.40	49.86	45.07
Bagging and weighing	62.36	124.71	291.00	41.50	37.52
Stitching	14.90	29.79	69.31	9.96	9.00
Total	174.81	322.02	759.03	110.62	100.00

Table 3. Time and Labour Requirements in 1989 to Process 100 Bags or One ton of Wheat and Paddy

Operation	Man minutes to process				Percentage of total man minutes for	
	100 bags		One ton of			
	Wheat	Paddy	Wheat	Paddy	Wheat	Paddy
Unloading	367	555	38.6	85.4	20.20	24.57
Cleaning	786	1 236	82.7	190.2	43.28	54.72
Weighing and bagging	600	401	63.2	61.7	33.07	17.75
Stitching	62	67	10.3	3.45	2.96	2.96
Total	1 815	2 259	191.1	347.6	100.00	100.00

Note: One bag of wheat weighs 95 kg whereas one bag of paddy weighs 65 kg.

sized and those handling less than 5 000 t per season were called small markets.

Mechanization

In advanced countries of the world wholesale marketing of foodgrains is generally done in loose form. The price is invariably fixed after actual testing of the grain samples. The grain, after cleaning and drying if necessary, is stored in tall silos made of concrete or metal until it is to be finally disposed off by the purchasing agency. Such a system which is highly capital intensive, can be advocated for adoption on a limited scale only in some of the largest markets. This system is unsuitable for adoption in the medium- and small-sized *mandis* as it will cause large scale displacement of unskilled labour and render the existing bag storage facilities surplus. Hence, a guarded or phased mechanization approach is advocated as follows:

Phased Mechanization

Objectives

The concept of phased mechanization in wholesale grain markets was aimed at achieving the following objectives:

1. Effectively handle and process the ever increasing volumes of grains arriving in the market;
2. Improve quality of the processed grains;
3. Rationalize the system of pricing (at least by the Government agencies) on scientific basis;
4. Minimize grain losses within and beyond markets;
5. Save marketing time of the farmer;
6. Avoid undue congestion in the markets;
7. Better utilization of space in the marketing yards;
8. Reduce drudgery of the labourers and improve their productivity; and
9. Avoid overall labour displacement as a result of mechanization.

Scope

The small, medium and large markets had different problems and, therefore, need different solutions. The large markets were proposed to be fully automated as per Western model which would require skilled manpower and huge initial capital. The medium markets were proposed to have a number of mechanical handling units. Most of the existing unskilled labour can be retained with or without minor improvements of the skills. However, because of higher productivity, some labour is likely to become surplus which will be needed by the organizations engaged in the manufacture, installation and maintenance of these units. In small markets only the cleaning operation is to be mechanized and the labour shortage is expected to be made up from the surpluses from medium and large markets.

Pricing

The price of foodgrains to be procured by the Government agencies is governed by the fair average quality (FAQ) grade and the moisture content (M.C.). For instance, the FAQ grades and moisture contents for wheat and paddy in 1992-93, as fixed by the Food Corporation of India (FCI) are shown in **Table 4**. In practice, neither the moisture content nor any of the refractions of grading are actually measured. Only judgement and experience of the quality inspector is relied upon to fix the price. The price of foodgrains to be procured by the private traders further depends on the supply-demand situations and the Government policies. Therefore, to give justice to the seller and the purchaser the official price should be fixed only after the moisture content has been measured by a moisture meter and the grade properly evaluated by actually measuring various refractions. However, a computerized grade evaluator needs to be developed to speed up this operation.

Table 4. Sepcifications for Purchase of Wheat and Paddy as per FAQ Standards for 1992-93.

Component	Maximum limit (percent)
Wheat	
Foreign matter	0.75
Other foodgrains	6.00
Damaged grains including karnal bunt and ergot affected grains	3.00
Slightly damaged grains	10.00
Shriveled and broken grains	12.00
Moisture	12.00
Paddy	
Foreing matter	
a) Inorganic	1.00
b) Organic	1.00
Damaged, discoloured, sprouted and weevilled grains	3.00
Immature, shrunken and shriveled	3.00
Admisture of lower varieties	10.00
Moisture	18.00

Small-sized Markets

These markets are to be governed by the flow chart in **Fig. 3**, except that the Government pricing should be rationalized and cleaning of the foodgrains be done only with efficient motorized cleaners. It is heartening to note that the Punjab State *Mandi* Board which is the only Government agency to regulate the conduct of marketing operations, has agreed to gradually replace the conventional hand-operated cleaners with efficient motorized cleaners in all the wholesale grain markets of Punjab.

Medium-sized Markets

These markets are to be governed by the flow chart in **Fig. 5**. One or two sampling analysis and pricing (SAP) booths should be erected near the enterance to the market for rationalizing the evaluation of the foodgrains price. Once the price has been fixed, the farmer can move on to one of the mechanical handling units (MHU) for processing of his products.

A typical mechanical handling unit (**Figs. 6** and **7**) comprises of one underground hopper, two vertical bucket elevators, one multi-grain vibratory cleaner equipped with cyclone dust collector, one surge bin, one automatic bagging and weighing machine and one horizontal slat conveyor with a bag stitching machine.

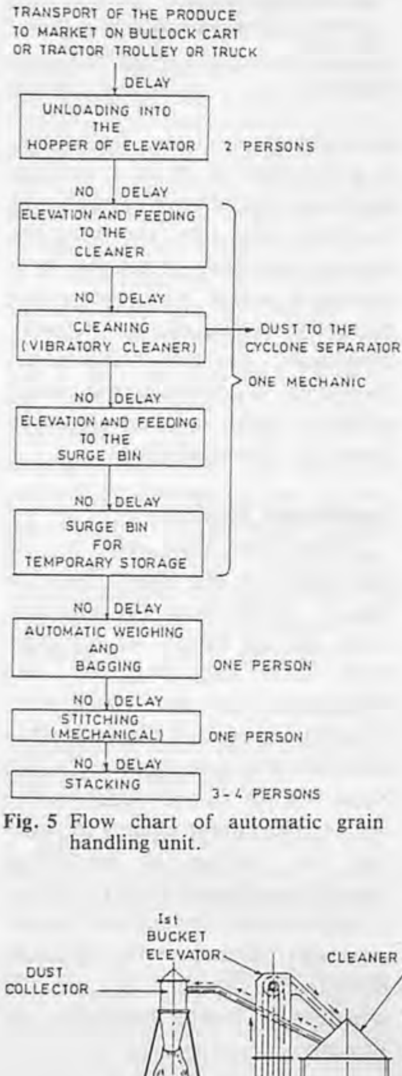


Fig. 5 Flow chart of automatic grain handling unit.

The grain from the tractor trolley of the farmer is manually unloaded with the help of long-handled shovels, into the underground hopper which has a holding capacity of about one t of wheat. This grain is then fed into the first vertical bucket elevator through an adjustable inlet. This 5 H.P. elevator lifts the grains at the rate of 100 bags of wheat or 50 bags of paddy per hour to a height of 7.60 m to feed one multi-grain vibratory cleaner. The 7.5 H.P. cleaner removes heavier and larger foreign particles by means of different mesh sized sieves. The fine and lighter particles are removed pneumatically and collected in a cyclone dust collector of 1.40 m diameter to avoid undue pollution in the market. The cleaned grain is fed into the receiving hopper of the second elevator. This elevator, as in the case of first one, lifts the grains up to 7.60 m high to feed a one t capacity surge bin. This bin feeds by gravity an automatic bagging and weighing machine. In one hour this machine can weigh up to 140 bags of one quintal capacity with an accuracy of ± 0.1%. The standard bags contain 95 kg of wheat and 65 kg of paddy. After the bag has been filled and weighed it is manually released to fall on a horizontal slat conveyor. This 2.00 m long and 0.33 m wide conveyor, which is powered by one H.P. motor, moves this filled bag to the stationery bag stitching machine. This double threaded stitching machine powered by one H.P. motor can make 2-3 stitches per centimeter at the rate of 8-12 stitches per second. The stitching machine is fixed on a pedestal and the bag is moved on the slat conveyor during stitching operation. The stitched bags are then stacked neatly behind the units awaiting transportation to the storage godowns or to the railway sidings for long distance transportation by trains.

A total of six mechanical handling units were installed in three markets of Khamano, Sahnewal and Doraha of Ludhiana district in 1980 which were fully put into operation only in 1982 after the marketing law was suitably amended. After stiff opposition by the commission agents, traders, workers, farmers and even Government procuring agencies in the initial years, this system is now accepted by all and has created its demand (**Table 5**). The capacity of such a unit was 100 bags of wheat or 50 bags of paddy per hour depending upon the foreign matter content of the incoming grains. Since 1989, the handling capacity of MHUs was doubled (200 bags of wheat or 100 bags of paddy per hour) by doubling the capacity of both elevators and installing two cleaners, two weighing machines, two slat conveyors and

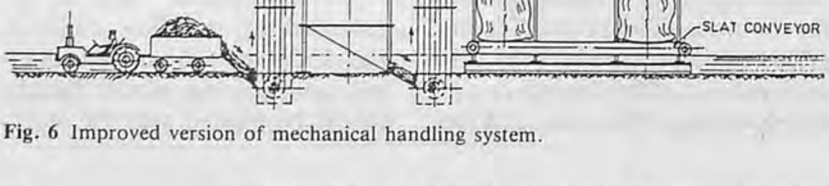


Fig. 6 Improved version of mechanical handling system.


Fig. 7 MHUs installed in a grain mandi.

Table 5. Progress of Mechanical Handling Units (MHUs), 1982 to 1993

Year	Total No. of MHUs installed	Total No. of partially mechanized markets*	Installed capacity/ Season Based on Cleaner Capacity (t)		Quantity Handled (t)	
			Wheat	Paddy	Wheat	Paddy
1982	6	3	9576.0	3749.0	175.9	290.1
1983	6	3	9576.0	3749.0	290.1	162.5
1984	6	3	9576.0	3749.0	1236.3	1989.3
1985	10	4	15960.0	6249.0	3005.0	2984.3
1986	22	8	35112.0	13747.8	3886.2	2131.7
1987	22	8	35112.0	13747.8	1725.0	7214.0
1988	22	8	35112.0	13747.8	4544.9	15000.0
1989	22	8	35112.0	13747.8	6918.4	14605.4
1990	22	8	35112.0	13747.8	4590.4	16232.4
1991	32	12	54710.0	32467.8	3679.4	17989.7
1992	68	29	191520.0	79267.8	1508.6	20122.8
1993 (Wheat)	88	34	300960	116707.8	—	

* Extra units have been installed in 1992 but could not be made operational due to non-availability of electric connection.

two parallel stitching machines and replacing the manual unloading of grains by mechanical unloading. The number of such units has increased from 6 in 1982 to 22 in 1986 to 34 in 1991 to 64 in 1992 and 88 in 1993.

Large-sized Markets

These markets should be re-oriented to handle and store foodgrains in bulk form by integrating marketing, handling and storage at one location (Singh and Sadhna, 1989) preferably alongwith processing facilities. This will reduce the use of gunny bags and also avoid unnecessary to and fro transportations with associated expenses. The end-product is expected to be better in quality and more competitive in price. A typical layout of such a complex is shown in **Fig. 8**.

Fig. 8 shows that as the farmer enters the market, a sample of his grains is taken for processing and fixing the price in the SAP booths. Simultaneously, the gross weight is also recorded. The farmer moves on to the dumping pits where his grain is mechanically unloaded on to one of the underground belt conveyors in accordance with the data supplied by the SAP booth. Then he goes to the payment booth where his tare weigh is done and payment made.

