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AMA

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EDITORIAL

During the ASAE Summer Meeting held in Kansas City, Missouri end June, it was discussed at international committee whether ASAE should rejoin CIGR from which it had once withdrawn. Most members agreed to rejoin and final decision will be made accordingly. In that respect ASAE seems to be moving in the right direction.

In view of realities of today's world, it can be said that we are not in an age where one society or one country can lead whole world but in an age where various people and organizations build up linkage paying regard to each other. CIGR has made such efforts for a long time. Though it encountered many structural problems in the past, CIGR is now in an attempt to improve its activity and the status of organization for making more intensified approach toward a global solution of agricultural engineering problems. It is expected for CIGR to play a key role in linking agricultural engineers all over the world. The most important work expected for CIGR is to shrink the gap between developed and developing countries. CIGR World Congress is to be held in Milano, Italy from end August to early September this year with nearly two thousand attendance. Hopefully the Congress will be rewarded with good results. Dr. G. Pellizzi, the president of CIGR, was pioneering to recognize the importance of AMA. He has served as the first cooperating editor of AMA in Europe. He has shown a deep and proper understanding of the problems in developing countries.

The formal name of ASAE was changed to "Society for Engineering in Agricultural, Food and Biological Systems". Also the title of the society journal was changed from "Agricultural Engineering" to "Resources". These changes seem very regrettable to me. *Agricultural engineering* is one of the most important key words for mankind at the present and in the future. Because more than half of world population lives in rural area, where the population growth rate is also the highest. This is the most serious problem mankind is faced with today. In other words the most important assignments on earth are to raise agricultural productivity, to improve farmers' livelihood and to promote agricultural mechanization in developing countries. Unless we solve these problems, economical gap between the north and the south, urban and rural areas, will never shrink, which will impact the entire world in a damaging way with much more tension to create confusion and wars. An immediate need exists to weigh feasible solution to the problems with concerted efforts both by developed countries and by developing countries. This task should be also supported by governments and business enterprises all over the world. We must give it wider publicity that to raise living level and purchasing power of farmers in developing countries is the only way to ensure the development of world industries and urban life.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
July, 1994

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Predicting Soil Moisture Status and Suitable Field Workdays under Tropical Conditions

by
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Abstract

A soil moisture model which estimates daily values of moisture content in the top 300 mm of the soil profile is described. The model was developed by computing evapotranspiration, surface run-off and drainage on a daily basis by using soil characteristics and climatological data.

Actual field measurements were carried out in Morogoro, Tanzania to observe the variation of soil moisture content for two consecutive farming seasons. Good agreement was obtained between the predicted values and experimental data.

The results show that the model can be extended and used to classify soil moisture data and thus enables one to determine the suitable field working days and non-working days once the soil workability criteria is defined. In this study, a day was found to be suitable for field work when the soil moisture content was at or below 95% of field capacity. Using weather data of the past 11 years, the occurrence of suitable field workdays was determined and the average number of days for soil tillage in Morogoro was established.

Introduction

Farm machinery planning and scheduling of field operations needs a knowledge of the time available for ploughing, planting and harvesting operations. A day is normally assumed suitable for field work when the soil is tractable. If excessive wheel slippage can reduce the tractor's effective pulling power or cause serious soil structure damage, then the soil is no longer considered to be tractable (Hassan and Broughton, 1975).

The main criteria for tractability is a specific maximum level of soil moisture which must either be measured or assumed. A high moisture content may reduce field trafficability and increase the risk of damage to soil structure, thereby preventing tillage and seeding operations from being carried out. At low soil moisture content, the soil is hard and more coherent due to cementation effect between the dried particles. Clods will be produced if the soil is tilled in this condition. It have been also reported that 150 mm soil layer largely determines whether the soil is tractable or not (Nath and Johnson, 1980).

A number of simulation models have been developed to predict the various elements of the soil moisture balance equation in order to determine the moisture status of the soil (Holmes and Robertson, 1959; Ligon et. al, 1965; Bolton et. al, 1968; Selirio, 1969; Elliot, 1977 and Idike, 1982). These models use the general soil moisture balance equation, but they differ in the calculation of individual elements, i.e., evaporation, drainage and run-off.

This paper reports the results of a study carried out to determine the effect of soil moisture on tillage operations in the semi-arid area of Morogoro, Tanzania. A simulation model which was used to estimate the soil moisture content on a day-to-day basis is described.

Soil Moisture Balance Model

Daily fluctuation of soil water level was modelled by estimating the movement of water into and out of the soil profile. Rainfall was the only inflow of water modelled. In this study, the upper 300 mm soil layer was considered for trafficability purposes and the following general equation, as proposed by Witney and Eradat Oskoui (1982), was used:

$$S_m = S_{mp} + R_a - R_u - D - E_v \quad \ldots(1)$$

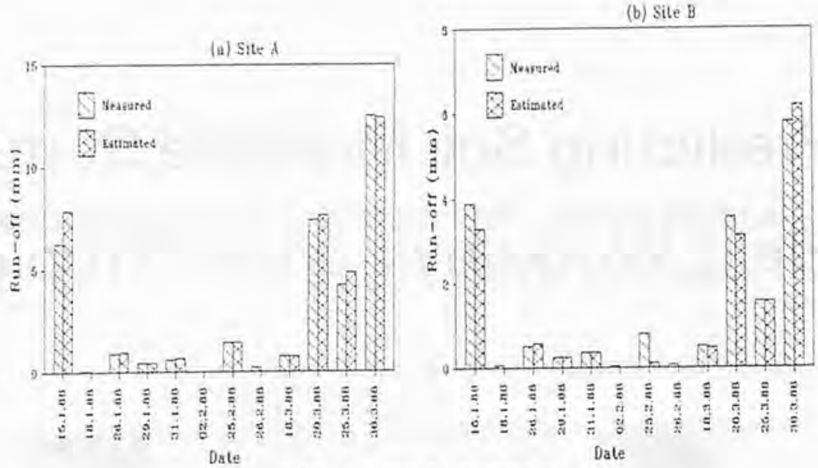

Fig. 1 Measured and estimated run-off.

Where:
S_m = Soil moisture content, mm
S_{mp} = Soil moisture content on previous day, mm
R_a = Daily rainfall, mm
R_u = Surface runoff, mm
D = Drainage, mm and
E_v = Evapotranspiration, mm

Surface run-off was computed as a function of current rainfall using a model developed by the USA Soil Conservation Service (SCS) (1972).

Using the SCS technique, run-off is designated by numbers called runoff curve numbers (R_{cn}) and is calculated as follows:

$$R_u = \frac{(R_a - 0.2S)^2}{(R_a + 0.8S)} \quad ...(2)$$

and S, watershed storage parameter was determined by:

$$S = \frac{25400}{R_{cn}} - 254 \quad ...(3)$$

The R_{cn}, which takes into account the soil type, land use and soil cover complexes, was estimated from tables. (Schwab et al. 1966; Hunt 1986). The input run-off curve number used in this study was 75, which represents short grass as the soil surface cover, and where the land is used for growing small grain, i.e., sorghum and millet in a fairly uniform flat land. **Figs. 1(a)** and **(b)** show the results of the predicted and measured runoff.

Water infiltrating the soil was estimated after the soil has reached field capacity. Excess water above soil holding capacity was considered sub-surface drainage. It has also been shown that the percolation rate of free water through the soil is empirically related to the wilting point of the soil (Hunt 1986). Drainage was thus determined using the following relationship:

$$D = \frac{\text{Amount of moisture above EC}}{2\ \text{PWP}} \quad ...(4)$$

Where:
FC = Field capacity
PWP = Permanent wilting point

Daily values of the evapotranspiration (E_v) were modelled in two steps. First, the potential evapotranspiration (P_2) using the Penman equation was determined as a function of open pan evaporation for conditions where sufficient moisture was in the soil for short grass vegetation.

In the second step, the Penman estimates (P_e) values, were adjusted to obtain actual evapotranspiration. This was done by using correction factors which took into account the daily rainfall and moisture depletion as proposed by Ligon et. al, (1965) and later by Witney and Eradat Oskoui (1982). The actual evapotranspiration was calculated as:

$$E_v = P_e \times K_d \times K_s \times K_r \quad ...(5)$$

Where K_d, K_s and K_r are correction factors for soil dryness, surface cover and number of rainy days, respectively (Appendix A).

Appendix A.

Correction factors for calculating actual evapotranspiration

A.1 Rainy day correction factors (K_r)

Number of consecutive days without rain	K_r
0	1
1-2	0.75
3-5	0.65
5 and above	0.55

A.2 Soil surface cover correction factor (K_s)

The effect of soil surface cover on evaporation is also accounted for by using a soil surface correction factor as proposed by Gerb (1966), which states that the rate of evaporation decreases linearly as the percentage surface cover (K_s) increases to 100%.

The following relationship was used:

$$K_s = 1 - 0.005P_c \quad ...(A1)$$

where P_c = percentage soil surface cover.

A.3 Soil dryness factor (K_d)

The soil dryness factor is defined as the ratio of the actual evapotranspiration to the potential evapotranspiration.

The relationship defined by;

$$K_d = E_v / P_e \quad ...(A2)$$

is determined graphically once the soil available water capacity is known (Agric. Compendium).

Figs. 2(a) and **(b)** show the typical resutls for the measured open pan evaporation as compared to the predicted values using the Penman model.

Field Workdays Prediction Model

Field working days suitable for tillage and planting operations are

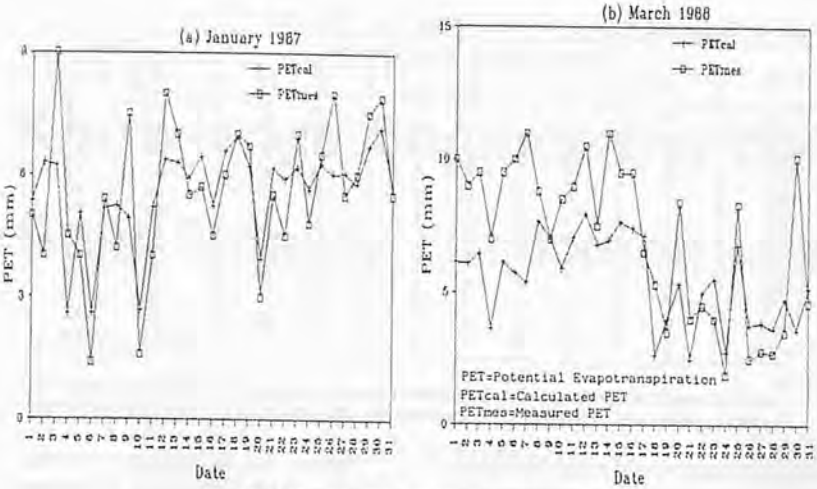

Fig. 2 Measured and estimated evaporation.

governed by the soil moisture and workability of the soil. A soil is workable if:

a) it has sufficient compressive strength to withstand the weight of the machinery;
b) it has sufficient shear strength to meet the traction requirements with acceptable wheel slip and soil damage; and
c) a suitable soil tilth can be produced.

The selection criterion for a workday and non-working day is very subjective since soil workability varies from soil to soil, machine to machine and from one operation to another. It is, however, generally agreed that tillage is best accomplished when it is done below 80% of available soil moisture, i.e., at soil moisture content of up to field capacity. Ideally, the soil should not be worked at a moisture content exceeding the lower plastic limit of the soil.

In this study, the soil workability criteria used was 95% of field capacity above which it was found that the quality of the resulting seed bed was poor and excessive wheel slippage was experienced.

The suitable field workdays for the investigated soils was then estimated and compared with the observed workdays during the experimental periods. **Table 1** is a summary of the observed and estimated workdays.

Results and Discussion

The soil water balance model (Eq.1) was used to predict soil moisture at two sites, in Morogoro. The predominant soil type at the experimental site is sand clay loam soil. The actual values of soil moisture were measured using gravimetric method. The predicted values using the model were compared with the average measured values over a period of two years. **Figs.** 3 and 4 show the typical trend found when using the model to estimate the soil moisture in January to March, 1988.

From the figures, the predicted moisture trend is the same when compared with the actual observed field moisture. However, the model tends to overpredict the soil moisture content. This can be due to several factors. The crop coefficient parameters, percentage coverage of soil by grass, and the run-off curve numbers are all estimated values. In order to improve the level of accuracy and reliability of these parameters, exact values have to established. Therefore, measurements of these input factors, including the effect of ground cover (e.g. corn stubble vs bare soil), on soil moisture would be beneficial future research work.