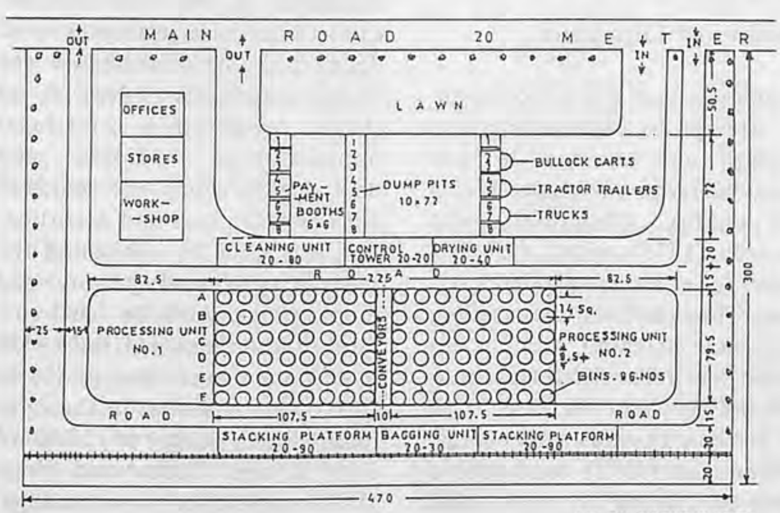


Fig. 8 Proposed layout of a fully mechanized integrated grain marketing, storage and processing facility. (Plan area = 14.1 ha)

Thus the farmer spends the least minimum time for the marketing of his product. The unloaded grain from the dump pits is carried on a system of conveyors, elevators and chutes to holding bins, cleaners, dryers, storage silos and to the wheat flour mill or the rice mill for processing, or to the bagging and weighing units for transportation by rail or road to further destinations. The entire handling system is operated and monitored by a sophisticated remote control system installed in the control room to ensure minimum grain losses and high plant efficiency. It is beneficial if the whole complex becomes self-sufficient in power generation from the by-products of an integrated rice milling unit. Thus several facilities such as cleaning units, drying unit, storage silos and bagging/weighing units can be better utilized over a much longer period. This will lower the operational costs and make the system more competitive. The implementation of such a system is still under consideration of the concerned agencies.

Conclusions

The adoption of phased, mechanization concept in post Green Revolution era offers a practical solution to the problems of glut and confusion that prevail in small-, medium- and large-sized grain markets in northern India. It helps in reducing grain losses and drudgery of labour while improving space utilization and quality of grains as well as labour productivity. If integrated marketing, handling, storage and processing concept is also adopted it will greatly reduce overall expenses per unit of grains in addition to the above mentioned benefits.

(Continued on page 64)

Studies on Centrifugal Decortication of Sunflower Seed

by
Rajvir Yadav
Assist. Professor
College of Agricultural Engineering and Technology
Junagadh 362001, India

Pratap Singh
Professor and Head
Dept. of Farm Machinery and Power
College of Technology and Agricultural Engineering
Udaipur 313001, India

Ghanshyam Tiwari
Assoc. Professor
Dept. of Farm Machinery and Power
College of Technology and Agricultural Engineering
Udaipur 313001, India

Abstract

The effect of peripheral speed of impeller, feed rate and moisture content of sunflower seed of EC-68414 variety on decorticating performance of centrifugal impeller type sunflower seed decorticator were studied. The decortication was done by feeding the seeds in a vertically rotating impeller at high centrifugal force and striking them on a rubber surface. The better decorticating efficiency of 82.20% and kernel damage of 15.04% was obtained at 9.80% moisture content, 150 kg/h feed rate and 2 825.53 m/min peripheral speed of the impeller.

Introduction

The sunflower (*Helianthus annus L*) crop is one of the important oil seed crops in India as well as in other countries. Its cultivated area is about 14.21 million ha, while the total production is about 5.92 million t. During the last few years the cultivation of sunflower has increased rapidly in Maharashtra, Karnataka, Andhra Pradesh and also in several other states of India. It contains 45-50% oil resulting in high production of oil per unit area and time. The sunflower oil contains 15% fat, is used for culinary purposes in the preparation of 'vanaspati' and in manufacturing of soap and cosmetics.

Review of Literature

Bilanski and Lal (1965) made an attempt to express breaking strength and damage of seed grains in terms of impact forces and energy. Chaudhary and Buchele (1975) tested a rubber sheller for evaluation shelling principle. They observed that shelling efficiency increased with the increase in cylinder speed and inflation pressure and decreased with an increase in moisture content. Makanjuola (1975) conducted a study on shelling of melon seeds by impact force. The impeller with four slots was found to be most effective in the speed range of 1 867 to 2 154 m/min. Singh et al (1978) designed and tested a ground nut decorticator. The highest decortication efficiency of 98.0% was observed at cylinder speed of 100 rpm, feed rate of 150 kg/h and 15% moisture content at 1.5 cm concave clearance. A rotary cylinder huller was used by Clark et al (1980) for separating kernels and hulls from sunflower seeds. Hussain et al (1978) developed a manually-operated caster bean-cum-sunflower seed dehuller and its performance was found satisfactory. Nag et al (1983) developed a centrifugal impeller type sunflower seed decorticator, which was rotated in a horizontal plane and decortication was done by subjecting the seeds at high centrifugal force and then striking them on hard surface. A decorticating efficiency (35 to 65%) and seed damage (18 to 25%) were observed in the optimum speed range of 2 000 to 2 600 m/min. Yadav and Singh (1991) developed a centrifugal (vertical impeller type) sunflower seed decorticator-cum-cleaner. The decorticating efficiency and cleaning efficiency were 82.20% and 91.22%, respectively, with 15.04% kernel damage. The present study was undertaken to minimize kernel damage and maximize decorticating efficiency by varying machine and system parameters.

Materials and Method

A decorticator consists of a hopper, feeding unit, shelling unit (impeller and impeller casing) and power transmission system (**Fig. 1**). A conical hopper with one side plane was provided for feeding the sunflower seed to the rotating impeller. A marked sliding flap was provided for regulating the feed rate. The impeller rotates in a vertical plane and throws the seeds towards the casing with the centrifugal force and striking them on rubber surface mounted on casing.

Decorticating efficiency and kernel damage percentage were evaluated at different moisture content levels (7.29, 9.80 and 13.22%), feed rates (90, 120, 150 and 180 kg/h) and peripheral speeds (2 338.49, 2 533.14, 2 728.00, 2 825.53, 2 922.86 and 3 117.71 m/min). A standard procedure (IS: 11473) specified by BIS for ground nut decorticator was followed for the experiment.

Results and Discussion

The results are presented in **Figs. 2** and **3**. The effect of moisture contents, feed rates and peripheral speeds of the impeller on decorticating efficiency and kernel damage are given in **Table 1**. The peripheral speed was observed as the most effective parameter which affects the decorticating efficiency and kernel damage. The percent increase in decorticating efficiency was greater in the range of 2 338.49 to 2 825.53 m/min peripheral speed. Beyond this range, the rate of increase in decortication efficiency was reduced (**Fig. 2**). The same trend was observed at all moisture content levels and feed rates. There was a decrease in decortication efficiency as the moisture content of seeds was increased. The kernel damage decreased for the same speed as the moisture content was increased. This might be due to the fact that at low moisture content level, the seeds become brittle and are prone to

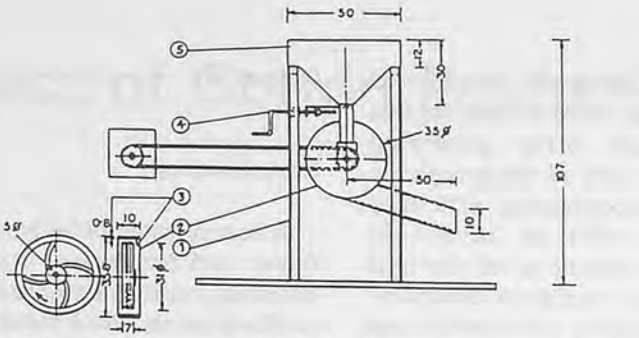


Fig. 1 Centrifugal sunlower seed decorticator.

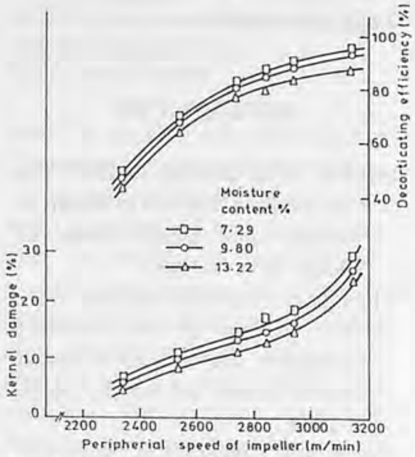


Fig. 2 Effect of peripheral speed on decorticating efficiency and kernel damage percentage at a feed rate of 150 kg/h.

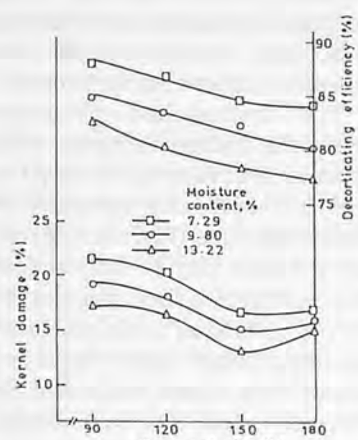


Fig. 3 Effect of feed rate on decorticating efficiency and kernel damage at a peripheral speed of 2 825.53 m/min.

Table 1. Effect of Peripheral Speed on Decorticating Efficiency and Kernel Damage at Different Feed Rates and 9.80% Moisture Content

Feed rate (kg/h)	Efficiency (percent)	Peripheral Speed of Impeller (m/min)					
		2 338.49	2 533.14	2 728.00	2 825.53	2 922.86	3 117.71
90	Decorticating efficiency	49.39	66.00	79.83	84.74	87.66	92.17
	Kernel damage	8.92	13.53	17.49	19.33	20.78	27.60
120	Decorticating efficiency	47.22	65.89	79.05	83.32	87.03	91.41
	Kernel damage	7.88	12.56	16.51	18.00	20.61	28.08
150	Decorticating efficiency	46.13	65.28	78.52	82.20	85.21	89.03
	Kernel damage	6.48	10.01	13.44	15.04	16.50	25.76
180	Decorticating efficiency	42.53	64.15	76.69	80.00	81.48	84.22
	Kernel damage	4.87	9.77	13.50	15.74	17.25	23.57

damage. The kernel damage was high at high speed because the fast centrifugal force generated damaged most of the kernels.

The decorticating efficiency decreased with an increase in moisture content at all the feed rates. The maximum decortication efficiency of 93.46% was obtained at 7.29% moisture content and 120 kg/h feed rate at peripheral speed of 3 117.71 m/min. Whereas at the same peripheral speed, the decorticating efficiency decreased as the moisture content level increased.

The decortication efficiency and kernel damage decreased with an increase in feed rate from 90 to 150 kg/h and then increased at higher feed rates (**Fig. 3**). The reason for this may be that at low feed rates the surface area available for striking of seeds is greater in comparison to higher feed rates. About 25% higher decorticating efficiency and 8% less kernel damage was observed as compared to the decorticator in which impeller rotated on horizontal axis (Nag et al).

Conclusions

A centrifugal impeller type sunflower seed decorticator is giving promising results in decorticating sunflower seeds hwich maximizes the decorticating efficiency and reduces problem of kernel damage to a great extent. The optimum working speed was found to be 2 825.53 m/min.

REFERENCES

Bilanski, W.R. and Lal, R. 1965. The behaviour of threshed materials in vertical wind tunnal. Trans. of ASAE, 8(3): 411-413.

Chaudhary, M.H. and Buchele, W.F. 1975. Effects of the operating parameter on a rubber roller sheller. Trans. of ASAE, 18(3): 482-486.

Cleark, B.P, Baker, G.W, War, P.J. and Maflock, S.W. 1980. Separating kernels and hulls from oil seed type sunflower seed. Trans. of ASAE, 24(1): 20-24.

Hussain, A.A.M., Sabur, M.A. and Rahman, M.M. 1980. Design and construction of manually operated caster bean-cum-jsunflower seed dehuller. AMA, 11(2): 83-84.

Indian Standard. 1985. Test code for groundnut decorticator. IS 11473. Bureau of Indian Standard, New Delhi.

Makanjuola, G.A. 1975. An evaluation of some centrifugal impaction devices for shelling melon seeds. J. Agric. Engng. Res., 20: 71-77.

Nag, K.N., Singh, P. and Bhandari, R. 1983. A centrifugal impeller type sunflower seed decorticator. AMA, 14(1): 55-58.

Singh, R., Srivastva, R. and Singh, B. 1978. Design and testing of ground nut decorticator. AMA, 9(4): 77-81.

Yadav, R. and Singh, P. 1991. Development of vertical rotating type sunflower seed decorticator-cum-cleaner. Paper presented in 27th Annual Convention of ISAE held at New Delhi, from 9-11 Oct. 1991.

(Continued from page 61)

Mechanization of Handling Operations in Wholesale Grain Markets in Northern India: A Case Study in Punjab

REFERENCES

Gill, K.S. 1971. Wheat Marketing Behaviour in Punjab Haryana. Post-harvest period 1968-71. A research bulletin published by the Deptt. of Economics & Sociology, Punjab Agricultural University, Ludhiana.

Gill, K.S. and Rajinder Singh, 1986. Marketing and Handling of Wheat and Paddy in the State of Punjab. Marketing, Transportation and Storage of Wheat and Paddy in Punjab, held on April 10, 1986 at Punjab Agricultural University, Ludhiana, pp 16-26.

Grover, P.C., Rajinder Singh and Mandeep Kumar, 1989. Evaluation of Grain Handling System in Medium Sized Mandis of Punjab. Proceedings of National Symposium on Handling, Marketing, Transportation and Storage of Foodgrains in India, held on October, 19-20, 1989 at Punjab Agricultural University, Ludhiana, pp 82-92.

Holman Leo E, 1989. Improving of grain handling in Indian wholesale markets. Report 4, The Ford Foundation, New Delhi.

Singh, Rajinder, S.S. Ahuja and K.S. Gill, 1972. A Study on Wheat Handling at Mandi Level in Ludhiana District, Journal of Agricultural Engineering, 10(4): 17-25.

Singh, Rajinder, S.S. Ahuja & K.S. Gill, 1975. Phased Mechanization. A research Bulletin published by the Deptt. of Processing and Agricultural Structures Punjab Agricultural University Ludhiana.

Singh, Rajinder and Sadhna Arora, 1989. Integration of Marketing, Storage and Processing Facilities. Proceedings of National Symposium on Handling, Marketing, Transportation and Storage of Foodgrains in India, held on October 19-20, 1989 at Punjab Agricultural University, Ludhiana pp. 101-106.

Mechanical Aspect of Cotton Production in Pakistan

by
Abdul Razzaq
Senior Subject Matter Specialist (Engg.)
Adaptive Research Farm
Sheikhupura, Pakistan

Introduction

In national economy, cotton is number one agricultural export commodity in the form of lint and other products. Inland, widely established textile and allied industry is based upon cotton. Its seed is a major source of vegetable oil supply to oil processing industry in the country. Seed as such and after oil extraction is also used as animal feed. Next to wheat it is grown on the largest area in Pakistan.

In order to obtain the highest yield of cotton, an optimization of bio-hydro-chemical combination through technology is essential. Broadly speaking, technology is of two types, viz; mechanical and non-mechanical. The mechanical aspect of technology involved in high yield cotton crops is discussed below.

Land Levelling

Precision land levelling is a must for uniform uptake of moisture and nutrients by plants. Levelling is also essential in avoiding uneven ponding of rain or irrigation watter in cotton fields. The excess water if not removed in time may damage cotton plants. Precision land levelling may very easily be carried out with the use of automatic laser controlled tractor mounted scraper. Laser equipment is expensive and the facility may be availed of through organizational setup. The literate farmers with appropriate training may precisely level their fields using dumpy level, scraper and leveller. The tractor mounted blade, commonly available among farmers, if carefully operated and followed by the leveller, may provide a reasonable standard of levelling.

Organic Matter Manipulation

For the enhancement and maintenance of soil worth and its fertility, sufficient quantity of organic matter is continuously added in the soil in the form of animal dung, manipulating crop residues and green manuring. Crop rotation consisting of alfalfa - cotton is an ideal combination. Alfalfa crop is chopped with disc harrow in March and ploughed under with furrow inverting plow. Similarly, in the case of cotton - cotton rotation, the preceeding cotton crop is slashed with slasher/shredder or rotavator after last picking. Green manuring crops can very well be adjusted in cotton - cotton and ratooned sugarcane - cotton rotations. In wheat - cotton rotation, wherein wheat has been harvested with combine, the entire residues are inverted in soil with mouldboard or disc plow and irrigation given along with an application of 30 kg/ha urea for its early decomposition. Similarly, an early irrigation is required to decompose soil manipulated crop residues, green manure and other organic matter.

Land Preparation

If the resultant moisture level of the irrigation given to decompose organic matter can remain and accommodate cotton sowing, land preparation tillage practices may be started. If not so, land should be irrigated afresh. On coming to proper moisture level, it should be chiselled twice in bi-direction followed by once disc harrow or twice cultivator. Using land plane, the tilled soil should be somewhat compacted and levelled. As an alternative to land plane, a light roller may also be used.

Cotton is a deep rooted crop. Its tap root may go down to 180-200 cm depth. It is, therefore, essential that subsoiling or ripping of land should invariably be carried out once in five years using subsoiler or ripper.

Sowing

For mechanized cultivation, cotton is sown with row-crop planter in apprriximately 75-cm line distance. The undelinted seed rate is 20-25 kg/ha for American varieties and 15 kg/ha for local ones. The planter requires clean delinted seed without fuzz. Delinting can be done using commercial sulphuric acid at the rate of one litre per 10 kg cotton seed. Sulphuric acid should be dropped on seed while stirring it in plastic pan. Stirring should be continued till the seed becomes free of fuzz and it is dark. It should be rinsed in water and dried.

The cotton seed is particularly sensitive to excessive sowing depth and should not be sown deeper than 5-6 cm. Such planter should be used which may place fertilizer along with sowing in bands at a distance of 5-7 cm from the seed-rows and approximately 5 cm below seeding level. The row-crop planter usually consists of one, two or four planting units and each unit should preferrably function independently of the others. A seed press wheel attached to the planter is essentially required to ensure close contact between the seed and the moist soil in order to speed up germination and the rate of emergence.

Despite the traditional 75 cm uniform spacing between rows, the planter may also be set to sow cotton in variable row-spacing; a new method. In variable row-spacing technique, the cotton can be sown in double rows along the edges of 140-cm wide raised beds that are separated by deep 60-cm wide irrigation furrows made with a ditcher. In this system, each row receives more light on one side than the other. Being very responsive to light, 70 to 80% cotton bolls may be produced on the open side. The system has the advantages of low water requirement, low evaporation losses, no need of thinning and easier and cheaper control of weeds.

Thinning

The plant population required for high yield in cotton is 45 000-60 000 plants/ha for American varieties and 55 000-70 000 plants/ha for local ones. Thinning is manually carried out but twice when plants are 15 and 30 cm high. However, a long-handled, small-bladed manual hoe may reasonably assist in thinning practice.

Weeding

If weeds emerge before cotton, they can be eradicated by using a rotary hoe. Subsequently, weeding can be carried out with inter-row cultivator. The high clearance inter-row cultivator with ridging and fertilizing replaceable attachments and being locally fabricated is an ideal implement. The first cultivation should be taken as early as possible after cotton has emerged and weeds are small and easily destroyable. This operation should be very precise and cultivator hoes be adjusted so as to cause no damage to young cotton plants, to move soil away from plant rows and create a small furrow along the seed-rows. The second cultivation should comparatively be deeper and the cultivator hoes are to move earth towards plant rows so it may cover weeds growing within rows. The subsequent cultivations should be shallow so as to be compatible with good weed destruction. The number of cultivations will depend upon the number of cycles of weed infestation. The cultivation should be stopped when cotton plants attain 80-90 cm height.

Fertilizing and Earthing Up

Nitrogen, phosphorus and potasium (NPK) are essentially required nutrients. Full recommended dose of phosphorus and potasium fertilizers is applied prior to sowing at the time of seed-bed preparation. These basal fertilizers are uniformly spread with tractor driven broadcaster and thoroughly mixed with soil using disc harrow. Nitrogenous fertilizer, as per recommendation, is split into three instalments; 1/3 rd at sowing, 1/3 rd with first irrigation and 1/3 rd at flowering. The first 1/3 rd part of nitrogenous fertilizer should be applied as a band with row-crop planter while sowing cotton. The high clearance inter-row cultivator with fertilizing and ridging attachment can be used to place in-crop-fertilizer along the rows and earth up. The earthing up practice also provides good drainage and anchorage to plants against lodging. Foliar application of fertilizer can be undertaken with power sprayer or tractor driven sprayer.

Dewatering

Cotton plants are sensitive to water ponding. On the advent of high rainfalls, the excess water should be removed from cotton fields immediately using tractor driven low-head, high volume propellor type of pump or with engine-pumping set.

Chemical Application

Apart from delinting and fertilizing, intensive chemical application is carried out on the cotton crop. There is pre- and post-emergence herbicidal, defoliant and 5-7 pesticide applications. All these chemicals can be applied very well with self-propelled or tractor-driven or manually carried power sprayers. On large scale, air craft applicators may also be used.

Picking

The entire cotton crop is manually picked and this job is cherishingly carried out by women in the country. Three to four pickings are common during the season. Two types of cotton harvesters, namely; strippers and pickers, are in use abroad. Cotton strippers remove the entire boll load irrespective of differentiating between open and immature bolls. After harvesting, a special machine separates lint from bolls and the accompanying trash. A more sophisticated but efficient machine is a self-propelled cotton picker. Its spindles can efficiently remove lint from open and still-closed bolls without damaging the plant. For second picking, if economically justified, the machine can also be used.

The mechanical cotton harvesting has not been adopted in Pakistan, nor should it be encouraged because the country's entire cotton growing and its processing system depends upon manual picking. In this concern, the main implications are listed below:

Presently, cotton harvesting machines have to be imported.

The operation is a highly skilled job.

To mechanically harvest, a cotton variety has to be erect growing in which all bolls open more or less simultaneously. Varieties being grown in Pakistan are bushy and give their full yields in about 3-4 pickings.

For mechanical harvesting, cotton has to be planted in rows precisely spaced to match the wheel base of the harvester machine.

For economical machine operation, the cotton fields should be as long as possible. Pakistan's present acre length fields are unsuitable.

The machine needs turning space at the two ends of the fields. It cannot pick cotton in the turning area and it has to be picked there manually and sticks have to be cut to create turning space.

The machine leaves at least 10% of cotton bolls unpicked close to the ground which have to be picked manually or written off as a loss.

Cotton fields earmarked for mechanical picking have to be defolicated by spraying defoliants a fortnight before harvest which is an extra expense.

The machine picked cotton contains leaves and other remnants of the cotton plants besides more dust. It cannot be ginned in Pakistan standard ginneries unless additional cleaning units are installed.

Lint from the machine-picked cotton comes out half to one grade below the hand-picked cotton and has a lower acceptance and lower price in the world market.

Post Picking

Having completed the picking of cotton, its plants should be chopped with the use of slasher/shredder or rotavator and covered with soil by ploughing with mouldboard plow or disc plow to a depth of 25-30 cm. This operation should be accomplished soon after the completion of picking when the stalks are still green and moist as this stage facilitates effective and economical chopping and burried material decomposes more thoroughly and rapidly. The mechanical chopping kills hibernating larvae of the pink bollworms. The practice of grazing goats in cotton fields and cutting and heaping stalks for fuel or burning after drying should be discouraged because a large quantity of organic matter goes up in flames which, if added, is "gold" for soil. ■■

Status and Prospect of Mechanization of Sugarcane Cultivation in Bangladesh

by
S.M. Iqbal Hossain
Asstt. Agric. Engineer
Sugarcane Research and Training Institute
Ishurdi, Pabna
Bangladesh

S.U.K. Eusufzai
Assoc. Agric. Engineer
Sugarcane Research and Training Institute
Ishrdi, Pabna
Bangladesh

M.A. Zaman
Assoc. Professor
Dept. of Farm Power and Machinery
Bangladesh Agricultural University
Mymensingh, Bangladesh

M. Abdullah
Senior Scientific Officer
Farm Machinery Division
Bangladesh Agricultural Research Institute
Gazipur, Bangladesh

Abstract

This paper describes the various cultural practices in sugarcane cultivation in Bangladesh. At present only land preparation is partially mechanized. All other cultural operations are done manually following conventional methods. About 10% to 12% sugarcane field in the mill zone area are prepared mechanically using tractors with disc plough, harrow, spring tine cultivator and ridger. Most of the sugarcane crop is grown in rainfed condition and only 5.5% of the total sugarcane farms are irrigated. There is a wide scope and prospect of introducing suitable agricultural machinery for land preparation, planting, weeding, pesticide application, irrigation, harvesting and ratoon shaving practices for sugarcane cultivation in Bangladesh.