In addition, the daily weather data used for this study, i.e., temperature, wind velocity, percent

Table 1 Observed and Estimated Field Work Days

Farming week No.	Date	1988		1987	
		Observed	Estimated	Observed	Estimated
1	Jan. 1-7	7	7	5	7
2	Jan. 8-14	7	7	1	1
3	Jan. 15-21	2	3	0	0
4	Jan. 22-28	5	7	4	2
5	Jan. 29-Feb. 4	5	7	5	7
6	Feb. 5-11	7	7	4	5
7	Feb. 12-18	7	7	6	7
8	Feb. 19-25	6	7	6	7
9	Feb. 26-Mar. 4	5	7	3	4
10	Mar. 5-11	7	7	5	7
11	Mar. 12-18	6	7	5	6
12	Mar. 19-25	1	1	2	1

Note:
1. Farming season week numbers 1-8 represent the time available for tillage operation.
2. Farming season week number 9-11 represent the time available for planting operation.

sunshine, relative humidity, radiation and rainfall were not exactly from the location where the experiments was conducted. This might have caused errors in the intermediate calculations of parameters such as the potential evapotranspiration. However, it is believed that if the projected values of such parameters are known together with the characteristics of soil and cover crop, the model can predict the soil moisture fluictuation reasonably well.

A computer programme was then developed to simulate the daily changes of soil moisture for the last 11 years. The programme is described in detail by Simalenga, (1989). The prediction of suitable days was accomplished by using the soil workability criteria and generating sequences of "go" and "no-go" days. A "go" day was defined as a field work day and "no-go" day was a day when field condition was too wet for the tractor to produce satisfactory seedbed. From the analysis, the average number of suitable days for tillage and planting operations in Morogoro was found to be 34 and 14 days, respectively **(Table 2)**.

Conclusions

The study has shown that the

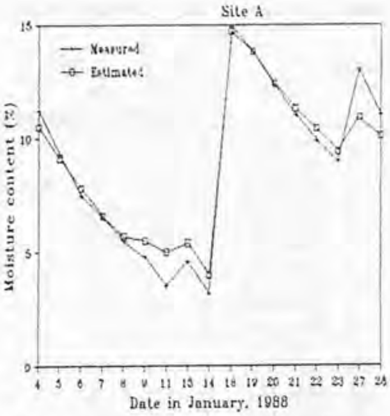

Fig. 3 Measured and predicted soil moisture.

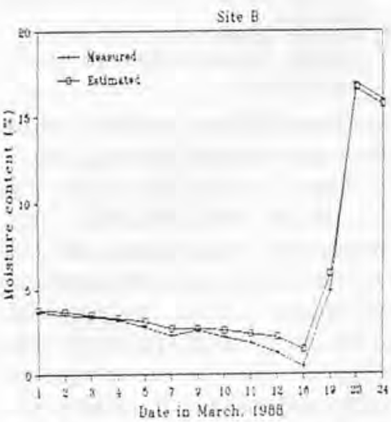

Fig. 4 Measured and predicted soil moisture.

Table 2. Estimated Number of Field Work Days, Morogoro

Year	Farming Season Week Number											Total	
	1	2	3	4	5	6	7	8	9	10	11	1 to 8	9 to 11
1988	7	7	3	7	7	7	7	7	7	7	7	52	21
1987	7	1	0	2	7	5	7	7	4	7	6	36	17
1986	7	6	0	0	0	7	2	2	7	5	1	24	13
1985	0	7	7	7	6	0	0	0	0	3	7	27	10
1984	5	7	3	0	0	0	0	0	2	7	1	15	10
1983	4	2	5	7	7	7	7	2	7	7	3	41	17
1982	4	7	7	7	7	7	7	7	7	7	6	53	20
1981	7	7	7	7	7	7	7	7	7	7	7	56	21
1980	6	7	7	7	1	1	4	3	2	0	7	36	9
1979	7	7	0	2	0	0	0	0	0	3	1	16	4
1978	7	0	0	0	0	2	7	5	5	6	1	21	12
Average	6	5	4	4	4	4	4	4	4	5	4	34	14

Note:
1. Farming season week numbers 1-8 represent the time available for tillage operation.
2. Farming season week numbers 9-11 represent the time available for planting operation.

soil water balance model can be effectively used to estimate the daily variation in soil moisture. The model can also be used to visualize the general condition of the field in terms of trafficability and, hence decide whether field operations can be done or not.

The model used in this study is empirical, thus more comparison with field observations from other areas with similar soil type should be made to obtain greater confidence in the basic assumptions used. However, if the model is used to simulate soil moisture for a location with a different soil type, the appropriate soil input parameters will have to be determined and incorporated into the model.

One limitation of the model which is worth noting is that it does not take into account the time of day when rainfall occurs. For example, a heavy rain in the late evening would result in a non-work day according to the model, even though the soil may have been dry enough to be tilled during the daytime. This effect, however, trends to balance-oput over the course of months or longer periods. Furthermore, the climatological data which were used in the model are from one station only and data collected from more stations in the same vicinity should give a higher confidence in the daily variability of soil moisture.

REFERENCES

Agricultural Compendium for rural development in the tropics and sub-tropics. 2nd Edition, Elsevier Publishing Co. Inc. 1985.

Bolton, J.B. Penn, F.T. Cooke, Jr. and A.M. Heagler. 1968. Days suitable for fieldwork, Mississippi River Delta Cotton Area. Research report No. 384. Department of Agricultural Economics and Agribusiness, Louisiana State University.

Gerb, B.W., 1966. The effect of surface applied wheat straw on soil water losses by solar distillation. Soil Science Society of America Proceedings, 30: 786-788.

Hassan, A.E. and Broughton, R.S., 1975: Soil moisture criteria for tractability. Can. Agric. Engg., Vol. 17, (2): 124-129.

Holmes, R.M. and Robertson, G.W., 1959: A modulated moisture budget. Monthly weather review. 87 (3): 1-7.

Hunt, D.R., 1986. Engineering models for Agricultural production. AVI publishing Company, Inc.

Idike, F.E., Larson, C.L. and Slack, D.C., 1982: Modelling soil moisture and effectsof basin tillage. Transactions of ASAE, Vol. 25, (5): 1262-1267.

Ligon, J.T.; Benoit, G.R.; Elam, A.B., 1965. Procedure for estimating occurrence of soil moisture deficiency and excess. Transactions of ASAE, 8 (2): 219-222.

Nath, S. and Johnson, W.H. 1980: Development of soil moisture model to predict soil moisture and tractability for harvesting. Agricultural mechanization in Asia (AMA) Vol. 11 (1): 73-78.

Schwab, G.O.; Frevert, R.K.; Edminster, T.W.; Barnes, K.K., 1966. Soil and water conservation Engineering. 3rd Edition, John Wiley & Sons, 1966.

Selirio, I.S. and Brown, D.M. 1972: Estimation of spring workdays from climatological records. Can. Agric. Engg., Vol. 14, (2): 78-81.

Simalenga T.E. 1989. Simulation model to predict field workdays and its use in machinery selection under tropical conditions. Unpublished Ph.D. thesis, Royal Vet. and Agric. University, Copenhagen, Denmark.

U.S.D.A.-SCS., 1972. Soil conservation service national engineering handbook, U.S. Department of Agriculture, 1972.

Witney, B.D.; Eradat Oskoui, K., 1982. The basis of tractor power selection on arable farms. Journal of Agricultural Engineering Research 27: 513-527

Knowledge Engineering-based Studies on Solar Energy Utilization in Kenya (Part II)

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Abstract

The nature and extent of the dust on the efficiency of solar generation of electricity was analyzed using the neural network system analysis technique. The results obtained showed a substantial reduction of the energy conversion efficiency of solar module by dust layer that accumulates on the surface of the solar module. The neural network model developed indicated that the energy conversion efficiency of the solar module is reduced from 6.46% to 4.79% by the dust (0.1 mm thick) covering over the solar cell surface at 420 W/m^2 of solar energy input which results in more than 25% of energy loss.

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Introduction

Kenya has a relatively uniform distribution of solar radiation throughout the year. This is good potential that should be utilized to generate energy, especially for agricultural and domestic use. In Part 1, it was reported that the software which can provide a quick and accurate means of gathering the vital information necessary for development, generation of installation and assessment of solar energy in Kenya was developed (Mailutha and Murase, 1993).

In the thinking of installation of solar cell generation of electricity, a unique problem arises, i.e., the adverse effect of the extreme surrounding conditions such as high temperatures and thick dust, on the efficiency of solar generation of electricity. Maximum efficiency will be obtained when the hardware is used under optimum conditions of the surrounding. Since the dust problem on the solar generation of electricity is unique only where such extreme environmental conditions exist and high demands for solar generation of electricity exist, no research report on this subject so far has been found. The research work reported in Part 2 concentrated on the effect of dust on the efficiency of solar generation of electricity. The effect of dust was analyzed by identifying the energy conversion system of solar module under influence of dust by using a neural network model.

Statement of the Problem

Figure 1 illustrates the energy conversion system of solar module. The output of the system is the amount of electricity (E_{out}) generated by the solar module. The input energy is the solar radiation (E_{in}). The efficiency of the solar generation of electricity is obtained by $\{E_{out}/(E_{in} \times S)\} \times 100\%$ where S is the area of the solar module. The conversion efficiency of the standard type of amorphous solar module falls in the range from 8% to 13% at the standard test conditions [AM-1.5, 100mW/cm^2, 25°C] (Kuwano and Takeoka, 1991). The efficiency is generally affected by the cell junction temperature and the air mass (AM) which is a function of local air pressure and solar elevation angle (Kyocera Corporation, 1992). In Kenya, the dust must be also considered as an influential factor. Since the data related to the effects of the temperature and the air mass on the efficiency of the solar generation of electricity of solar modules have been provided by the manufacturers of solar modules, the investigation concentrated on the influence of dust in this study. The tilt angle of solar module from the horizontal should be taken into account as a factor which influences the accumulation of falling dust over the surface of the solar module and also varies the power output of the solar module due to the change in its effective area against the solar radiation.

It was assumed that the energy conversion system of solar module with the dust effect would behave nonlinearly. The system involves three input parameters (1. solar radiation, 2. amount of dust covering the solar module surface, 3. tilt angle of the solar module) and one output parameter (generated electricity). The identification of the system was attempted by using the Kalman filter neural network of which details were discussed in Part 1 (Mailutha and Murase, 1993).

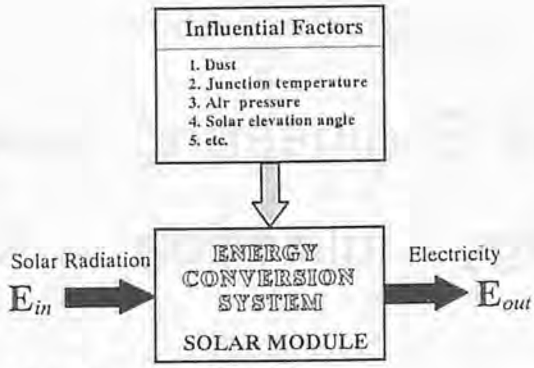

Fig. 1 Factors affecting the energy conversion efficiency of solar module.

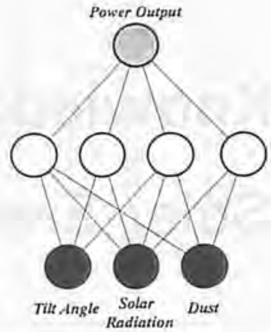

Fig. 2 Neural network used to model solar energy conversion system.

System Identification by Neural Network

Neural Network Structure

Figure 2 illuustrates the three layered neural network structure to model the energy conversion system of solar module with the dust effect. Three input units are needed to carry designated input parameters, i.e., the solar radiation, the amount of dust and the tilt angle of the solar module. One output parameter, i.e., the amount of electricity generated by the solar module requires to fit the neural network with one output unit. Four units were employed in the hidden layer. Both hidden unit and output unit have a sigmoid nonlinearity in this model.

Experimental Procedure

The system can be analyzed by examining the neural network model trained properly with adequate training data which should be obtained by experiment in this case. In this experiment, two input parameters, i.e., the amount of dust covering the solar module and the tilt angle of the solar module were considered to be controllable. The experiment was carried out under the natural solar radiation conditions. The experiment was conducted from September 1993 to November 1993 at the Department of Agricultural Engineering, Jomo Kenyatta University College of Agriculture and Technology, Nairobi, Kenya.

Two amorphous solar modules (Sanyo: Amorton AMP-0415, Area = 0.1 m^2) were used as a main component of the experimental system. The solar modules were mounted on metallic frames at a height of 0.3m from the ground. A radiation sensor (Koito:IKS-35) was used to measure the energy input. For data acquisition, a data logger (Kyowa: UCAM-5BT) was used. The fine dust particle (0.94 g/cm^3 in density) used in this research was obtained from clay soil by sieving through 0.6 mm sieve. the fine dust particles. The box was specifically fabricated for this dusting exercise **(Fig.3).** One solar module was confined inside the box of a known volume space (1 m^3). The solar module confined in the box was subjected to dust by applying fine dust particles on its surface. The other solar module was always kept outside of the box with dust free conditions for control. A measured quantity of dust was blown to float initially over the space in the box and then fall free on the surface of the cell. Four different dust densities (0, 47, 142, 284 g/m^3) were applied. The dust was not directly placed on top of the module. A very thin self adhesive clear plastic wrap of predetermined fixed size was placed on the surface of the module and then the dust fell freely onto the wrap. The difference between the total weight of the dust plus the wrap, and the wrap alone gave the amount of dust actually collected on the surface of the solar module. The tilt angle of the module from the horizontal was varied from zero degrees to 32 degrees at intervals of eight degrees. For each tilt angle, for sets of data were taken, the variable being the amount of dust, i.e., 0 g, 47 g, 142 g, and 284 g of dust. Twenty replications for each set of measurements were carried out to obtain 400 data sets which

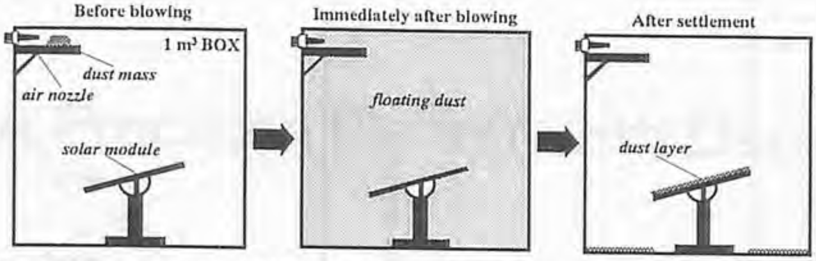

Fig. 3 Schematic representation of experimental procedure to cover the solar module with dust.

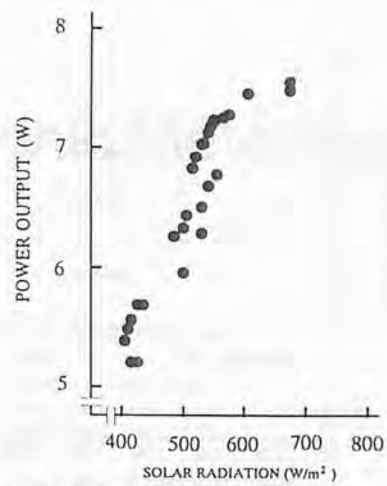

Fig. 4 Experimental data used for the Kalman neuro training.

were used for the source of training data. The measured power output was directly used without any correction to the standard test conditions since the solar module performance is not the subject matter of investigation in this study. The solar module performance has been already identified by the manufacturer.

Training Data

The number of iterative calculations in the Kalman neuron training process can be significantly reduced by avoiding unnecessary or excessive amount of training data feed. It is necessary to select some suitable training data from the original data obtained by the experiment in accordance with certain criteria. In this study, the following criteria were applied. The data sets involving the energy conversion efficiency more than 13% were eliminated. According to the data provided by the JKUCAT meteo station, the highest solar radiation recorded in this area was 750 W/m^2 during the experimentation. Therefore, the data sets recording the solar radiation level higher than 400 W/m^2 were also discarded. The data sets recording the solar radiation level lower than 400 W/m^2 were also eliminated because such low level of input energy may result in significant error of output reading of the solar module. By random selection from the remaining data, 28 sets of training data were obtained. **Figure 4** is a plot of all training data selected. The apparent scattering of data shown in **Fig. 4** is due to the dust effect, the effect of tilt angle and also measurement error. The inspection data which are also selected from the trimmed data are shown in **Table 1.** The inspection data are to be used to evaluate the performance of the trained neural network in its modeling function.

Results and Discussion

After 26 iterative calculations, the mean absolute error of outputs reached 6.294×10^{-3} (within the range of about ±0.9% deviation from the target value of training output data). The learning process was terminated at this point by assuming acceptable convergence. The trained neural network was tested by using the inspection data indicated in **Table 1**. The test results are capsulized in **Table 2**. The maximum error resulted from the test with the inspection data was 3.8% as shown in **Table 2**. It can be concluded that the neural network obtained based on the experimental data can simulate the behavior of the energy conversion system of solar module with the dust effect within the practical range of the solar module utilization.

No immediate indications of reduction of energy conversion efficiency due to the dust effect can be observed from the experimental data since not all of the input parameters were controlled. The neural network developed, however, can estimate the energy loss due to the dust effect within the modeling range. **Figure 5** shows that the power output decreases as the accumulation of dust on the solar module surface increases. The more negative effect of dust occurs when the input solar radiation level becomes smaller as indicated also in **Fig. 5.** The maximum energy loss calculated from the neural network model dveloped takes place when the energy conversion efficiency of the solar module is reduced from 6.46% to 4.79% by the dust (0.1 mm thick) covering over the solar cell surface at 420 W/m^2 of solar energy input which results in more than 25% of energy loss. As will

Table 1. Inspection Data to Verify Performance of the Trained Neural Network

Data number	Tilt angle (degree)	Solar radiation (W/m^2)	Dust thickness ($\times 10^{-2}$mm)	Power output (W)
1	0	551.5509	1.34	7.3939
2	8	552.9386	0.19	7.3810
3	16	435.8679	9.73	5.7009
4	24	480.6740	7.91	6.2055
5	32	531.6264	2.07	7.0844

Table 2. Error Resulting from the Trained Neural Network Using Inspection Data

Data number	Measured output (W)	Calculated output (W)	Error (%)
1	7.3939	7.3340	0.8
2	7.3810	7.3394	0.6
3	5.7009	5.4836	3.8
4	6.2055	6.2649	1.0
5	7.0844	7.0961	0.2

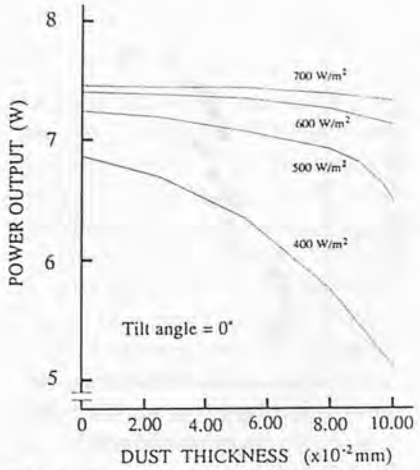

Fig. 5a Power output as affected by the dust accumulation on the solar module surface (Tilt angle: 0°).

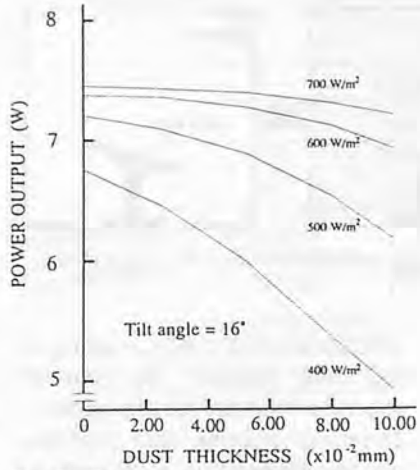

Fig. 5b Power output as affected by the dust accumulation on the solar module surface (Tilt angle: 16°).

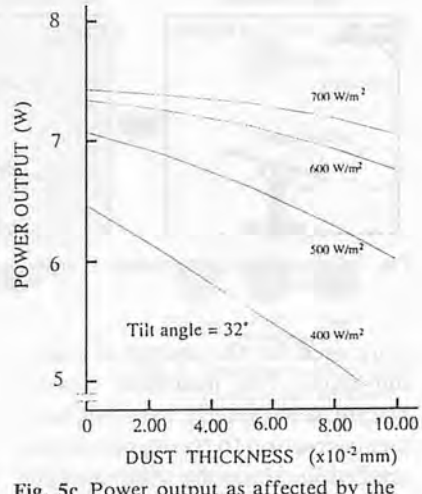

Fig. 5c Power output as affected by the dust accumulation on the solar module surface (Tilt angle: 32°).

be observed from these figures, dust is quite a problem that should be addressed to if maximum output of the software is to be obtained.

No appreciable effect of tilt angle of the solar module on the amount of dust accumulated on the solar module surface was observed. Apparent influence of the tilt angle appeared on the result such that the power output decreased as the effective area of the solar module decreased by increasing the tilt angle as shown in **Fig. 6**. It is quite obvious that the tilt angle of the solar module will affect the power output. As the incident angle at which the radiation rays strike the solar module surface decreases, the effective area of solar module surface generating the power also decreases.

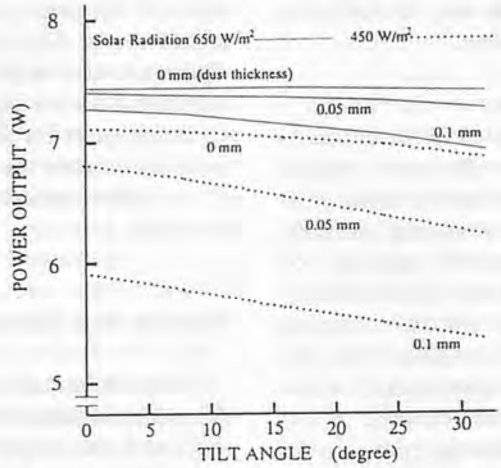

Fig. 6 Power output as altered by the change of tilt angle of the solar module under various conditions of solar radiation and dust accumulation.

Conclusions

This research demosnstrated that the amount of radiation received on the solar module, the dust that blows and settles on the solar module surface and the tilt angle of the solar module, all have an effect on the efficiency of solar generation of electricity. Dust, in perticular, affects the energy conversion efficiency of solar module to some significant degree.

It is necessary to know the amount of radiation available at a site where solar energy generator is to be installed. The amount of insolation available may not be easily controlled. However, it is easier to provide the solar modules or panels with the best conditions for maximum efficiency such as dust free conditions.

REFERENCES

1. Kuwano, Y. and A. Takeoka (1990). *Guide Book for Solar Cell Applications* (*Taiyodenchi katsuyo Gaidobukku*), Pawa-sha, Tokyo, Japan. (in Japanese)
2. Kyocera Corporation (1992). *Harnessing of the Sun*, Kyocera Corporation, Tokyo, Japan.
3. Mailutha, J.T. and H. Murase (1993). Knowledge Engineering-Based Studies on Solar Energy Utilization in Kenya-Part I, AMA, 24(4): 57-62.
4. Murase, H.; S. Koyama; N. Honami and T. Kuwabara (1991). Kalman Filter Neuron Training, Bull. of the Univ. of Osaka Prefecture, Ser. B, Vol. 43, pp.91-101.

A Precision Planter with Electronic Metering

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Abstract

A bullock-drawn seed planter with a simple electronic metering system was designed and tested. It has an electronically controlled check valve system that facilitates precision planting of seeds. The field tests indicated insignificant variation in actual plant spacings from the required spacing. Seed damage was minimal with an appreciable germination percentage and crop stand.

Introduction

Precision planting is a prerequisite for mechanical cultivation and is an important factor in efficient land use. It provides acceptable crop stands for efficient production. Labour intensive operations of thinning and weeding can be mechanized easily in a precision planted crop.

Though sophisticated precision planting systems are in development in developed countries, the immediate need for developing countries is to have a low-cost precision planter. The objective of this work is to develop an electronic precision planter for use in animal drawn implements.

Planter Prototype

The system consists of two main sections, namely; bulk flow seed feeding device that meters the seeds at a constant seed rate, and an electronically controlled check valve system in each furrow opener to plant the seeds in hills in a precise manner.

Seed Feeding Device

The bulk flow device was chosen in order to keep the cost and complexity of the device at a minimum level and to get a reasonably reliable control of seed flow for most of the pulse, millet, and vegetable crop seeds. The system consists of a hopper and a simple agitating shaft driven by a ground wheel through a chain drive. The shaft carries a rubber disc against each metering hole serving for one furrow opener. On rotation, the discs agitate the seed mass and let the seeds flow as a fine stream to the furrow openers through suitable seed tubes. The metering holes are regulated by a sliding shulter valve controlled by an indexing screw. The bulk seed flow for this device can be precisely calibrated using the indexing arrangement.

Electronically Controlled Check Valves

This section of the system consists of an optical device, check value control and a check valve agitating system.

Optical Device for Measuring Planter Travel — A separate tail wheel of 25-cm diameter hinged to the planter's tool bar carries the optical device. A circular disc of 10-cm diameter with 40 equally-spaced holes on its periphery rotates with the tail wheel and is so mounted that it rotates between opto-isolator sensors. The opto isolator senses each hole on the rotating disc's periphery and issues a pulse output. The distanced covered by the planter is then measured in terms of the number of pulses being output in a span of time.