Introduction

Bangladesh consists of about 14.4 million ha of land of which about 8.82 million ha (61.3% of total) are arable. The total land area planted to sugarcane cultivation is about 166.5 thousand ha (**Table 1**) of which about 93.9 thousand ha is in the mill zone and about 72.6 thousand ha in the non-mill zone where sugarcane is produced mainly for chewing and "*gur*"* production

Table 1. Area, Production and Yield of Sugarcane

Year	Area ($\times 10^3$ ha)	Production ($\times 10^3$ ton)	Year	Area ($\times 10^3$ ha)	Production ($\times 10^3$ ton)
1981	148.9	6600	1986	160.3	6640
1982	161.1	7136	1987	164.7	6896
1983	165.9	7257	1988	173.2	7207
1984	166.7	6960	1989	172.0	6707
1985	163.5	6878	1990	187.8	7423

Average area = 166.5 × 10^3 ha.
Average Yield = 40 to 45 t/ha.
Average production = 6.97 × $10^3$6 ton.

Source: Statistical Yearbook of Bangladesh (1991). p.148.

The annual average sugarcane production in the country is about 6.97 million t some 30% of which is crushed in 16 sugar mills. The balance is used for gur making, chewing and seed sett purposes.

The annual sugar and gur production in the country are about 0.2 and 0.3 million t, respectively, which can meet only 60% of the total requirement (0.3 million t sugar and 0.6 million t gur). Bangladesh has to import 50 to 100 thousand t of sugar every year.

The average yield of sugarcane in the country is very low i.e., 40 to 45 t/ha, although the production potential of sugarcane is as high as 222 t/ha (Ali, 1993). The low yield of sugarcane is mainly due to improper and poor land preparation, untimely planting, poor intercultural operations such as weeding, disease and pest control and inadequate supply of fertilizer and irrigation water.

Sugarcane grows well all over

* Raw sugar.

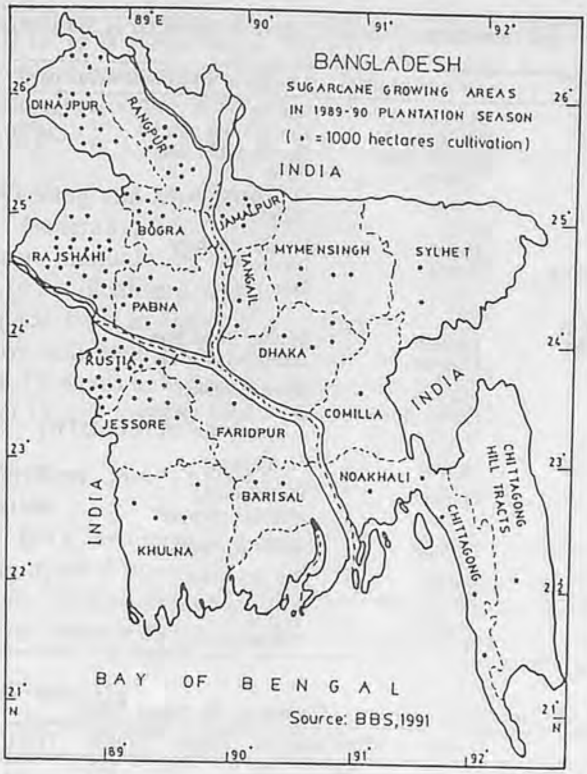


Fig. 1 Distribution and location of sugarcane cultivation in Bangladesh.

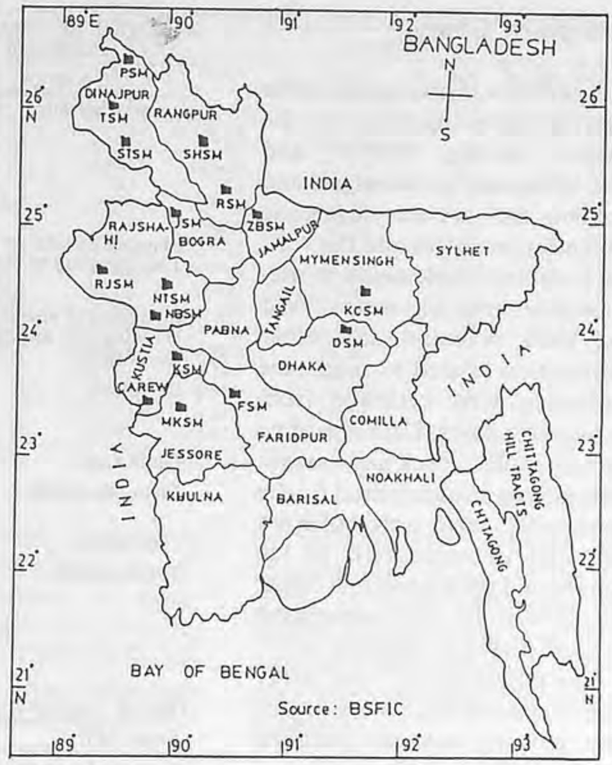


Fig. 2 Location of 16 sugar mills in Bangladesh.

Table 2. Potential Areas for Sugarcane Cultivation in Bangladesh

Division	Greater District	Potential areas for sugarcane cultivation (× 10³ ha)			
		Good	Medium	Poor	Total
Rajshahi	Dinajpur	65	198	200	463
	Rangpur	0	148	59	207
	Rajshahi	8	132	151	291
	Bogra	0	25	4	29
	Pabna	1	17	55	73
	Sub total	74	520	469	1 063
Khulna	Jessore	0	134	123	257
	Kustia	0	104	157	261
	Khulna	0	65	79	144
	Barisal	0	61	18	79
	Patuakhali	0	27	0	27
	Sub total	0	391	377	768
Dhaka	Mymensigh	13	103	104	220
	Tangail	20	15	68	103
	Dhaka	10	43	94	147
	Kishorgonj	0	47	67	114
	Jamalpurl	0	34	69	103
	Faridpur	0	12	160	172
	Sub total	43	254	562	864
Chittagong	Sylhet	43	195	162	400
	Chittagong	2	47	10	59
	Comilla	0	0	68	68
	Noakhali	0	0	16	16
	Sub total	45	242	256	543
	Grand total	162	1 407	1 664	3 238

the country except in some low lying areas. But its cultivation is concentrated in the West and North-West region because of its high resistance to drought. Evidently almost all the sugar mills are located in this region. **Figure 1** shows the main sugarcane cultivation area and **Fig. 2** shows the location of the 16 sugar mills in the country.

The potential areas for sugarcane cultivation is shown in **Table 2**. Of the total 12.3 million ha agricultural land, only 3 238 thousand ha is suitable for sugarcane; 162 thousand being good, 1 407 thousand ha medium and 1 664 thousand ha poor. About one-third of the entire sugarcane area is in the Rajshahi division. The West and North-West low rainfall zone (Rajshahi and Khulna division) is termed as the sugarcane belt of the country. Yearly rainfall in this area starts from April and continues to October. Some 60% of the rainfall is concentrated in the month of June, July and August. The rest of the months are almost dry and crop production in these months requires irrigation water.

Method of Study

A survey was conducted in the sugarcane growing areas of the country during 1990-91 and 1991-92 in order to investigate and evaluate the present sugarcane cultivation practices and the various tools and implements in use. Sugarcane growing areas, yield and yield potential and other information related to sugarcane cultivation were reviewed from various literatures. Data regarding tractor, trailer, truck and various tools and implements used by the sugar mills' farm were collected from the 16 sugar mills of the country and the Bangladesh Sugar and Food Industries corporation through personal contacts.

The objectives of this study were to evaluate the various sugarcane growing cultural practices together with the tools and implements in use and the prospect of introducing improved agricultural machinery for sugarcane cultivation in Bangladesh.

Status of Mechanization

The present status of mechanization of sugarcane cultivation in the country is summarized in **Table 3**, including machinery and implements used for different cultural operations together with their power sources.

Table 3. Power Sources and Implements Used for Different Operation of Sugarcane Cultivation

Operation	Power source	Machines and implements used
Land preparation	Humman Bullock Power tiller Tractor	Spade Indigenous plough Spring tyne, disc Plow Disc harrow, Ridger
Planting of setts or Transplanting of settling	Human Human	Spade, country Plow Hand hoe
Intercultural operations Weeding and mulching Earthing up	 Human Human	 Spade, hand hoe Indigenous tools
Irrigation	Human Engine/motor	Sewing basket, Don, hand pump, pump (for STW or DTW)
Fertilizing	Human	Hand tools
Plant protection	Human	Hand tools, Manual sprayer
Harvesting	Human	Knife & spade
Transportation	Bullock Power tiller Tractor Automobile	Bullock cart Trolly Trailer Truck

Table 4. Agricultural Machines and Implements Owned by the Sugar Mills

Sugar Mill	Tractor	Plow	Harrow	Ridger	Trailer	Truck
Carow and company ltd (C&Co)	52	24	18	7	163	13
Mobarakgonj Sugar Mill (MKSM)	90	16	18	5	296	15
Kustia Sugar Mill (KSM)	78	16	16	8	148	36
Faridpur Sugar Mill (FSM)	48	11	8	4	113	15
North Bengal Sugar Mill (NBSM)	144	23	20	10	312	11
Natore Sugar Mill (NTSM)	81	4	12	0	265	5
Zeal Bangla Sugar Mill (ZBSM)	63	17	13	8	133	3
Joypurhat Sugar Mill (JSM)	128	16	15	9	386	20
Rongpur Sugar Mill (RSM)	89	13	15	3	341	3
Setabgonj Sugar Mill (STSM)	119	13	12	5	286	7
Panchagar Sugar Mill (PSM)	118	20	18	12	350	11
Thakurgaon Sugar Mill (TSM)	76	14	18	7	220	44
Deshbandah Sugar Mill (DSM)	14	0	0	0	63	1
Rajshahi Sugar Mill (RJSM)	89	16	10	4	190	8
Shyampur Sugar Mill (SHSM)	81	14	17	6	281	7
Kalia Chapra Sugar Mill (KCSM)	73	3	10	2	236	6
Total	1343	220	220	90	3783	205

Source: Annual report, 1980-90, BFSIC, Dhaka.

Tillage for Land Preparation

Sugarcane is a deeply-rooted plant with root zone varying from 0.6 to 1.2 m (Uichanco, 1981). For better root penetration, deep tillage is essential for sugarcane. In addition to providing a deeper and wider root zone for the plant, deep tillage allows easy deep percolation of water to prevent water logging, conservation of moisture and facilitation of aeration.

The farmers' fields are sometimes tilled by tractors hired from the mills; but most of their lands are tilled by animal-drawn country plow. Generally, 5 to 6 plowing followed by ladering and subsequent trenching by bullock-drawn country plow is a common practice for sugarcane land preparation by the farmers.

Sett Preparation and Planting

At present sugarcane setts are prepared manually using sharp-edged knife called *hasua*. Planting of sugarcane setts (seeds) is done manually following conventional method. In this method 7 to 8 months old sugarcane plants are cut into 2 or 3 eyed setts by knife and placed in the 1 meter spaced farrows at a distance of 0.5 m between the setts and to a depth of 8 to 10 cm. About 90% of the total sugarcane area is planted using this method.

A new pre-germinated sett transplanting method called 'Spaced Transplanting (STP)' is being practiced recently. In this method, one eyed or two eyed setts are germinated in plastic bag or soil bed and 45- to 60-day old plants are transplanted in the main fields. This new method is more labor intensive than the conventional method and requires about 10 to 15% more labor. But this method saves about 70% seeds and gives higher yield (Ali et al., 1989).

Weeding and Mulching

Generally, 2 to 3 weedings are done manually by hand hoe and 2 to 3 mulchings are done by hand spade both in the mill zone and non-mill zone area. No mechanzied systems have been introduced yet in this regard.

Fertilizer and Pesticide Application

Both fertilizers and pesticides are applied manually using hand tools. Liquid pesticides are sometimes applied by manual sprayers.

Earthing Up

Earthing up is a major intercultural operation which is done manually using spade 1 to 2 times a crop year.