Controller Pulsing Check Valves — The pulse output from the preceding stage is processed by a 7 414 Schmitt inverter and is made to trigger a 74 193 up/down presettable counter. The counter is configured in a 'Divide by N' mode with its terminal count presettable by a DIP switch. The counter counts the triggering pulses by decrementing itself from the terminal count until it reaches zero. Upon reaching zero, it resets by loading back the terminal count and starts the counting cycle once again. The counter's output is wired to a 7 425 NOR gate, which sets its output when the counter reaches zero in each cycle.

The NOR gate output is inverted again and is made to trigger a 555 timer configurated as a monostable. The output from this stage activates the check valves as explained in the next section.

By appropriately choosing the terminal count input through the DIP switch, the counter can thus be made to measure the required spacing, before activating the check valves each time.

Check Valve Activating System

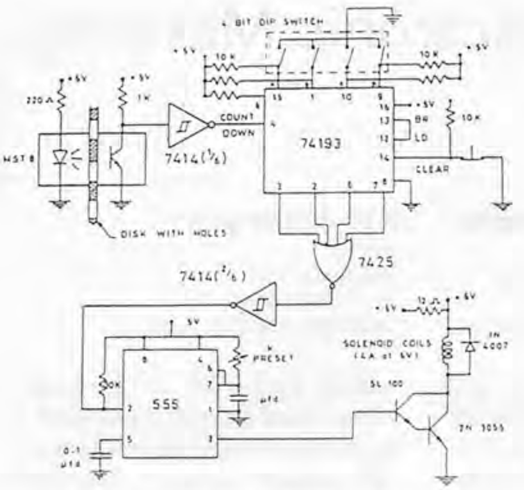

Fig. 1 Electronic seed metering circuit.

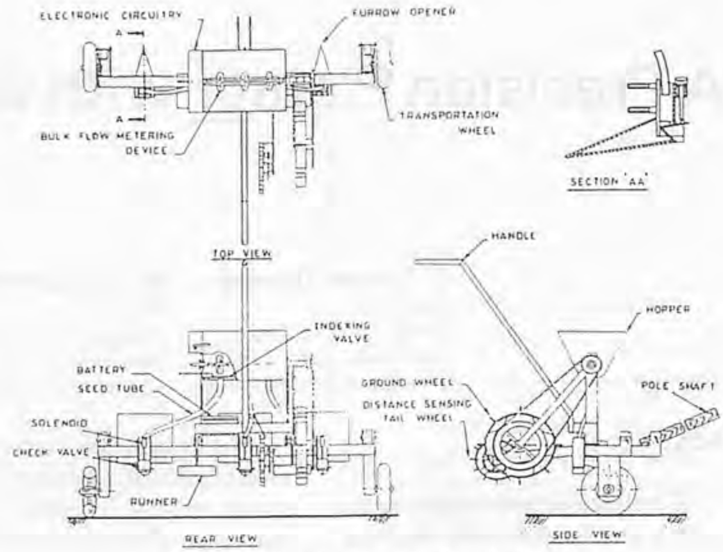

Fig. 2 Electronically-metered seed planter.

Table 1. Accuracy of the Electronically Metered Planter

Spacing adjusted for (cm)	Mean spacing observed in field test (cm)	Standard deviation in field test (cm)	Coefficient of variation in field test
10	12.7	3.10	0.244
15	15.2	4.42	0.290
20	21.3	6.82	0.320

(Number of samples of seed placements observed = 100)

Table 2. Observations on Number of Seeds Metered/Hill

Spacing adjusted for (cm)	Theoretical number of seeds metered	Mean number of seeds metered in the field	Standard deviation in the field	Coefficient of variation in the field
10	3	3.62 (4)	0.888	0.245
15	3	2.98 (3)	0.634	0.212
20	3	3.12 (3)	0.721	0.231

(Number of samples of seed placements observed = 100)

— Each furrow opener of the implement is provided with a check valve activated by a solenoid. All the activating solenoids, each consuming 1A at 6V, are connected in parallel and driven by a Darlington pair of SL 100 and 2N 3055 transistors. The output from the monostable triggers the check valves through the drivers and solenoids. The monostable's output is also adjustable which will, in turn, control the time for which the valves will be open in each planting cycle. This control is found necessary to control the seeds in each hill scattering at the instance of placement. The power for the electronic circuit and the solenoids are derived from a 6V, 11AH storage battery mounted on the implement frame. The circuit diagram of the electronic system is presented in **Fig. 1**.

There is also a provision to 'clear' the counter to zero at any instant of time to reinitiate the planting cycle.

The planter has a set of row markers to align plant rows in subsequent passes. Check row planting can be effected by using the 'clear' facility at the head land mark, at each fresh planting run. There are runners provided to control depth of planting. **Fig. 2** shows the planter's construction.

Performance

The planter was put under field trials for its performance. Sorghum was sown at spacings of 10, 15 and 20 cms. After the emergence of seeds, the spacings and number of plants per hill were sampled at random and recorded (**Table 1**). The observations indicate an insignificant variation of plant spacing from the theoretical setting.

Table 2 shows the observations on the numbers of emerged plants/hill, implying an insignificant variation of the numbers of seeds planted per hill, including an appreciable germination.

Conclusion

The designed planter is capable of metering seeds electronically at precise plant spacings. Field tests have indicated the degree of precision obtained and appreciable germination of the planted seeds.

REFERENCES

Chancellor, W.J. 1969. Seed tape system for precision selection and planting of small vegetable seeds. Trans. A.S.A.E. 12(6): 876-879.

Harriot, B.L. 1974. Planting mechanism for seed tablets. Trans. A.S.A.E. 17(3): 447-448, 451.

Short, T.H., S.G. Huber. 1970. The development of a plantary vacuum seed metering device. Trans. A.S.A.E. 13(6): 803-805.

Wilkin, D.E., D.H. Lenker. 1981. A microprocessor controlled planter. Trans. A.S.A.E. 24(1): 2-4, 8.■■

Multi-crop Seeder Development

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Abstract

Four prototypes of upland seeders were developed for sowing upland cross, namely; 1) semi-automatic seeder; 2) automatic seeder; 3) plow-attached seeder (convertible to a push type model); and 4) power tiller-attached multi-crop seeder. They could be used for sowing corn, soybean and mungbean. The prototypes were tested for maize (being the target priority crop) with a capacity of 0.03, 0.024, 0.136 and 0.183 ha/hr, respectively. A feasibility analysis shows a benefit cost ratio of 2.45, 1.08, 1.24 and 1.00 with a corresponding break even point of 0.30, 0.60, 0.53 and 2.63 ha, respectively. **Figs. 1 to 5** show the schematic diagrams of these machines.

Introduction

There exists today various designs of seeders ranging from the simplest, manually operated one to the most complex computerized robot seeders.

In the Philippines, the current practice of sowing crops in small upland farms consists of two methods, i.e., 1) making holes on the soil with a pointed stick and dropping the seeds therein manually; and 2) dropping the seeds along a prepared furrow and covering them with soil.

Local designs of upland seeders are available but are beset with either technical and economic problems, including inefficient metering device causing seed damage, and unsatisfactory performance under wet and sticky soil condition rendering the machine technically unacceptable while the relatively high cost of some seeders inhibit the farmers' investment.

In order to address these problems, a multi-crop seeder development project was pursued by

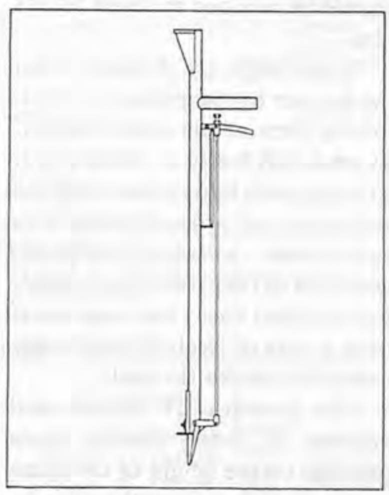

Fig. 1 Semi-automatic multicrop seeder.

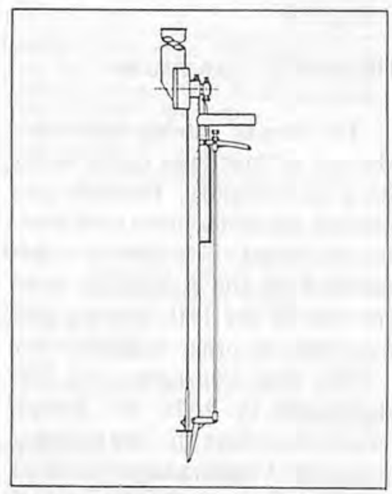

Fig. 2 Automatic multicrop seeder.

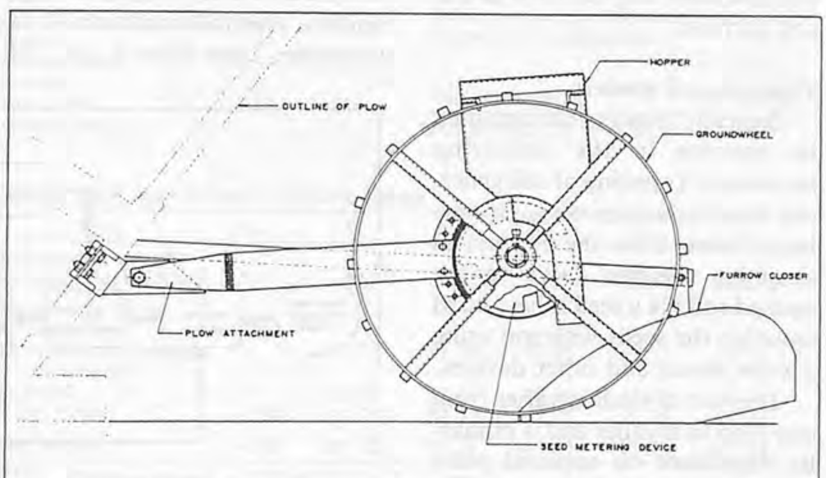

Fig. 3 Operational diagram of multicrop seeder.

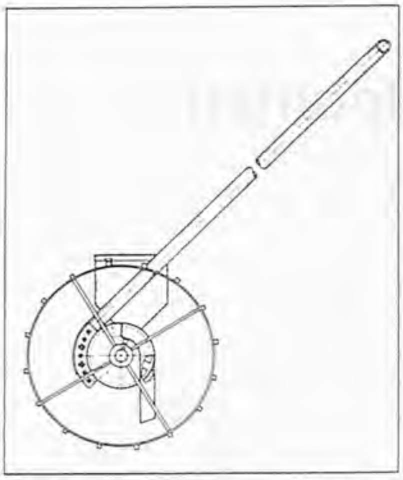

Fig. 4 Push-type seeder converted from plow-attached seeder.

the Agricultural Mechanization Development Program (AMDP) of IRRI with maize as the target priority crop.

Review of Literature

The idea of sowing seeds with the aid of machines dates as far back as antiquity. Persians and Hindus are said to have used seeding machines. The idea was not adopted by the Europeans until the end of the 17th century and even later in other countries.

The first European drill was developed in 1636 by Joseph Locatelli of Corinth. The machine was called "sembradore." It could not deposit the seeds in the ground but laid them only in rows on the soil surface.

Principles of Seeders

Basically, seeders are designed to operate in the following sequence: 1) opening of soil generally by a furrow opener; 2) metering of seeds from the hopper; 3) dropping metered seeds to the opened soil via a seed tube; and 4) covering the seeds with soil using furrow closer and other devices.

The rate of seeding varies from one crop to another and is primarily dependent on required plant population. In the case of maize, the Institute of Plant Breeding

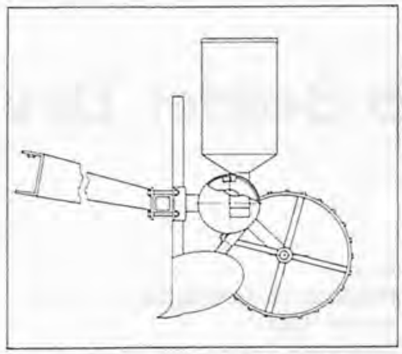

Fig. 5 Power tiller attached multi-crop seeder.

(IPB) of the University of the Philippines at Los Baños recommends 75 cm spacing between rows. For 25 cm distance between hills, one m should be maintained while for 50 cm distance between hills, two plants are required. In any case, the plant density level should be retained at about 53 333 /ha.

When seeds are dropped from the hopper to the ground, the folloiwng phenomena could happen: 1) seeds fall freely to the ground; 2) seeds come into contact with the seed tube; and 3) seeds collide with each other attaching different velocities as they reach the ground. For an ideal case, the seeds must be in a state of freely falling bodies until they strike the soil.

The breadth of spread and velocity of freely falling seeds depends on the height of dropping and is directly proportional to it. The final velocity is equal to $\sqrt{2gh}$ under a free fall condition. It is, therefore, clear that a free fall condition may be ensured by seed tubes which widens down their length. In such tubes the greater part of seeds (60-80%) drop down freely without coming into contact with the tube wall. The other prerequisite is that the tube wall should be smooth. Excessive deviation of the delivery tube from the vertical or their possible deflection adds to irregularity of falling seed quantities in a unit of time. In such instance, a considerable prtion of seeds strike against the tube wall in falling down and rebounding in various directions with varying velocities.

The spreading of heavy seeds with smooth cuticle released from the tube is generally lower than that experienced by light seeds with coarse cuticles.

Previous research findings recommend that the maximum value of the angle of deviation of a seed tube from the vertical axis should not exceed 15 degrees.

Methodology

The development of the multi-crop seeder was undertaken following the systematic design process involving the end users (**Fig. 6**). Pertinent literature were reviewed and traditional practices of sowing upland crops were studied, including the existing upland seeder prototypes available

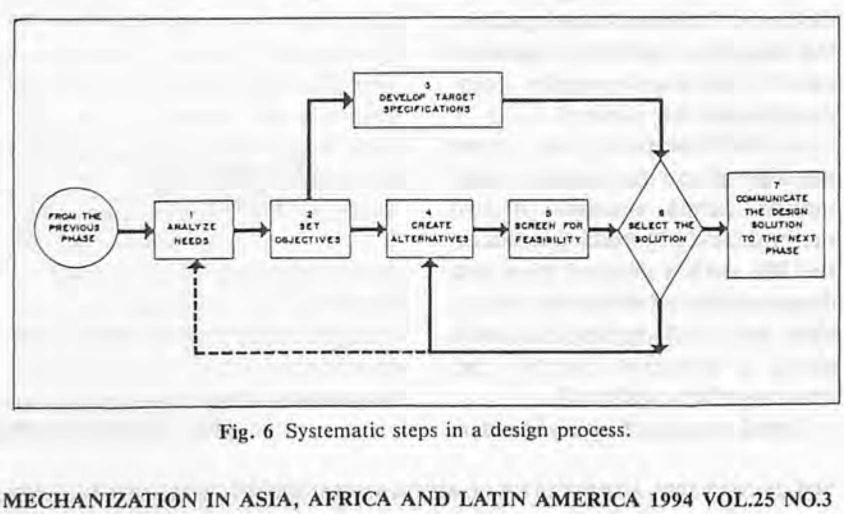

Fig. 6 Systematic steps in a design process.

(both local and foreign design) with emphasis on the performance of seed metering devices.

Prototypes were designed, fabricated, laboratory-tested followed by pilot testing in the farmer's field to gather comments, criticisms and suggestions. Based on the pilot test results, the features of the final prototypes were established. **Table 1** presents a summary of the test results.

Each seeder prototype was subjected to a feasibility analysis **(Tables 2 to 11)** to determine their economic viability as a basis of recommendation for the farmers.

Results and Discussions

Semi-automatic Seeder

The semi-automatic seeder (SAS) is an improvement of the traditional practice of sowing maize and other upland crops using pointed stick to make holes where the seeds are dropped and covered with soil.

The SAS can be used for sowing both in zero tillage and in cultivated soil conditions. The number of seeds per hill is determined by the operator. Based on the test results, the SAS has a capacity of 0.030 ha/h (or approximately 4 man-days per ha as against the traditional sowing of 6-8 man-days per ha) at a hill-to-hill distance of 25 cm and 75 cm between rows **(Table 1)**. An economic feasibility analysis of SAS resulted to a payback period of 0.72 year, 0.30 ha break-even point and 2.45 benefit cost ratio **(Table 2)**.

Automatic Seeder

This is an improvement over the SAS model wherein a seed metering device was provided as suggested by the farmers. It can deliver one to two seeds per hill (with the SMC 305 maize variety), with a capacity of 0.024 ha/h (or 5 man-days per ha), with the hill-to-hill distance being determined by the operator. It has a payback period of 2.13 years, break-even point of 0.60 ha and 1.08 benefit cost ratio **(Table 2)**.

Plow-attached Multi-crop Seeder

This model was designed as a simple attachment to the native plow which almost every small farmer possess. It has a capacity of 0.136 ha/h (or one man-day per ha). Hill-to-hill distance can be varied and can be used for seeding maize, soybean and mungbean using the appropriate cell plate/seed metering device. It can be converted to a push type seeder. Its payback period, break-even point and benfit cost ratio is 1.74 years, 0.53 ha and 1.24, respectively **(Table 2)**.

Table 1. Summary of Test Results of Various Upland Seeders Using SMC 305 Maize Seeds

Model	Seeds/Hill	Average Capacity (ha/h)
Semi-automatic seeder	as desired by operator	0.030
Automatic seeder	1-2	0.024
Plow-attached seeder*	1-2	0.136
Plow-tiller attached seeder*	1-2	0.183

*Hill-to-hill distance can be varied to 25, 33 and 50 cm using appropriate seed metering device.

Table 2. Summary of Economic Feasibility Analysis of Upland Seeder Prototypes

Model	Payback Period (years)	Break-even Point (ha)	Benefit Cost Ratio
Semi-automatic seeder	0.72	0.30	2.45
Automatic seeder	2.13	0.60	1.08
Plow-attached seeder	1.74	0.53	1.24
Plow tiller-atached seeder	2.80	2.63	1.00

Table 3. Investment and Operating Costs of (Traditional) Manual Seeding of Maize in Upland Farms

Investment Cost	
Swamp buffalo	₱12 000.00
Plow	500.00
	₱12 500.00
Fixed Cost	
Depreciation	
a) Swamp buffalo[1]	₱1 200.00
b) Plow[2]	90.00
Interest on average investment[3]	2 782.50
Repair and maintenance (R&M)[4]	1 250.00
	₱5 322.50
Variable Cost	
Furrowing	₱ 300.00
Sowing	840.00
	₱1 140.00

[1] Straight line method, 50% salvage value and five-year's life span.
[2] Straight line method, 10% salvage value and five-year's life span.
[3] Thirty percent interest rate.
[4] Ten percent of purchase cost.
NOTE: Current exchange rate is US$1.00 = ₱27.

Table 4. Investment and Operating Expenses of Seeding Maize Using Semi-automatic Seeder

Investment Cost	
Swamp buffalo	₱12 000.00
Plow	500.00
Semi-automatic seeder (SAS)	350.00
	₱12 850.00
Fixed Cost	
Depreciation	
a) Swamp buffalo	₱ 1 200.00
b) Plow	90.00
c) SAS	63.00
Interest on average investment	2 840.25
Repair and maintenance	1 285.00
	₱ 5 478.25
Variable Cost	₱ 560.00

NOTE: US$1.00 = ₱28.

Table 5. Cash Flow of Semi-automatic Seeder

Item	Y_0	Y_1	Y_2	Y_3	Y_4	Y_5
Incremental Benefits						
a) Labor cost reduction	—	580	580	580	580	580
Incremental Costs						
a) Seeder	350	—	—	—	—	—
b) Interest on average investment	—	57.75	57.75	57.75	57.75	57.75
c) R&M	—	35.00	35.00	35.00	35.00	35.00
Total Costs	350	92.75	92.75	92.75	92.75	92.75
Net Benefits	−350	487.25	487.25	487.25	487.25	487.25

NOTE: Payback period = 350/487.25 = 0.72 year.
BCR = 580 (2.436/[350 + 92.75 (2.436)] = 2.45 (at 30% discount rate).
BEP = (5.322 − 5 478.25)/(560 − 1 140) = 0.30 ha.

Table 6. Investment and Operating Expenses of Seeding Maize Using Automatic Seeder

Investment Cost	
Swamp buffalo	P12 000.00
Plow	500.00
Automatic seeder	600.00
	13 100.00
Fixed Cost	
Depreciation	
a) Swamp buffalo	P 1 200.00
b) Plow	90.00
c) Automatic seeder	108.00
Interest on average investment	2 881.50
Repair and maintenance	1 310.00
	P 5 589.50
Variable Cost	
Seeding	P 700.00

NOTE: US$1.00 = P28.

Table 7. Cash Flow of Automatic Seeder

Item	Y_0	Y_1	Y_2	Y_3	Y_4	Y_5
Incremental Benefits						
a) Labor cost reduction	—	440	440	440	440	440
Incremental Costs						
a) Automatic seeder	600	—	—	—	—	—
b) Interest on average investment	—	99	99	99	99	99
c) R&M	—	60	60	60	60	60
Total Costs	600	159	159	159	159	159
Net Benefits	600	281	281	281	281	281

NOTE: Payback period = 600/281 = 2.13 years

BCR = 440 (2.436/[600 + 159 (2.436)] = 1.08

$$BEP = \frac{FC_1 - FC_2}{VC_2 - VC_1} = \frac{(5\,322.50 - 5\,589.50)}{(700 - 1\,140)} = 0.60$$

Table 8. Investment and Operating Expenses of Seeding Maize Using Plow-attached Multi-crop Seeder

Investment Cost	
Swamp buffalo	P12 000.00
Plow	500.00
Seeder (plow-attached)	1 000.00
	P13 500.00
Fixed Cost	
Depreciation	
Swamp buffalo	P 1 200.00
Plow	90.00
Seeder	180.00
Interest on average investment	2 947.50
Repair and maintenance	1 350.00
	P 5 767.50
Variable Cost	
Operator	P 300.00

NOTE: US$1.00 = P28.

Table 9. Cash Flow of Plow-attached Seeder

Item	Y_0	Y_1	Y_2	Y_3	Y_4	Y_5
Incremental Benefits						
a) Labor cost reduction	—	840	840	840	840	840
Incremental Costs						
a) Automatic seeder	1 000	—	—	—	—	—
b) Interest on average investment	—	165	165	165	165	165
c) R&M Cost	—	100	100	100	100	100
Total Costs	1 000	265	265	265	265	265
Net Benefits	−1 000	575	575	575	575	575

NOTE: Payback period = 1 000/575 = 1.74 years

BCR = 840 (2.436/[1 000 + 265 (2.436)] = 1.24

$$BEP = \frac{FC_1 - FC_2}{VC_2 - VC_1} = \frac{(5\,322.50 - 5\,767.50)}{(300 - 1\,140)} = 0.53$$

Table 10. Investment and Operating Expenses of Seeding Maize Using Power Tiller-attached Multi-crop Seeder

Investment Cost	
Seeder	P 1 500.00
Power tiller	16 000.00
	P17 500.00
Fixed Cost	
Depreciation	
a) Power tiller	P 2 880.00
b) Seeder	270.00
Interest on average investment	2 887.50
Repair and maintenance	1 750.00
	P 7 787.50
Variable Cost	P 204.00

NOTE: US$1.00 = P28.

Table 11. Cash Flow of Power Tiller-attached Multi-crop Seeder

Item	Y_0	Y_1	Y_2	Y_3	Y_4	Y_5
Incremental Benefits						
a) Labor cost reduction	—	935.50	935.50	935.50	935.50	935.50
Incremental Costs						
a) Seeder	1 500	—	—	—	—	—
b) Interest on average investment	—	247.50	247.50	247.50	247.50	247.50
c) R&M	—	150	150	150	150	150
Total Costs	1 500	397.50	397.50	397.50	397.50	397.50
Net Benefits	−1 500	538	538	538	538	538

NOTE: Payback period = 1 500/538 = 2.80 years

BCR = 935.50 (2.436/[1 500 + 397.50 (2.436)] = 1.00

$$BEP = \frac{FC_1 - FC_2}{VC_2 - VC_1} = \frac{(5\,322.50 - 7\,787.50)}{(204.50 - 1\,140)} = 2.63 \text{ ha.}$$

Power Tiller-attached Multi-crop Seeder

This machine has the same metering device as the plow-attached seeder but is designed as a power tiller attachment. It employes a modified hoe-type soil opener combined with a moldboard for furrow opening and automatic seed "coverer." Hill-to-hill distance can be varied and can be used for sowing maize, soybean and mungbean. It can deliver one to two seeds per hill with a capacity of 0.183 ha/h or 0.70 man-day per ha. The payback period is 2.80 years, a benefit-cost ratio of 1.00 and 2.63 ha break-even point.