Irrigation

In Bangladesh more than 90% of the sugarcane field is rainfed resulting in low yield. Sugarcane needs 1 200 to 1 500 mm of water either from rainfall or irrigation (Anon, 1989 and Hossain, 1992). The quantity of rainfall and time of rainfall are very much uncertain. Moreover, sugarcane planting season (November to February) is usually dry and irrigation is essentially required at this time to ensure better germination/establishment of setts/settlings and higher yield. During the period from 1981 to 1990 only about 5.5% of the total sugarcane area was irrigated (**Table 5**).

Table 5. Irrigated Sugarcane Fields, 1980-90

Year	Area produced ('000' ha)	Area irrigated ('000' ha)	Area irrigated (%)
1980-81	148.9	9.4	6.3
1981-82	161.1	9.8	6.1
1982-83	165.9	6.5	3.9
1983-84	166.7	7.9	4.7
1984-85	163.5	7.6	4.6
1985-86	160.3	10.6	6.6
1986-87	164.7	10.8	6.6
1987-88	173.2	7.4	4.3
1988-89	172.0	11.6	6.7
1989-90	187.8	—	—
Average	166.4	9.1	5.5

Source: Statistical Yearbook of Bangladesh, 1991, pp.163-184.

Table 6. Sugarcane Cultivated Area and Sugarcane Hauled in Mill Zone, 1990-91

Sugar mill	Area cultivated (ha)			Sugarcane hauled		
	Owned by mill	Owned by grower	Total	Total (× 10^3t)	By mill (%)	By growers (%)
C&Co	1011	6030	7041	101.17	60	40
MKSM	24	6270	6294	118.42	80	20
KSM	28	13981	14009	112.37	63	37
FSM	7	747	754	89.27	57	43
NBSM	1448	9296	10744	134.73	65	35
NTSM	0	7692	7692	73.26	44	56
ZBSM	14	5128	5142	73.26	44	56
JSM	20	6924	6944	124.22	59	41
RSM	617	4863	5480	114.94	81	19
STSM	986	3363	4349	65.18	88	12
PSM	37	4436	4473	55.81	90	10
TSM	809	4656	5465	58.48	74	26
DSM	0	1141	1141	10.94	49	51
RJSM	34	8468	8502	58.90	36	64
SHSM	10	4243	4253	98.11	66	34
KCSM	14	1605	1619	17.23	82	18
Total	5059	88843	93902	1306.29		
Average					62	38

Harvesting

Sugarcane harvesting starts from the first week of November with the start of sugar mills and continues up to mid-March. Harvesting is a labor-intensive operation requiring about 150 laborers (40% of the total laborer requirement) and is done manually by using spade or *hashua*. Manual harvesting accounts for more than 7% yield loss since the canes are cut 8 to 16.5 cm above the ground level (Ali and Matin, 1989).

Ratooning

This practice is most important in sugarcane cultivation as it reduces the cost of land preparation, planting and planting material which together amount to 30% of the total production cost of sugarcane production (Hossain and Hossain, 1993). About 30% of the total land for sugarcane is kept for ratoon cultivation. Since there is no mechanical basal harvester and stubble shaver in Bangladesh, manual harvesting leaves long stubbles in the field causing less tillering and reduced yield (Sharma and Singh, 1988). Introducing basal harvesting and stubble shaving (as practiced in Australia, USA and Mauritius) in the country may increase yield of sugarcane.

Transportation

About 62% of the sugarcane harvest is transported to the sugar mills by mechanical means like tractor driven trailers and trucks owned by mills (**Table 6**). Rail wagons are also used by some mills for transportation of sugarcane. The rest, 38%, is transported by bullock or buffalo carts owned by the growers.

For crushing by the growers using animal driven machines called country crusher or using power driven machines called power crusher for gur production, the sugarcane is transported by bullock carts.

Scope and Prospect of Mechanization

The shortage of draft power is being felt in the rural areas of Bangladesh because rearing of animals is becoming expensive and no land is available for the production of fodder crop. Besides, 40-50% of the draft animals being female and the poor quality of the animals are the major causes of the shortage of draft power in the country (Jabbar, 1980).

Sugarcane needs deep tillage for proper growth and higher yield which is not possible with animal drawn plows (Hossain, 1992). Tractor operated implements are very much needed for deep tillage of sugarcane fields.

Mechanical trenchers or ridgers operated by tractors are necessary as deep planting enhances germination and protects cane lodging. Manual trenching or ridging is very laborious and time consuming. Besides, trenching by animal draft power is not deep enough.

The new sett cutting machine is much more effective and efficient than the conventional method (Hossain et al., 1993).

Planting in rows by tractors gives higher yield and efficient management of intercultural operations like weeding, mulching, earthing up and fertilizer and pesticide application with mechanical means.

Irrigation water will increase the yield of sugarcane by 30% or more (Hossain, 1993).

Manual harvesting of sugarcane by *hasua* is more cumbersome than other chores and laborers are sometimes reluctant to do this job. Timely harvesting and ratoon keeping with manual labor is difficult.

The low yield of ratoon canes calls for the introduction of sugarcane harvester and ratoon shaver together with other ratoon management practices in Bangladesh (Hossain and Hossain, 1993).

Conclusion

Complete mechanization of sugarcane cultivation is not possible overnight. Partial mechanization of some specific or selected operation where human or animal power is inadequate and discouraging, can be suggested.

Farm operations like tillage, weeding, irrigation, harvesting and ratoon shaving should be brought under an immediate mechanization program.

In introducing machines for power cultivation of sugarcane, emphasis should be given on the following factors:

1. The size and capacity of the machine should suit the average plot size of the farmers.
2. The machine should have a low operating cost and should increase the farmers' net income.
3. New machines should be developed in the country keeping in view the cultural and socioeconomic conditions of the farmers. The design and operation of the machine should be as simple as possible.

REFERENCES

Ali, M.; Matin, M.A. 1989. Assessment on cane losses due to indiscriminate harvesting. Bangladesh Journal of Sugarcane. 11: 114-115.

Ali, M.Y.; Imam, S.A. and Ali, M.K. 1989. Ropa akh chash. Sugarcane Research and Training Institute, Ishurdi, Pabna, Bangladesh.

Ali, S.M.E. 1993. Hardnessing agricultural potentiality in Bangladesh with reference to sugarcane production. Seminar paper. 19th senior staff course, Bangladesh Public Administration Training Center (BPATC), Savar, Dhaka, Bangladesh.

Alim, A. 1974. An Introduction to Bangladesh Agriculture. 1st Edition, January, 1974.

Anonymous. 1980-90. Annual report. Bangladesh Sugar and Food Industries Corporation

Anonymous. 1980-90. Annual Report of 16 sugar mills of Bangladesh.

Anonymous. 1987-91. Statistical year book of Bangladesh.

Anonymoous. 1987-91. Agricultural year book of Bangladesh.

Anonymous. 1989. Notes on the Australian Sugar Industries, March, 1989.

Uichanco, Edilberto A. 1981. The Australian sugarcane cultural system: A fully mechanized, high yield, high efficiency way to produce sugar. AMA. 12(3): 11-16.

Jabbar, M.A. 1980. Draft power shortage and mechanization of tillage in Bangladesh. Bangladesh Journal of Agricultural Economics. 3(1): 1-26.

Hossain, S.M.I. 1992. Sugarcane cultivation in Bangladesh: Need for mechanization. The Bangladesh Observer. July 27, 1992.

Hossain, S.M.I. 1992. Sugarcane irrigation in Bangladesh. The Bangladesh Observer. December 20, 1992.

Hossain, S.M.I. and A.H.M.D. Hossain. 1993. Sugarcane ratooning: A profitable cultivation practice. The Bangladesh Observer. December 3&5, 1993.

Hossain, S.M.I., S.U.K. Esufzai and M.A. Hossain. 1993. Design and fabrication of power operated sugarcane sett cutting machine. Bangladesh Journal of Sugarcane. Vol. 12-15: 13-18.

Sharma, M.P. and K. Singh. 1988. Mechanization of sugarcane ratoon culture in India. AMA. Vol. 19(1): 45-47. ■■

Mathematical Models for Diesel Consumption for Farm Tractors in Allahabad District, India

by
R.H. Kazmi
M.Sc.Ag.Engg. Final-year Student
Allahabad Agricultural Institute
Allahabad - 211 007
India

Tufail Ahmad
Professor and Head
Dept. of Ag.Mech. and Process Engg.
Allahabad Agricultural Institute
Allahabad - 211 007
India

Abstract

The present work developed a quantitative relationship between diesel consumption and tractor age, annual use and labour cost for maintenance of the different makes of tractors used by the farmers of Allahabad district. The tractors selected for the study were HMT Zetor - 2511, Escort - 335, Massey Ferguson - 1035 and International B-275. The operating parameters of 80 tractors of different age groups were recorded. Multiple regression model for diesel consumption of tractors of different makes were developed.

Introduction

With the increasing use of farm machinery, farm tractors play an important role in enhancing agricultural productivity. The farmers will not reach their full potential until research engineers as well as tractor manufacturing units assume their proper role in the hierarchy of research development and training activities. The diesel consumption of tractors constitutes a major portion of operating costs. Diesel consumption of tractors depends upon age of tractors, annual use and labour cost for maintenance. Hence, there was a need to develop a model for diesel consumption which could help in deciding the optimal overhaul and replacement age of tractors.

The present study was undertaken to determine a quantitative relationship in diesel consumption of different makes of the tractors used by the farmers in Allahabad district. The makes of tractors were HMT Zetor - 2511, Escort - 335, Massey Ferguson - 1035 and International B-275.

Methodology

To conduct the study, a survey in Allahabad district was done. Geographical information of the area, type of soil, and administrative division, etc. were collected with the help of geographical and political maps of the district. For the selection of farmers, a three

Fig. 1 Map of Allahabad district.

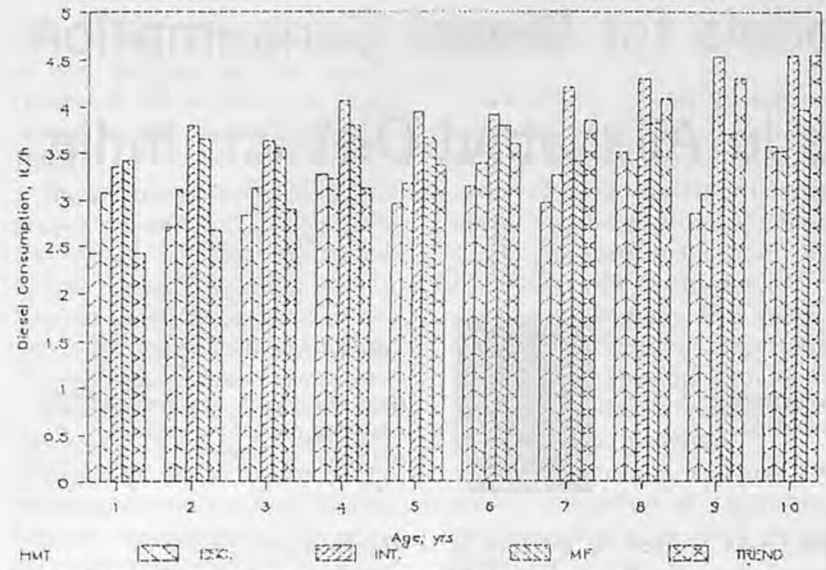


Fig. 2 Effect of age on diesel consumption of different makes of tractors.

Table 1. Annual Use, Diesel Consumption and Labour Cost for Different Ages of HMT Zetor - 2511 Tractor

Age (yrs)	Annual use (h)	Diesel consumption (ℓ/h)	Labour cost for maintenance (Rs)
1	1 000	2.50	200
2	800	2.50	400
3	600	2.75	500
4	300	3.00	800
5	600	3.00	600
6	400	3.00	800
7	300	3.00	700
8	800	3.50	1 200
9	900	3.00	800
10	500	3.50	1 000

Table 2. Annual Use, Diesel Consumption and Labour Cost for Different Ages of Escorts - 335 Tractor

Age (yrs)	Annual use (h)	Diesel consumption (ℓ/h)	Labour cost for maintenance (Rs)
1	900	3.00	300
2	1 000	3.00	400
3	700	3.50	600
4	900	3.00	500
5	800	3.00	800
6	700	3.25	500
7	600	3.50	1 000
8	400	3.00	800
9	400	3.00	1 800
10	600	3.50	1 200

Table 3. Annual Use, Diesel Consumption and Labour Cost for Different Ages of Massey Ferguson - 1035 Tractor

Age (yrs)	Annual use (h)	Diesel consumption (ℓ/h)	Labour cost for maintenance (Rs)
1	600	3.50	300
2	400	4.00	500
3	500	3.50	500
4	600	4.00	600
5	700	4.00	500
6	800	3.50	1 000
7	1 000	3.50	2 000
8	300	3.50	500
9	900	3.50	1 500
10	500	4.00	1 000

Table 4. Annual Use, Diesel Consumption and Labour Cost for Different Ages of International B-275 Tractor

Age (yrs)	Annual use (h)	Diesel consumption (ℓ/h)	Labour cost for maintenance (Rs)
1	1 000	3.50	400
2	700	3.50	700
3	900	3.75	800
4	400	4.25	500
5	500	4.00	400
6	600	3.50	600
7	400	3.75	800
8	300	4.50	700
9	500	4.50	2 000
10	600	4.50	1 500

stage sampling technique was used, as the three zones of its district (Jamunapar, Gangapar and Dowaba) were grouped at the first stage, *tehsils* at the second stage and villages at the third stage.