Conclusions and Recommendations

Of the four multi-crop seeders developed, the semi-automatic seeder has the most favorable payback period (0.72 years), break-even point (0.30 ha), benefit cost ratio (2.45) and is, therefore, recommended for small farms greater than one-third ha while the automatic seeder is recommended for use in upland farms more than 3/5 ha.

The plow-attached seeder can plant one ha in one day with a benefit-cost ratio of 1.24 and a payback period of 1.74 years. It is highly recommended for farmers who own a plow and a farm area of more than half ha while the power tiller attached multi-crop seeder is suitable for sowing maize fields greater than 2.63 ha.

(Continued on page 28)

Techno-economic Investigations on Cotton Spraying Using Knapsack Sprayer

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Abstract

Cotton is one of the most important cash crops in India which consumes 60 percent of pesticides produced in the country. Usually farmers spray high quantity of pesticide on cotton crop resulting into high ground and drift losses and ecological and environmental destructions. In view of this, the work was undertaken to suggest a more effective technique of spraying the cotton crop. This work was carried out at ASPEE Research Institute Bombay, India. The field trials were carried out on cotton crop. By measuring the plant parameters at different stages of crop growth the leaf area index, spray volume required and the walking speed to be maintained were calculated. A tail boom was designed and fabricated for the later stages of crop growth. The field trials were conducted to study the spray volume deposition as well as the bio-efficacy on cotton crop under four different treatments, namely: i) control, with no pesticide application; ii) using the farmer's method of spraying; iii) using the scientific method of spraying with artificial infestation; and iv) using the scientific method of spraying with natural infestation. From the results the scientific method of spraying was found better than the farmer's method of spraying in terms of volume deposition and distribution on targets. It was also found that the new technique ws equally good from bio-efficacy point of view. The analysis shows that the new technique could yield about 60 percent reduction in the overall cost over the farmer's method of spraying. A nomogram was finally prepared to help the farmers in selecting the nozzle(s) and finding spray volume, walking speed and tail boom dimensions for different stages of crop growth.

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Introduction

India has 160 million ha of cultivable area of which 80 million ha of crops are protected from pests by the use of chemical pesticides. Chemical pesticides have played and will continue to play a major role in the rapid advancement of agricultural production. In India total pesticide production is 80 000 t per annum, 60% of which is used for cotton crop (Chongappum 1989, Jose 1987). The crop losses due to pests on an annual basis is valued around Rs. 6 000 crore, including grain losses during storage (Gupta 1989).

In recent years, Indian farmers have found cotton crop to be highly remunerative. Cotton is grown in over 7.4 million ha of land which is 5.6% of the total cultivable area in the country (Jaiswal 1986). Cotton is most susceptible to the pests such as insects, fungi, bacteria, viruses, weeds, nematodes, rodents and birds. Sometimes losses due to individual pest have been observed to be as high as 20% by insects, 33% by weeds, 26% by diseases, 6 to 8% by rodents, 1 to 2% by birds and 1 to 3% by others (Patel 1988). To protect the crops, farmers use a larger quantity of pesticides than actually required. Cotton crop is sprayed 7 to 13 times during growth period. This causes high losses of pesticides (ground and drift losses) and requires more time for pesticide application. This also contributes to health hazards as well as ecological and environmental destruction. Malpractices in spraying have been a major cause of high residual levels of pesticides on the crop. There is, therefore, a need to minimize the pesticide use for maximum pest control. It is essential to spray a required volume at different stages of growth for the maximum deposition on the targets and minimum ground and drift losses. This paper deals with a new pesticide application technique to determine how much volume to spray and which nozzle(s) and boom to use at different stages of crop growth.

Scientific Terms Used

Volume Median Diameter (VMD)

This parameter is usually employed to describe the droplet spectrum. It is the droplet diameter which satisfies the condition that half the spray volume is of droplets smaller than a droplet whose diameter is VMD and the other half of the spray volume is contained by larger droplets. This can be obtained from a volume cumulative curve of droplet size spectrum. It is the diameter corresponding to 50% cumulative. Droplets in the range of 120 to 300 micron VMD were found efficacious.

Number Median Diameter (NMD)

Number median diameter is the average diameter of the droplets without any reference to thier volume. The diameter corresponding to 50% cumulative number curve will give NMD.

Uniformity Coefficient (UC)

The ratio of VMD and NMD is called uniformity coefficient. It indicates the range of sizes of droplets. The more uniform the size, the nearer ratio is to unity.

Droplet Density (DD)

The number of droplets per unit area of leaf surface is called the droplet density. Droplet density of 20-50 droplets of pesticide per square centimeter is most effective against cotton pests.

Spread Factor

The diameter of the actual droplet and the diameter once it is incident on some object are different because after impingement the droplet spreads. The ratio of the diameter after incidence to the diameter before incidence is called the spread factor for the particular object as far as the particular liquid is concerned. It is greater than unity. The spread factor is affected by the size of the droplets, surface of droplet incidence and the formation of the spray liquid.

Leaf Area Index (LAI)

Leaf area index is the area of one side of the leaves divided by the corresponding ground area. It is dimensionless. It is considered to be a gauge to assess the crop growth.

Materials and Methods

The laboratory experiments were conducted to determine the performance characteristics of 12 different nozzles and spread factor which were used for the calculation of spray volume used and deposited on targets, walking speed and for selection of nozzle(s) for different stages of cotton. The spray volume is given as:

$$V = LAI \times DD_T \times FS \times V_{VMD} \times 100 / PC \quad \ldots(i)$$

Where,

V = spray volume, l/ha;
LAI = leaf area index;
DD_T = theoretical droplet density, droplets/cm^2;
FS = factor of safety;
V_{VMD} = volume of droplet of VMD size, l and
PC = percentage of useful volume, per cent. It is the ratio of volume deposited on the leaves to the total volume multiplied by hundred.

For a given nozzle with known discharge rate and the swath, the speed with which the operator will have to walk was arrived at as:

$$S = \frac{q}{r \times V_o} \quad \ldots(ii)$$

Where,

S = walking speed, m/min;
q = discharge of the nozzle, l/min;
r = row to row spacing of the crop, m and
V_o = spray volume, l/sp.m

Dimensions of boom depend upon the plant parameters and the nozzle parameters, assuming that the plant canopy is of rohmbus shape and the proposed nozzles cover the both sides of the leaves. The following equations give the boom dimensions:

$$L = \sqrt{H_2^2 - 4R_1(R_1 - T_2 / \tan O)} \quad \ldots(iii)$$

$$H_3 = (H_2 - L) / 2 + H_1 \quad \ldots(iv)$$

$$B = Y + O / 2 \quad \ldots(v)$$

Where,

$Y = \tan^{-1}[R_1 / (H_2 - L_1)]$, $L_1 = (H_2 - L) / 2$
O = Cone angle of nozzle, degree
$H_2 = H - H_1$ = Plant canopy height, cm

H = Plant height, cm
H_1 = Height of first leaf from ground, cm
L = Boom length, cm
R_1 = Distance of operator from plant canopy center, cm
H_3 = Height of lower nozzle from ground, cm and
B = Inclination of nozzle center with boom axis, degree

Thus, from these equations the boom length, height of lower nozzle from ground and nozzle inclination with boom axis are calculated.

The field trials were conducted at 15 days interval to evaluate the volume deposition, bio-efficacy and economy of different treatments. The randomised block design (RBD) having four treatments each with five replications was used. The details of the treatments are given in **Table 1**. The lady finger crop was grown in alternate rows with cotton to provide artificial pest infestation because the pests may not attack the cotton crop at all. Cotton seedlings of H-4 variety and lady finger were sown in polythene bags (3 seeds per bag) on 1st August, 1989 and on 16th August, 1989 when these were transplanted. Mainly aphids and jassids insects were expected to attack the crop in all the growth stages. To check these pests, insecticide Monocrotophos, which is marketed as Monophos was used. The proportion of active ingredient in this formulation was 36%. The concentration recommended for cotton crop is 0.05%, hence in one litre of water 1.4 ml (0.05/36.0 × 1000) of Monophos was to be mixed during all the stages of spraying. Knapsack sprayer was used for spraying and different nozzles and booms were used for different stages of crop growth.

Aphids and jassids were counted before spraying, after 24 h and after 48 h of spraying to check the bio-efficacy of different treatments. For this, four plants per sub-block and three leaves per plant were taken.

Table 1. Details of Different Treatments Used for Cotton Spraying

Treatment	Level and Type of Infestation	Nozzle(s) Used	Pesticide Application Rate
Treatment-1	Natural	No spraying	No spraying
Treatment-2	Natural	Those used by farmer	As followed by farmer
Treatment-3	Artificial infestation	Those selected for different stages	Calculated from LAI
Treatment-4	Natural	Those selected for different stages	Calculated from LAI

An assessment by droplet size determination using spread factor, a standard sample paper (Kremecote card) was put on the targets for which spread factor is already determined, and after spraying, the sample is analyzed for its droplet size spectrum for a standard area. Considering the spread factor, the spray volume was calculated. This technique was used in the present study to measure the volume deposited on the leaves. To determine the spray volume deposited on targets, glossy papers were used. Five plants were used from each sub-block and six glossy papers were put on each plant to calculate the volume deposited on both sides of leaves in different treatments at six stages of crop growth. For measurement of ground losses, 20 glossy papers were used in each treatment. To determine drift losses, 14 poles were erected and two glossy papers were fixed on each pole on the boundary of the plot.

A nomogram was developed to help the farmers in selecting the nozzle(s) and determining spray volume and walking speed. The parameters measured in this study as well as those given by Jose (1987) and Sudhakar (1988) used.

Results and Discussion

The width of the plant canopy is essential in selecting a nozzle. The swath of the selected nozzle should be more or less equal to the plant width so that there is a little or no loss of spray with a good coverage of the canopy. The plant canopy height is to be considered while evolving proper spray technique. As the cotton crop grows, the plant height increases more than the plant width, making it almost impossible to penetrate the canopy with overhead spraying. At such stages the overhead spraying will not give proper spray distribution. Hence, other ways of orienting the nozzle become necessary to reach the otherwise inaccessible portions of the canopy. So the plant height and the height of first leaf from ground are main parameters to be considered for nozzle orientation with respect to the plant canopy. Five plants from each sub-block of treatment T4 were used for the measurement of plant height (H), width of the plant, height of first leaf from ground and number of leaves per plant, **Table 2**. From these data the LAI, spray volume, walking speed and boom dimensions were calculated and nozzle(s) was/were selected (**Table 3**).

Bio-efficacy of Spraying

Percentage reductions (PR) of aphids in treatments T2, T3 and T4 were highly significant with respect to treatment T1 (control), except during first two stages. The values of the coefficient of variance were very high (up to 83%) for the first two stages of crop growth. This may be due to the mild pest attack recorded during these stages. It was observed that the treatment T4 was equally good as treatment T2 in all the stages of crop growth. Therefore, from the bio-efficacy point of view the

Table 2. Plant Parameters Recorded During Different Stages of Cotton Crop of Treatment T4

Age of crop	Plant Parameters*				
	LAI	Plant height	Height of first leaf from ground	Plant width	Average number of leaves per plant (round figure)
DAT		cm	cm	cm	
24	0.02	18.9	10.7	13.6	7
38	0.06	27.3	14.2	36.1	18
52	0.32	61.9	15.2	50.0	43
66	0.45	68.5	16.9	71.4	85
80	0.64	81.7	16.4	84.7	89
94	0.87	101.4	15.0	99.1	116

*Average of 25 replications.
DAT — days after planting.

Table 3. Spray Volume, Nozzle(s), Boom Dimensions and Walking Speed for Different Stages of Crop.

Age of crop	LAI	Spray Volume	Nozzle(s)	Tail Boom Dimensions*			Walking speed
				L	B	H	
DAT		l/ha		cm	degree	cm^3	km/h
24	0.02	65.55	N_1	—	—	—	2.2
38	0.06	69.70	N_1	—	—	—	1.8
52	0.32	150.54	N_2	—	—	—	1.2
66	0.45	169.65	N_3	—	—	—	1.5
88	0.64	208.22	$2N_1$	68	62	15	2.4
94	0.87	218.19	$2N_1$	105	53	6	2.3

*L—Boom length, B—Nozzle inclination with boom axis and H—Height of lower nozzle from ground.

scientific method of spraying was found to be as efficient as the farmer's method of spraying. However, an overall saving in spraying cost of nearly 60% was obtained by using the scientific method of spraying over the farmer's method of spraying. The savings in pesticide used in treatment T4 over T2 varied from 36.8 to 50%. Similarly, the savings in spraying time required in T4 over the T2 varied from 12.4 to 39.8%.

Spray Volume Deposition

In the initial stages of crop growth the ground losses were found very high and volume deposited on leaves was very minimal. As the crop growth progressed the ground losses decreased and the spray volume deposition on the leaves increased. In all the stages, the volume deposited on upper sides (up to 49%) of the leaves was higher than that on the lower sides (up to 10%) of leaves. Also, the drift losses were observed to be very low (0.4-2.6%) compared to the ground losses (40-96%). The spray volume accounted was less than the volume sprayed. The unaccounted volume might have been lost by evaporation and/or consumed by the plant stems and branches. It was also observed that the scientific method of spraying adopted in treatments T4 was better than the farmer's method of spraying adopted in T2 from both spray deposition and distribution points of view. The spray deposition in the scientific method was up to 59% and that in farmer's method was up to 32%.

Selection of Nozzles and Boom

A nomogram was developed for the selection of proper nozzle and boom for the different stages of cotton crop growth **(Fig. 1)**. This can be used for obtaining the volume of liquid to be applied per unit area and also to know the speed with which the operator has to walk so as to apply the selected volumes using selected nozzle(s) and nozzle location on the tail boom. The leaf area index was correlated to the height of the cotton plant for the convenience of farmers.

The LAI values were plotted against plant height. A smooth curve was drawn and the following equation was found:

$$LAI = -0.176 + 0.562 \times 10^{-2}H + 0.137 \times 10^{-3}H^2 - 0.451 \times$$

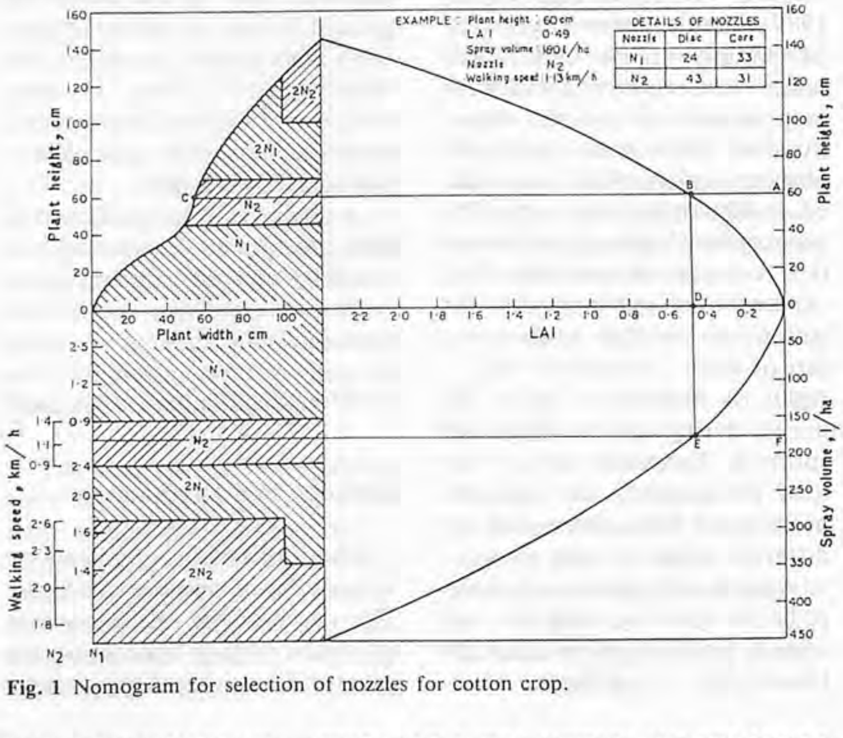

Fig. 1 Nomogram for selection of nozzles for cotton crop.

$10^{-6}H^3$ ...(vi)

Where,
LAI = leaf area index and
H = plant height, cm.
R = 0.9982

Based on the LAI (**Table 4**) values for the different stages, the spray volumes were calculated assuming VMD 300 μm, droplet density 25 droplets per sq. cm. **Table 5** lists the volume for the different stages of crop. The LAI and spray volume were correlated and the following relation was found to exist:

$$V = 69.464 + 246.925(LAI) - 61.925(LAI)^2 - 53.6(LAI)^3 + 37.51(LAI)^4 \quad ...(vii)$$

Where,
V = spray volume, l/ha and

The correlation coefficient, R of the above relationship was 0.99.

For the later stages of crop growth the tail boom was used. The dimensions of the boom such as boom length, nozzle inclination and height of lower nozzle from ground were calculated on the basis of plant parameters and shown in **Table 5**. While calculating the boom dimensions it was assumed that the operator will walk 50 cm away from plant row while using nozzle N1 and 65 cm while using nozzle N2 and also the height of first leaf from ground 15 cm for all the stages of cotton crop. For the selection of nozzle the plant width is a very important factor as the swath of the nozzle selected must match the width of the crop.

The different curves, i.e., plant height vs LAI, spray volume vs LAI and plant width vs plant height were plotted (**Fig. 1**). The area under the curve drawn between crop width and crop height was divided into strips based on the nozzle swath. The walking speeds were also record-

Table 4. Average of Plant Parameters of Cotton for Three Years

Age of crop DAT*	LAI	Plant Parameters** H cm	W cm	H1 cm	H2 cm	PC %
24	0.03	24.0	19.8	13.8	10.2	6.49
38	0.18	35.0	38.9	14.8	20.2	19.17
52	0.63	66.3	55.4	16.4	49.9	51.05
66	1.23	92.2	78.1	17.9	74.3	60.49
80	1.52	113.7	94.8	16.6	97.1	71.90
94	1.99	134.8	115.8	14.9	119.9	—

DAT—Day after transplanting. LAI—Leaf area index.
H—Height of plant. W—Width of plant.
H1—Height of first leaf from ground. PC-Percentage of useful volume, %.
*—These parameter are interpolated for different DAT of crop.
H2 = Plant canopy height, cm = H − H1.

Table 5. Details of Volume, Nozzle(s) and Boom for Different Stages of Crop Growth

Age of crop	Volume	Plant height	Plant width	Nozzle	Boom Dimensions L		B		H3		Walking speed
					N1	N2	N1	N2	N1	N2	
DAT	l/ha	cm	cm		cm	cm	degree	degree	cm	cm	km/h
24	64.31	24.0	19.8	N1	—	—	—	—	—	—	1.89
38	132.74	35.0	38.9	N1	—	—	—	—	—	—	0.93
52	174.46	66.3	55.4	N2	—	—	—	—	—	—	1.07
		70.0	58.2	2N1	66.2	—	63.3	—	14.4	—	—
66	287.46	92.2	78.1	2N1	89.6	—	57.0	—	8.8	—	1.72
80	298.87	113.7	94.8	2N1	123.1	—	50.3	—	2.8	—	1.65
				2N2	—	69.3	—	68	—	29.7	2.51
94	483.88	134.8	115.8	2N2	—	109.4	—	60	—	20.2	1.55

2N1—Two nozzles of N1 type used at a time.
2N2—Two nozzles of N2 type used at a time.

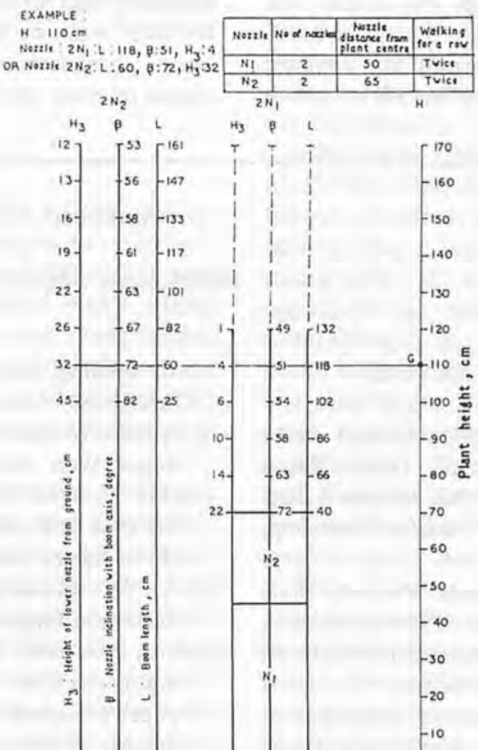

Fig. 2 Nomogram for selection of boom dimensions for cotton crop.

ed on the vertical scale parallel to the spray volume axis as shown in **Fig. 1**. The boom dimensions such as boom length, nozzle inclination and height of lower nozzle from ground were marked on the different vertical scales with crop height.

The nomogram gives the volume of the spray to be applied, nozzle to be used and the walking speed to be maintained as per height of the plant. For example, for a plant height of say 60 cm, draw a line from point A parallel to LAI axis. This line cuts the curve drawn between plant height and LAI at B. Draw a vertical line from point B to cut the LAI axis at D to read the LAI as 0.49. Extend BD to E to cut the curve drawn between spray volume and LAI. Draw a line EF parallel to LAI axis to read the volume of spray required as 180 l/ha. Extend AB to C to cut the curve drawn between plant width and plant height. The point C lies on the portion marked for nozzle N2. Hence, the nozzle N2 will be used. Finally, to determine the walking speed, extend the line FE to cut the walking speed axis and read the walking speed as 1.13 km/h.

To select the boom dimensions **Fig. 2** can be used. For example, for a plant height of 110 cm draw a horizontal line from point G to read the boom dimensions and the type of the nozzle on the two set of vertical scales.

Conclusions

The scientific method of spraying was found better than the farmer's method of spraying in terms of volume deposition and distribution on targets. It was also found that the new technique was equally good from bio-efficacy point of view. The analysis shows that the new technique could yield about 60% reduction in the overall cost over the farmer's method of spraying. A nomogram prepared would be quite useful to the farmers in selecting the nozzle(s) and determining spray volume, walking speed and tail boom dimensions for different stages of crop growth.

REFERENCES

1. Chongappum, Raj, India Today, June 15 1989.
2. Eugenc Kind and Ron King (1983) Droplet size vs Biological effectiveness of oil spray, Blackwell, Oxford: 146-157.
3. Gupta, Y.P, (1989), SCIENCE REPORTER, November, 1989.
4. Johnston, D.R. (1985) The ULVA System can we gauge its success B.C.P.C. Monograph No. 28.
5. Jose, K.J, (1987) Field performance of spray nozzles on cotton crop. Unpublished M Tech. Thesis, I.I.I., Kharagpur.
6. Patel, S.L. (1988) Information Bulletin No. 1 ASPEE Research Institute Bombay.
7. Sudhakar, S.M. (1988) Development of spraying technology for cotton crop. Unpublished M Tech. Thesis, I.I.T., Kharagpur.
8. Tunstall, J.P. Mathews, G.A. and Rhodes, A.A.K (1961) A modified Knapsack Sprayer for the application of insecticide to cotton. Cotton Green Revolution. 38: 22-6. ■■

(Continued from page 22)

Multi-crop Seeder Development

REFERENCES

Aban et al., (1986). Upland seeder development at IRRI. Paper presented at the 9th MAF-IRRI Technology Transfer Workshop, Bohol, Nov. 6-8.

AIT-IDRC Seeder Project; Final Report, March 1989 Thailand.

Bernacki et al. Agricultural Machines, Theory Construction. Vol. I, 1972. US Department of Commerce.

Borlagdan, P.C. Seeding and Transplanting Mechanization Status in the Philippines. Paper presented at the Regional Workshop on Design of Seeding and Transplanting Equipment. August 28-September 6, 1989. Wisma Kinasih, Caringin-Bogor, West Java, Indonesia.

Larsen, W. et al. Self-propelled No-Till Plot Drill. Applied Engineering in Agriculture. 1987.

Love, S.F. Planning and Creating Successful Engineered Designs.

Morris, R.A. 1980. Tillage and seeding methods for dry-seeded rice. Paper presented at the Cropping Systems Conference, IRRI, Los Baños, Laguna. March 3-7.

Morrison, et al. Conservation Planter, Drill and Air-type Seeder Selection Guide. Applied Engineering in Agriculture, 1989.

Oznerzi, A. Seed Distribution Performance of Furrow Openers Used in Drill Machines. Agricultural Mechanization in Asia, Volume 17, No. 2. 1986.

Richey, Agricultural Engineers Handbook.

Singh, G. et al. A Manual Seeder for Soybean. Paper presented at the World Soybean Research Conference. March 26-29, 1979. North Carolina State University. ■■

Feasibility Study on

Different Manual Pumps in Farmers' Fields

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Abstract

Three manual pumps, namely; BRRI disphragm pump (BRRI pump); Twin treadle pump; and Rower pump were evaluated in the farmers' fields. The average discharges (ℓ/s) were 4.03 for the BRRI pump, 1.4 for the Rower and 1.5 for the Treadle pump at 1.25, 1.6 and 1.16 m operating heads. The discharge of BRRI diaphragm pump was higher than those of the Treadle and Rower pumps. At full cost basis, per hectare Irrigation cost for rice cultivation by the BRRI pump was Tk. 9 582.00 which was the lowest among the three pumps. The cost for the Treadle and Rower pumps were Tk. 16 145.00 and 18 979.00, respectively. At cash cost basis, these cost were Tk. 1 063.00 and 1 842.00, respectively, for the Treadle and Rower. On the other hand, at full cost basis per hectare the irrigation cost for rice cultivation by the power pump was Tk. 1 688.00.