The tractors were selected randomly. The operating parameters for one year were recorded. Two tractors of each make for each age group were selected for the study. The tractors taken for study were of one to 10 years of age.

The survey location of different villages in Allahabad which were surveyed is given in **Fig. 1**. The graph which shows the effects of age on diesel consumption of the different makes of tractors are given in **Fig. 2**. The parameters for the different tractors were age of tractor in years; annual use hours; labour cost, for maintenance; and diesel consumption in ℓ/h are given in **Tables 1-4**.

Assumptions

1. The observation taken in this study were in consultation with the farmers and the repair shops.
2. The condition of tractors deteriorates with age resulting in increasing diesel consumption.
3. The working condition of all the zones were identical.
4. The labour cost for maintenance of the tractor was on the basis of actual charge made by the tractor repair shops.

Results and Discussions

The multiple regression analysis was done by the Micro stat package and the multiple regression model for diesel consumption litre per hour of the different makes of tractors was found. The diesel consumption of the tractors was taken as dependent variable, denoted by Y. The age of the tractor, annual use, and labour cost for maintenance were taken as independent variables, denoted by X_1, X_2 and X_3, respectively.

i) HMT Zetor - 2511

$$Y = 2.4346 - 0.0599X_1 - 0.0002343X_2 + 0.0015X_3$$

Where,

Y = Diesel consumption, ℓ/h
X_1 = Age of tractor, years
X_2 = Annual use, h
X_3 = Labour cost for maintenance, Rs. and multiple correlation coefficient

$R_{y.123} = 0.9031$
$R^2 = 0.8157$ i.e. 81.57% of the total variation is explained by the independent variables.
$F_{cal} = 8.836 > F_{3,6}(5\%) = 4.76$

Hence, the null hypothesis is rejected. Therefore, there is significant contribution of the variables X_1, X_2, X_3 on the variation of the dependent variable Y. Therefore, the model is adequate. There is a high positive correlation between Y and X_1, X_2, X_3.

ii) Escorts - 335

$Y = 3.2145 + 0.0751X_1 - 0.0000772X_2 - 0.0004408X_3$
$R_{y.123} = 0.9013$
$R^2 = 0.8123$ i.e. 81.23% of the total variation is explained by the independent variables.
$F_{cal} = 4.92 > F_{3,6}(5\%) = 4.76$

Therefore, the null hypothesis is rejected at 5% level of significance. Hence, the model is adequate. There is a high positive correlation between age of tractor and diesel consumption. This means that as the age increases diesel consumption increases.

But the other two factors have very slight negative correlation with diesel consumption which shows that as these factor increase, diesel consumption decrease.

iii) Massey Ferguson - 1035

$Y = 3.2009 + 0.0393X_1 + 0.00063X_2 - 0.00054X_3$
$R_{y.123} = 0.8013$
$R^2 = 0.7420$ i.e. 74.2% of the total variation is explained by the independent variables.
$F = 7.210 > F_{3,6}(5\%) = 4.76$

Therefore, H_o is rejected. Hence, there is significant contribution of the variables X_1, X_2, X_3 on the variation of dependent variable Y. Hence, model is adequate. There is a high positive correlation between age of tractor and diesel consumption which means that as age increases diesel consumption increases.

iv) International B-275

$Y = 4.2777 + 0.0107X_1 - 0.0011X_2 + 0.00034X_3$
$R_{y.123} = 0.9103$
$R^2 = 0.8284$ i.e. 82.84% of the total variation is explained by all the three independent variables.
$F_{cal} = 6.754 > F_{3,6}(5\%) = 4.76$

Hence, the hypothesis is rejected at 5% level of significance. Therefore, the model is adequate. According to the equation, there is high positive correlation between age and diesel consumption. But there is slightly negative correlation between annual use and diesel consumption.

Conclusion

All the models for different makes of tractor are adequate at 5% level of significance. There is always high positive correlation between age of tractors and diesel consumption. As the age of the tractor increases, the diesel consumption increases. ■■

FINDER SYSTEM FOR AMA ARTICLES AVAILABLE

A computerized finder system consisting of a database listing of all technical articles in Agricultural Mechanization in Asia, Africa and Latin America since it began publication in 1971, along with searching software, is available without charge. The system is on a 3 1/2 inch diskette for use with IBM-compatible computers. Requests for this diskette should be sent to:

William Chancellor
Bio/Agric. Engineering Dept.
University of California
Davis, CA 95616, USA
(e-mail: wjchancellor@ucdavis.edu)
(fax: 916-752-2640)

The diskette will be sent by air-mail. Those with access to the INTERNET may download AMA-96.EXE (or a larger agricultural engineering database, AE-NDX95.EXE) by using File Transfer Protocol (FTP) from POPPY.ENGR.UCDAVIS.EDU (or 128.120.65.75 for those wishing to use numeric characters), User = anonymous, Password = guest. Before "getting" either file by FTP, first type: binary <enter>. Either of the above files should then be placed by itself in a hard-disk subdirectory. Typing the file name (without extension) <enter> will result in a ready-to-run system activated by typing: HI <enter>.

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.

419

Design, Development and Evaluation of a Low Cost Power Operated Groundnut Decorticator Cum Cleaner: Prusty, P.C., M. Tech. Student; S.K. Nanda, Reader; and D.K. Das, Prof. and Head; respectively, Dept. of Farm Machinery and Power, C.A.E.T., Orissa University of Agric. and Tech., Bhubaneswar, India.

The machine that was developed hence subject of this paper, has a decorticating unit and a cleaning unit with a blower which are powered independently by a single electric motor. Decorticating cylinder peripheral speed of 177 m/min (215 rpm) was found to be optimum considering the maximum decortication capacity of 170 kg/h and breakage of kernel within one percent at 5.26% m.c. (w.b.) of the pod. The cleaning efficiency of the blower was 95% at an air speed of 5 m/min. The total power requirement was 1 200 watts and the cost of fabrication of the machine was U.S.$65.00.

430

Performance Evaluation of a Mechanical Peeler for Cassava: Palaniswamy, P.T., Assist. Professor, Dept. of Agrl. Processing; S. Pugalendhi, Assist. Professor, Dept. of Bio-Energy; T. Pandiarajan, Ph.D. Scholar, Dept. of Agrl. Processing; V.V. Sreenarayanan, Professor, Dept. of Agrl. Processing, respectively, Tamil Nadu Agricultural University, Coimbatore 641 003 India.

A horizontal feed cassava peeler was fabricated and tested with tubers of varying moisture content in relation to peeling efficiency and starch loss. The various machine parameters like rotor length, blade angle, speed of rotation and position of the feeding chute were optimized.

The rotor length was kept at 10, 20, 30 and 40 cm. The blade angle selected were 35, 50 and 65 degrees. The speed of rotation used were 540, 800, 1 100 and 1 350 rpm. The feed chute was kept at 30°, 60° and 90° with reference to the axis of rotation of the peeling rotor shaft. The moiosture content tried were 30%, 50% and 75% (w.b.) 30 cm rotor length, 50° blade angle, feed chute with 90° to rotor shaft and 1 100 rpm speed of rotation and tuber with 50% m.c. yielded a maximum peeling efficiency of 85.43% with a starch loss of 3.90%. The capacity of the machine was 1 000 kg/h and the cost of peeling was worked out to be Rs. 3.50/t.

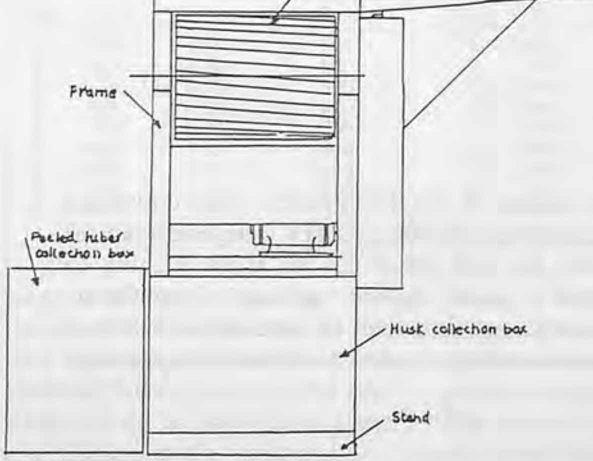


Fig. Schematic diagram of cassava peeler.

431

Studies on Energy Consumption in Commercial Rice Mills of Allahabad Region : Jacob, Kurian; Saji T. Saviour; Tufail Ahmad, Professor and Head, respectively, Dept. of Process Engineering and Agricultural Structures, College of Agri. Engg. and Technology, Allahabad Agricultural Institute, Allahabad, India.

The study was conducted on energy consumption in three leading commercial rice mills of Allahabad region. The selected mills were CLRU, Jasra, SDRM, Jari, and GLKRRM, Naini. The Naini mill was involved in the production of rough rice or paddy whereas the other two mills produced parboiled rice by traditional double steaming method.

The results indicate that the total energy consumed for paddy processing were 741.426 kWh/t, 524.359 kWh/t and 19.629 kWh/t in Jasra, Jari and Naini mills, respectively. The food energy ratio (FER) for these three respective mills were 1.77, 3.06 and 6.73. The FER was above 2.8 in Jari and Naini mills and hence was favourably energetic. ■■

EIMA '96 — International Agricultural Machinery Manufacturers Exhibition
November 9-13, 1996
Bologna, Italy

One hundred thousand visitors for EIMA's 1995 edition: an absolute record for such a highly specialized show, devoted to mechanization in the agricultural, garden and animal husbandry fields. A clear sign of its "high ratings" with Italian and foreign economic operators, technicians, experts, farmers and jobbers, whose numerous presence confirmed the wide popularity EIMA has won for itself, which will be repeated at the 27th edition of EIMA and EIMAGARDEN, whose dual title marks EIMA's further specialization in the "green" sector, both professional and amateur, whilst at the same time maintaining its maximum visibility formula: display area subdivided into 14 product sectors, no "company" advertising, exhibition facilities reserved for manufactures only, visits upon invitation during the last two days of its foreseen five-day total.

Designed and organized by UNACOMA through its subsidiary UNACOMA Service Srl., in collaboration with Bologna Fiera, EIMA has always been the international mechanization world's top image venue, its most complete window on the farming and gardening equipment universe and its platform for launching innovations. With its range of events including sepcial shows on the fairground premises, meetings and debates on topics of pre-eminent interest to the scientific, technical and professional agricultural and industrial world, EIMA's 27th Edition is an absolute "must" for all agro-environmental operators.

Technical data:

- Bologna's Fair neighbourhood covers a total surface of 250 000 m^2: 18 covered air-conditioned pavilions for an exhibition of 104 000 m^2.
- Airport at 6 km, railway station and town centre at 2 km; the superhighway exit directly to the fair (n. 8); parking for 4 200 cars.

In the light of the '95 results — over 1 400 exhibitors from 37 different countries, a range of 16 300 models of machinery on display, 100 000 visitors from a hundred nations — and confirmation of the positive overall trend of the mechanization market for the present year, we may look forward to a '96 Edition of EIMA that amply fulfils all the exhibitors' and economic operators' expectations.

In addition, we are pleased to inform you that full up-to-the-minute information on EIMA and EIMA Garden is available on INTERNET at the following address: **http:/www.smart.it/EIMA**. Web operators are invited to let us have their Internet addresses so that we can send them future communications about EIMA by this means.

World Food Summit
November 13-17, 1996
Rome, Italy

The idea of a world summit on food security was first raised in 1994 by FAO's Director-General, Dr. Jacques Diouf. His proposal was unanimously accepted by the FAO Conference in October 1995 and supported by the United Nations General Assembly in December 1995.

Heads of state and government from close to 200 countries are expected to gather at FAO Headquarters to agree on the blueprint for a coordinated campaign, in partnership with civil society and international organizations, to eradicate hunger.

The personal participation of national leaders is instrumental in mobilizing all government ministries and agencies concerned with food security — from agriculture, fisheries, forestry and the environment to foreign affairs, trade, economy and development cooperation.

As a world forum, the Summit will take a global perspective in dealing with all aspects of food security. At the same time it will address the specific challenges faced by different regions of the world.

The agreements reached at the Summit will place food — the first and fundamental requirement for life — at the top of the global agenda alongside peace and stability.

The Summit will last for five days. Heads of state and government will address the Summit from midday on Friday 15 November, through Sunday 17 November.

For further information, contact: World Food Summit Secretariat, FAO Headquarters viale delle Terme di Caracalla, 00100 Roma, Italy Fax: (396) 5225-5249, e-mail: foodsummit@fao.org

International Agricultural Engineering Conference 1996
December 9-12, 1996
Pune, India

With the grand success of the International Agricultural Engineering Conference held in 1994 at the Asian Institute of Technology (AIT), Bangkok, Thailand and participants from 21 countries attending the above conference, the next conference has been scheduled from December 9-12, 1996, in Pune, India. The conference will be the first ever conference to be held outside Thailand and expect to be attended by scientists, researchers, engineers, extension workers and executive planners from various continents of the globe.

The 1996 conference aims to provide a common platform for formal exchange of ideas and research findings thus providing future direction to all the concerned for the betterment of agriculture.

The conference will be jointly organized by Bhumata Charitable Trust, Pune, Yeshwantrao Chavan Pratishthan, Indian Council of Agricultural Research, and Asian Association for Agricultural Engineering.

Contact: Dr. Suresh S. Dhumal, Bhumata Charitable Trust. 6/11, Pritam Nagar, Kothrud, Pune, India - 411 029. Tel.: +91-212-36 0708, Fax.: +91-212-64-4828.

---

3. International Conference on Housing and Engineering in Livestock Farming

March 11-12, 1997
Kiel, Germany

This conference applies to scientists, engineers and manufacturers who develop and distribute new techniques as well as to farmers and consultants as users of latest scientific results.

Main Topics

Current Legislation and Consequences; Man-Power; Livestock Housing Design; Automation in Livestock Production; Emissions from Livestock; New Housing Systems in Pig Production; Dairy Farming; and Climate Control.

Call for Papers

Experts in the mentioned topics who wish to contribute with a paper to the success of this conference are invited to submit an abstract to:

Institut für Landwirtschaftliche Verfahrenstechnik
Prof. Dr. H.J. Heege
Christian-Albrechts-Universität zu Kiel, D-24098 Kiel

For any information concerning registration and general information please contact:
Dr. Dorothee Holste
Phone: *49-431/880-2355 oder 880-3790, Fax: *49-431/880-4283
e-mail: dholste@ilv.uni-kiel.de

Agriculture Asia '97 and Postharvest Horticulture Asia '97

May 15-18, 1997
Philippine Trade Training Center, Manila, Philippines

Agriculture Asia '97, the second show in this biennial series, will feature a comprehensive line up of technologies and services in agriculture, irrigation and related agri-industries. Incorporated are two specialized shows being organized for the second time: Fisheries and Aquatic Resources Asia '97 and Animal Production and Health Asia '97.

Expected to be bigger and better in 1997, Agriculture Asia '97 is being staged concurrently with Postharvest Horticulture Asia '97 exhibition and conference, the only one of its kind in the Philippines and in the Southeast Asian Region to showcase the specialized nature of the requirements of the postharvest sector in terms of technology, services and products.

Should you require further information, please feel free to contact us through the address below or by fax through number (63-2) 815-3152.

HQ Link Philippines, Inc., Unit B, 8th Floor, Cacho-Gonzalez Building, 101 Aguirre Street, Legaspi Village, The City of Makati, Metro Manila, Philippines Tels: (63-2) 810-3694, 810-5685, 892-6045.

5th International Symposium on Fruit, Nut, and Vegetable Production Engineering

September 3-10, 1997
Davis, California, U.S.A.

The Fifth International Symposium on Fruit, Nut, and Vegetable Production Engineering will take place in the U.S.A. (California). Prior Symposiums were held in Israel (Bet Dagan) in 1983; France (Paris) in 1988; Denmark, Sweden, and Norway in 1991; and Spain (Valencia-Zaragoza) in 1993.

The objective of the symposium is to bring together researchers involved in all aspects of engineering for the production of fruit, nut, and vegetable crops.

Abstracts will be accepted for oral or poster presentations in the following areas:

- Cultural systems: planting, pruning, thinning, managing of fertilizers, and chemical and biological pest control.
- Harvesting methods and systems: mechanization, handling, robotics and sensors.
- Post harvest operations: quality evaluation, grading and sorting, damage and waste reduction, packaging, transportation, and processing technologies including technology for lightly processed fruit and vegetables.
- Human and environment factors: Ergonomics, safety, productivity, GIS systems, dust and noise control.

Contact: Dept. of Biological and Agric. Engineering, University of California, Davis, California 95616-5294, U.S.A. Phone: (916) 752-0102, Fax: (916) 752-2640, e-mail: bioageng@ucdavis.edu

Agritech Spring '96 Closed
More than $50 Million in Business Done at Agritech

Tel Aviv, Israel. May 19, 1996 — Agritech Spring '96 closed on Thursday 16 May with the Israel Export Institute reporting on agri-business deals worth over $50 million being closed at the exhibition.

About 7 000 overseas visitors came to the Tel Aviv Fairgrounds, including buyers, government representatives, farmers and researchers. Over 100 different nations were represented at the exhibition. India brought the largest delegation, numbering 1 500. They were joined by 500 visitors from China, and substantial delegations from Slovenia, Argentina, Turkey and countries from all five continents. Middle-Eastern and North African nations were also well represented, with visitors from Egypt, Jordan, Morocco and other countires attending the tri-annual agrotechnology fair.

Said Israel Export Institute Agriculture Department Head Yitzhak Kiriati, "Business deals were conducted on the governmental as well as the corporate level. Following Agritech, Israeli agricultural companies have increased their share of business across the globe, including in China, India, CIS countries, Thailand, Morocco, and Egypt, as well as Mexico, Spain and Turkey."

Those inputs to be exported from Israel include irrigation and greenhouse equipment, seeds, plastics and software. Increasingly, integrated solutions and turnkey projects are also making their mark.

IFTEX '96 Exhibition
September 28-29, 1996
London, U.K.

Interest is blooming in the floricultural industry for the new look IFTEX '96 exhibition. Relocated at the Business Design Centre, London on 28-29 September, familiar faces are booking their stand space for what promises to be a great show.

Exhibitors from around the world, and across the industry, have already reserved prime locations at IFTEX, where they expect to do business with old and new customers. Already, companies or supplying groups from 14 countries have signed up, with the most recent being Jamaica, Israel and Denmark.

Nearly 90% of space has already been taken in the core area of the show featuring fresh flowers and plants. This section always draws the key buyers who visit the exhibition specifically to source new suppliers and varieties.

At the same time these buyers are also searching for the sundries and services that support this industry; there is a large demand by visitors to meet freight companies, transportation providers, and companies providing pots, packaging, labels etc. IFTEX is seen by these visitors as a 'one-stop-shop' where all their needs can be fulfilled, without having to visit packaging, gardening and transport shows.

Further exhibition enquiries:
Malcolm Taylor, BGLA Ltd., 4 St. Mary's Hill Stamford , Lincs PE9 2DP. Tel: +44 (0) 1780 482044.

Mini Coconut Dehusker

The most common method of dehusking coconut is by piercing a full nut against a sharp pointed iron stake permanently fixed on the ground and quickly twisting to separate the husk from the shell. Many attempts have been made to mechanize this operation and a new device has been designed

and developed by V. Ganesan and L. Gothandapani of the Department of Agricultural Processing, College of Agricultural Engineering, Tamil Nadu Agricultural University for dehusking coconut.

The working part of the dehusker consists of a tong like structure mounted on a pillar. The coconut is kept suitably over a platform below the tong. The jaws of the tong is penetrated into the husk portion of the coconut by downward pressing and subsequently the jaws of the tong is opened which results in the separation of the husk from the nut.

The coconuts could be dehusked easily without force. The cost of this gadget is around Rs.200/-. With the help of this gadget the time taken for dehusking one coconut is less than a minute.

For further information contact:
V. Ganesan, Dept. of Agric. Processing, College of Agric. Engineering, Tamil Nadu Agricultural University, Coimbatore-641 003, South India.

The Second Edition of the IAMFE Directory

(Sweden)

After several delays, we have now printed The second edition of the International Directory of Manufacturers, Machinery, Equipment and Instruments for Agricultural Research (The IAMFE Directory). Extra copies can be purchased for USD 10/copy (members of IAMFE) and USD 20 (non-members), respectively. The edition is limited.

The IAMFE Directory will only be as good as the IAMFE network can make it. We call upon everyone to contribute with addresses and information for the next edition on manufacturers (Index B and C in the enclosed directory), important research institutions and consultants (Index D), Publications on Mechanization of Agricultural Research (Appendix 1) and Directories of Manufactured Machinery and Equipment for Agriculture in General (Appendix 2).

Contact: International IAMFE Centre, c/o Department of Agricultural Engineering. P.O. Box 7033, Swedish University of Agricultural Sciences, S-750 07 Uppsala, Sweden.

ASAE Standards 1996

Standards Engineering Practices Data

(U.S.A.)

Standards 1996. This hardbound 43rd Edition contains more than 200 standards, engineering practices, and data — one-third of which were newly adopted, revised, or reaffirmed in the past year. ASAE places at your fingertips the latest standards for equipment and systems involved in producing, storing, handling, and processing biological products.

Contributors to *ASAE Standards 1996* share their knowledge and experience on such subjects as: agricultural machinery, irrigation, drainage, livestock housing, food processing, commodity storage, safety, turf and landscape equipment, electric power applications, environmental issues, and more. Standards are developed through the Cooperative Standards Program (CSP) and undergo rigorous review by ASAE technical committees and task groups.

ASAE Standards 1996 is for anyone who needs the most current standards and practices related to engineering for food, agriculture, and biological systems.

Published annually by ASAE, $135.00 List, $44.50 ASAE member.

Physical Principles of the Plant Biosystem

(U.S.A.)

by George E. Merva

This new textbook covers the basic physical, chemical, and thermodynamic principles of the plant biosystem from the viewpoint of their actions in the biosphere. Author Dr. George E. Merva, professor at Michigan State University, brings together important aspects of energy transfers with related areas pertinent to the green plant environment. This text lays the engineering groundwork to tie physical and biological concepts together in the context of the biosystem.

Students will become aware of the natural physical and chemical actions peculiar to the plant biosystem which enables the biosystems engineer to minimize unwanted biological reactions while enhancing beneficial responses. This integrative text introduces differential equations through a solution method which allows the engineer to resolve problems without closed-form solutions. These techniques are applied not only to familiar problems such as heat flow in metals, but also to problems in the biosphere such as the motion of water droplets from a sprinkler. In addition, each chapter contains exercises to increase the student's understanding of the plant biosystem.

272 pages, 8 1/2 × 11 inches, hardbound, $47.00 List, $38.00 ASAE member.

Mail to: ASAE, Dept. 1651, 2950 Niles Road, St. Joseph, MI49085-9659 USA.

The Age of Synthesis

A Treatise and Sourcebook

(USA)

by Carl W. Hall

This century is widely recognized as the Age of Analysis. *A posteriori* evidence is accumulating to demonstrate that the next century will be the Age of Synthesis. Synthesis will supplement analysis as a major thrust in our technological society. Synthesis requires a vision to project into the future, and demands a more holistic approach. Synthesis can help reduce the "two cultures" syndrome. Both natural and unnatural or human-made systems, involving the arts, sciences, the professions, and the applied fields, are discussed, as well as the philosophy of Plato, Aristotle, Kant, and many other recognized philosophers.

Carl W. Hall, Ph.D., P.E., is a consultant in Arlington, VA. He has degrees from The Ohio State University, University of Delaware, and Michigan State University, and participated in the SMG Program at Harvard University.

248 pages, 6 × 9 inches, hard cover, $49.95 (US).

Published by Peter lang Publishing, Inc., 275 Seventh Avenue, New York, NY 10001, U.S.A. ■■

INSTRUCTIONS TO AMA CONTRIBUTORS

The Editorial Staff of the AMA requests contributors of articles for publication to observe the following editorial policy and guidelines in order to improve communication and to facilitate the editorial process :

Criteria for Article Selection

Priority in the selection of articles for publication is given to those that —

a. are written in the English language ;
b. are relevant to the promotion of agricultural mechanization, particularly for the developing countries ;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission ;
d. deal with practical and adoptable innovations by small farmers with a minimum of complicated formulas, theories and schematic diagrams ;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article ;
f. are printed, double-spaced, under 4,000 words (approximately equivalent to 8 pages of AMA-size paper) ; and those that
g. are supported by authentic sources, reference or bibliography.
h. written on floppy disc.

Rejected/Accepted Articles

a. As a rule, articles that are not chosen for AMA publication are not returned unless the writer(s) asks for their return and are covered with adequate postage stamps. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
b. When an article is accepted but requires revision/modification, the details will be indicated in the return reply from the AMA Chief Editor in which case such revision/modification must be completed and returned to AMA within three months from the date of receipt from the Editorial Staff.
c. "The AMA does not pay for articles published. However, the writers are given collectively 5 free copies (one copy air-mailed and 4 copies sent by surface/sea mail) of the AMA issue wherein their articles are published. In addition, the main author is given an article on floppy disc with AMA true format. Co-authors can get a copy from main author.
d. Complimentary copies: Following the publishing, three successive issues are sent to the author(s).

Procedure

a. Articles for publication (original and one-copy) must be sent to AMA through the Co-operating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article may be sent directly to the AMA Chief Editor in Tokyo.
b. Contributors of articles for the AMA for the first time are required to attach a passport-size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
c. The article must bear the writer(s) name, title/designation, office/organization, nationality and complete mailing address.

Format/Style Guidance

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

Co-operating Editors

F M Fonteh | E A Baryeh | A A K El Behery | A M El Hossay | B S Pathak | D B Ampratwum | R J Bani | I K Djokoto | D K Some | J C Igbeka

E U-Odigboh | K C Oni | U B Bindir | N G Kuyembeh | A H Abdoun | A B Saeed | Surya Nath | A I Khatibu | A K Mahapatra | S Tembo

I de A Nääs | A E Ghaly | E J Hetz | A A Valenzuela | O Ulloa-Torres | H O Laurel | S G C Magana | W J Chancellor | M R Goyal | A L Philips

G R Quick | S M Farouk | M A Mazed | M Gurung | Wang Wanjun | A M Michael | T P Ojha | S R Verma | Soedjatmiko | M Behroozi-Lar


J Sakai

B A Snobar

C J Chung

C C Lee

I Haffar

M Z Bardaie

M P Pariyar

E S Eldin

A D Chaudhry

A Q Mughal

R ur Rehman

R M Lantin

R P Venturina

S Illangantileke

S F Chang

T S Peng

S Phong-supasamit

C Rojanasaroj

V M Salokhe

G Singh

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

Manbahadur Gurung
Natural Resource Training Institute, (Construction) Lobesa, P.O. Wangdiphodrang, Bhutan

Wang Wanjun
Senior Engineer of Chinese Academy of Agricultural Mechanization Sciences, Honorary President of Chinese Society of Agricultural Machinery, No. 1 Beishatan, Deshengmen Wai, Beijing, China

A.M. Michael
Vice-Chancellor, Kerala Agricultural University, Vellanikkara, 680654, Thrissur Dt., Kerala State, India

T.P. Ojha
H.I.G.-30, Gautam Nagar, Bhopal 462 023, India

S.R. Verma
Prof. of Agricultural Engineering, College of Agril. Engg., Punjab Agricultural University, Ludhiana - 141004, India

Soedjatmiko
Head of Subdirectorate of Agric. Engineering, Ministry of Agriculture, Jakarta, Indonesia

Mansoor Behroozi-Lar
President, Iranian Society of Agricultural Machinery Engineers, P.O. Box 31585-574, Karaj, Iran

Jun Sakai
Professor Emeritus, Dept. of Agric. Engineering, Faculty of Agriculture, Kyushu University 46-05, Hakozaki, Higashi-ku, Fukuoka 812, Japan (Mailing address: 31-1, Chihaya 2-chome, Higashi-ku, Fukuoka 813, Japan)

Bassam A. Snobar
Professor & chairman, Piant Production Dept., Faculty of Agriculture, University of Jordan, Amman, Jordan

Chang Joo Chung
Professor, and Dean, College of Agriculture and Life Sciences, Seoul National University, Suweon 441-744 Korea 103

Chul Choo Lee
Research Professor, Seoul Woman's University, Mailing Adress: Rm. 514 Hyundate Goldentel Bld. 76-3 Kwang Jang Dong Ku, Seoul, Korea

Imad Haffar
Associate Professor of Agric. Mechanization, Faculty of Agricultural Sciences, United Arab Emirates University, Al Ain, P.O. Box 17555 UAE

Muhamad Zohadie Bardaie
Professor and Deputy Vice Chancellor (Development Affairs), Universiti Pertanian Malaysia, 43400 UPM, Serdang, Selangor, Darul Ehsan, Malaysia

Madan P. Pariyar
Consultant, Rural Development through Self-help Promotion Lamjung Project, German Technical Cooperation, P.O. Box 1457, Kathmandu, Nepal

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

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

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

Rafiq ur Rehman
Director, Agricultural Mechanization Research Institute, P.O. Box No.416 Multan, Pakistan

Reynaldo M. Lantin
Agricultural Machinery Expert, Regional Network for Agricultural Machinery, c/o United Nations Development Programme P.O. Box 7285 ADC Pasay City Metro Manila, Philippines

Ricardo P. Venturina
President & General Manager, Rivelisa publishing House, 215 F, Angeles St. cor Taft Ave. Ext., 1300 Pasay City, Metro Manila, Philippines

S. G. Illangantileke
Head, Dept. of Agric. Engineering, Faculty of Agriculture, University of Peradeniya, Sri Lanka (Mailing Address: Postharvest Specialist and Regional Representative South West-Asia, International Potato Center (CIP), Regional Office, IARI Campus, New Delhi 11012, India)

Sen-Fuh Chang
Professor, Agric. Machinery Dept. National Taiwan University, Taipei, Taiwan

Tieng-song Peng
Deputy Director, Taiwan Agricultural Mechanization Research and Development Center, FL. 9-6, No. 391 Sinyi Road, Sec. 4, Taiwan

Surin Phongsupasamit
Associate Professor, Dept. of Mech. Engineering, Faculty of Engineering, Chulalongkorn University, Ban 10330, Thailand

Chanchai Rojanasaroj
Research and Development Engineer, Dept. of Agriculture, Ministry of Agriculture and Cooperatives, Bang-Khen, Bangkok 10900, Thailand

Vilas M. Salokhe
Associate Professor, Div. of Agric. and Food Engineering, Asia Institute of Technology, Bangkok, Thailand

Gajendra Singh
Professor and Deputy Director General (Engineering) Indian Council of Agricultural Research (ICAR) Krishi Bhawa, Dr. Rajendra Prasad Road, New Delhi-110001, India

Yunus Pinar
Associate Professor, Agric. Engineering Dept., Faculty of Agriculture, University of Ondokuz Mayis, Kurupelit, Samsun, Turkey

Pham Van Lang
Director, Vietnam Institute of Agricultural Engineering, Vien Truong, Vien Cong Cu Va Co Gioi Hoa Nong Nghiep Phuong Mai, Dong Da - Ha Noi, Viet Nam

—EUROPE—

Anastas Petrov Kaloyanov
Professor & Head, Research Laboratory of Farm Mechanization, Higher Institute of Economics, Sofia, Bulgaria

Pavel Kic
Associate Professor, University of Agriculture Prague, Faculty of Agric. Engineering, 165 21 Praha 6-, Suchdol, Czechoslovakia

Henrik Have
Prof. of Agric. Machinery and Mechanization at Institute of Agric. Engineering, Royal Veterinary- and Agricultural University, Agrovej 10 DK2630 Tastrup, Denmark

Giuseppe Pellizzi
Director of the Institute of Agric. Engineering of the University of Milano and Professor of Agric. Machinery and Mechanization, Via G. Celoria, 2-20133 Milano, Italy

Aalbert Anne Wanders
Staff Member, Dept. of Development Cooperation, Netherlands Agricultural Engineering Research Institute (IMAG), Wageningen, Netherlands

John Kilgour
Senior Lecturer in Farm Machinery Design at Silsoe College, Silsoe Campus, Silsoe, Bedford, MK45 4DT, UK ■■


Y Pinar

P V Lang

A P Kaloyanov

P Kic

H Have

G Pellizzi

A A Wanders

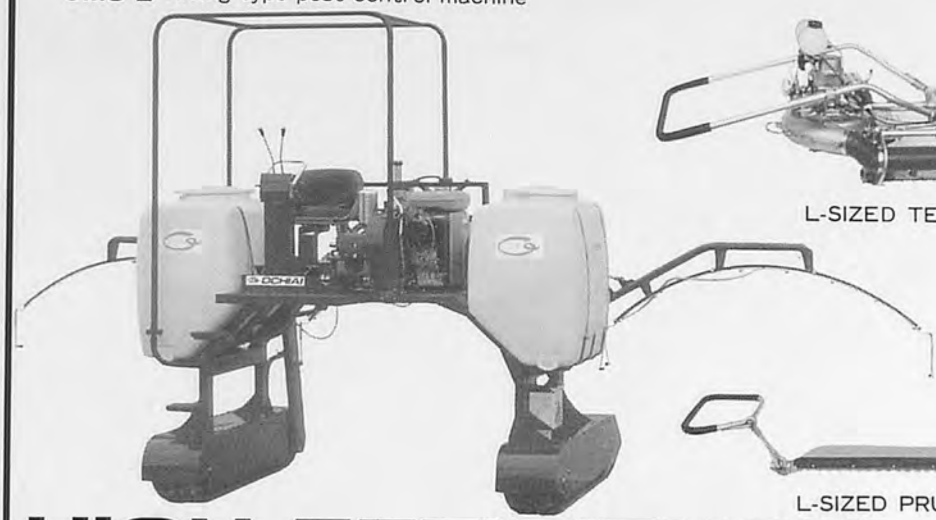
J Kilgour

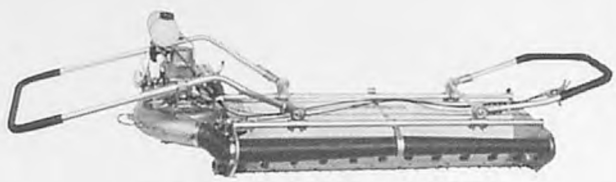
BACK ISSUES

(Vol. 26 No. 1, Winter 1995 ~)

OCHIAli is the top-ranking tea-leaf piker manufacturer in Japan. OCHIAI's products are used in tea-producing areas worldwide.

OMS-2 Riding type pest control machine



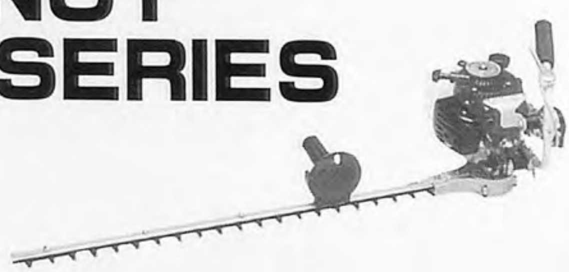


L-SIZED TEA PLUCKER *V-8*

L-SIZED PRUNER *R-8*

HIGH-EFFICIENCY RIDING TYPE SERIES

OM-25 Full-width tea picker



ENGINE PRUNER *E-6*

GUIDE TO OCHIAI

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

OCHIAI HAMONO KOGYO CO LTD

OCHIAI-SHOJI CO., LTD.

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