Although the repair and maintenance cost of diaphragm pump was highest among the three pumps, it was identified as the most suitable for rice irrigation. The Treadle and the Rower pumps might be suitable for irrigating vegetables.

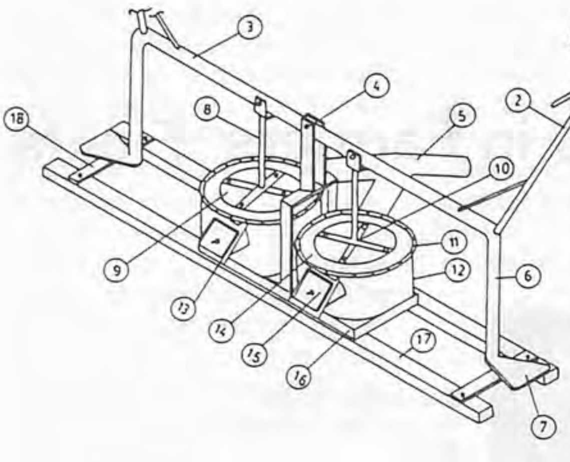
Introduction

Presently 25% of the agricultural land in Bangladesh is irrigated of which about 30% is irrigated by the traditional water lifting devices like *Don* and swing basket. The capacities of these devices are limited u p to 1 m head and they are suitable for irrigation during the dry season.

In order to solve these problems the BRRI developed a diaphragm pump in 1978. About 100 units of this pump were distributed or sold to different agencies or farmers to study farmers' reaction and to collect data for further improvement. Preliminary results were satisfactory. Therefore, an extensive extension and comparative evaluation study of the pump in the farmers' fields was essential before their large scale introduction to the farmers. We expected that the BRRI pump along with the Treadle and the Rower pumps might become popular to the farmers. Hence, proper and adequate extension work was carried out for them.

Ghani et al, (1983) and Islam et al, (1980) conducted laboratory tests on the BRRI and the Rower pumps. They found that the BRRI pump with 1.52 to 3.05 m head appeared the most promising water lifting device. But the Rower pump at more than 3.04 m head was satisfactory due to its lower price, operating cost and power requirement. The Rower pump with a suction head of 7.62 m was considered to be the best for the small farmers.

There exists a communication gap between the researchers and the farmers. Even when a suitable design is available, commercial manufacturers are rarely interested in producing these pumps, because their demand is still uncertain. Farmers usually suspect that locally made machine may be



SL	NAME OF THE PARTS
1.	Grip
2.	Handle
3.	Lever
4.	Pin
5.	Suction Manifold
6.	Pedal
7.	Footing
8.	Lift Arm
9.	Sendwitch Plate
10.	Reinforcing Bar
11.	Ring
12.	Suction Chamber
13.	Delivery Outlet
14.	Diaphragm
15.	Valve Weight
16.	Base Frame
17.	Base
18.	Stop Bar

Fig. 1 BRRI diaphragm pump.

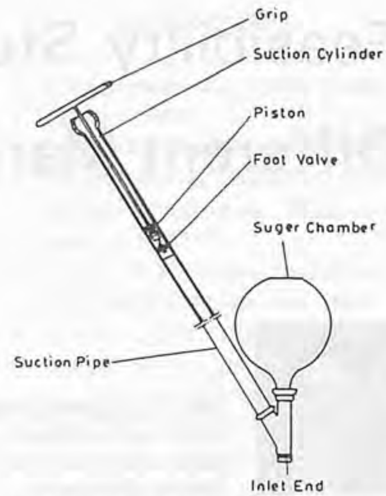


Fig. 2 Sketch of rower test pump.

inferior to imported ones. For this reason a project was conducted for evaluation of the BRRI, the Treadle and the Rower pumps and their proper extension in farmers' fields of greater Barisal district.

Materials and Methods

Description of Manual Pumps

BRRI Diaphragm pump — The BRRI diaphragm pump **(Fig. 1)** is made primarily from 14 gauge mild steel sheet, wood, rubber, nuts and bolts, washers and metal bushing at three wearing points. One or two persons can operate the pump. The upward movement of the lever pulls the diaphragm to expand and thus draws water from a pond or a stream. When the handle is lowered, the diaphragm shrinks and the volume of the chamber decreases and pushes the water out of the chamber. The water movement is controlled by the inlet and outlet flap valves.

Rower pump — The Rower pump is mainly a reciprocating pump **(Fig. 2)**. The cylinder is made of PVC pipe. The piston is made of aluminum and is impregnated with leather lined bucket. The check valve is a moulded plastic part with a simple flap valve of rubber (inner tube). The pump is installed 30° angle from the horizontal to the well in the ground through a 'Y' connector.

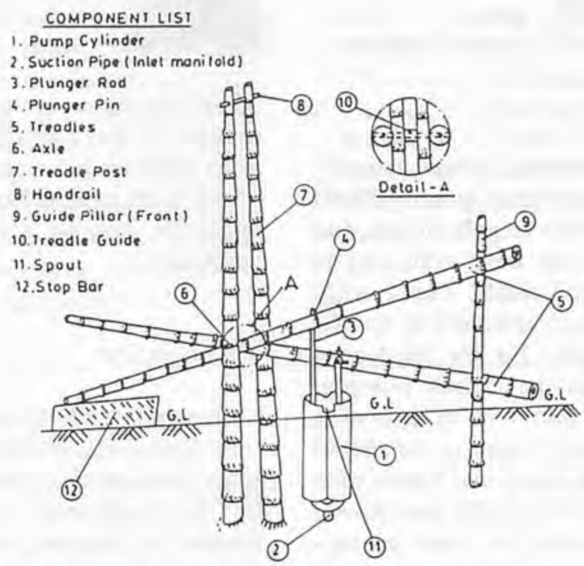


Fig. 3 RDRS — Twin treadle pump.

Twin treadle pump — The Twin treadle pump is mainly a shallow tubewell suction pump **(Fig. 3)**. The pump head is a twin cylinder made of steel sheet. The plungers are moulded PVC cup seals. The check valves are simple flap valves made of rubber (inner tubes). The pump superstructure is made of bamboo and normally installed with a bamboo tubewell.

The pump is operated by the body weight of the operator who uses his legs and muscles, keeping them on levers (treadles). One or two persons can operate the pump.

Research and Demonstration Sites

Two sites, research and demonstration, were selected for the conduct of the study. In the Boro season, three research sites were selected for evaluating the performance of the pumps. The sites were Kalosgrame, Gournadi (Barisal) and Shaitpakia (Jhalokati). The farmers in the sites managed everything except irrigation which was provided by the project personnel with manual pumps. The research sites were selected on the following criteria:

(a) It should be located near a perennial water source.
(b) Water should be available within 3 m head during the dry season.
(c) The land owner should be real farmers who can afford all agricultural inputs in time. In each of the research sites, three separate plots were selected for irrigation by the three manual pumps according to crop need.

In addition to the research sites, several demonstration sites namely, Amirabad (Jhalokati), Dumki - Satani (Potuakhali), Kashipur and Taltarmat (Barisal) were selected. The aims of demonstration were: a) to evaluate the popularity potential of the pumps: and b) to create awareness on the part of the farmers of the Barisal Irrigation Project about the advantages of the pumps. The farmers managed everything, including irrigation.

Production of Prototypes of BRRI Pumps

The manufacture the BRRI pump was decided at the *upazila* or district level workshops so that the farmers of the selected sites could easily avail themselves of the opportunity for repair of their pumps. Accordingly, several contracts had been made with the manufacturers of different upazila workshops for production of the pump.

Socio-economic Survey

A survey questionnaire was designed to collect information on the socio-economic status of the farmers. Altogether 176 farmers were interviewed — 14 from Chamta, 40 from Shaitpaika, 35 from Karapur, 40 from Kalashgramme and 47 from Morakati villages.

Results and Discussions

Performance evaluation of pumps — **Table 1** shows that the surface water level in different parts of greater Barisal district varied from 0.50 to 2.00 m. This implies that there is a great potential for efficient use of different manually operated pumps where the power pumps are not economical.

The discharges (ℓ/s) of the BRRI pump were 4.5 at Jhalokhati, 4.1 at Kalashgramme and 3.5 at Gournadi research sites, respectively, at 0.61, 1.25 and 2.0 m heads. The discharges of the Treadle pump at the said places were 1.5, 1.4 and 1.2, respectively, at 0.5, 1.0 and 2.0 m heads and that of the Rower pump were 2.2, 1.5 and 0.9, respectively, at 0.5, 1.00 and 2.00 m heads **(Table 1)**.

The number of pumping days per season (3-5 h/day) of the BRRI pumps were 35 at Jhalokati, 47 at Kalashgramme and 60 at Gournadi. The highest number of days at Gournadi research site was required because of comparatively higher seepage and percolation rate. In the Gournadi research site, the irrigation by Treadle and Rower pumps were supplemented by the BRRI pump. The reason was the quantity of water lifted by

Table 1. Irrigation Parameters of Different Pumps Observed at Different Research Sites

Research site	Soil type	Area cultivated (ha)	Pumps used	Pump head (m)	Total pump operation (days/ season)	Frequency of irrigation per season	Total pump operation per season (h)	Supplement by BRRI pump (h)	Disc-harge (li/sec.)	Water applied by pumps per season (mm)	Rainfall (mm)	Total water required per season (mm)
Shaitpaika (Jhalokati)	Silty clay	0.265	BRRI Pump	0.61	92	35	175	—	4.5	1 070	123	1 193
		0.056	Treadle Pump	1.50	94	32	102	10	1.5	1 177	123	1 300
		0.056	Rower Pump	0.50	72	17	80	—	2.2	1 131	123	1 254
Kalashgramme (Barisal)	Silty clay loam	0.178	BRRI Pump	1.25	81	47	188	—	4.1	975	584	1 559
		0.063	Treadle Pump	1.30	72	44	176	—	1.4	824	584	1 408
		0.045	Rower Pump	1.00	76	43	131	—	1.5	988	584	1 572
Gournadi (Barisal)	Silty clay	0.269	BRRI Pump	2.00	91	60	360	—	3.5	1 686	164	1 850
		0.080	Treadle Pump	2.20	92	7	133	98	1.2	1 733	164	1 897
		0.061	Rower Pump	2.00	86	12	128	80	0.9	1 907	164	2 071

Note: Duration of irrigation was calculated between 10 days after transplantation and 15 days before harvest.

the Treadle and the Rower pumps were not sufficient to irrigate the plots taken for them due to the fact that the tidal water remained only 2-3 h in the canal.

The command areas of Treadle and Rower pumps are almost equal. But that for the BRRI pump were from 3.5 to 4.5 times greater than those of the other two pumps (**Table 2**).

Among the three pumps, the BRRI pump created the most problems in all the research and demonstration sites. First, the diaphragm of the BRRI pump had to be replaced 1 to 3 times in one season (**Table 2**). Second, decaying of the inner wooden part of the sandwich plate shortened its durability. Other parts like the inlet and outlet valves, pin, supporting arm welding, frames etc. created some problems during the operation. In the Treadle and the Rower pumps, only the buckets created problem in the field. The repair cost of the BRRI pump was Tk. 137, 154 and 245, respectively, at Shaitpaika, Katashgramme and Gournadi (**Table 2**). But in any of the research sites per season the repair cost of the Treadle or the Rower pumps did not exceed Tk. 30.

Table 2. Problems of the Test Pumps

Research	Pump	Operator	Name of parts	Type of failure	Frequency of (times/ season)	Repairing cost (Tk/ season)	Av. Command area (ha/season)
Saitpaika	BRRI Pump	2	Diaphragm	Torn	2	45.00	—
			Base frame	Broken	1	48.00	0.55
			Thread lost	Thread lost	2	20.00	
			Footing	Welding collapse	2	24.00	
	Treadle Pump	1	Rope	Torn	5	10.00	0.15
	Rower Pump	1	Leather bucket	Loosen	1	24.00	0.12
Kalashgram	BRRI Pump	2	Diaphragm	Torn	2	45.00	
			Base frame	Broken	1	48.00	0.55
			Nut-bolt	Thread lost	2	20.00	
			Footing	Welding collapse	2	24.00	
	Treadle Pump	1	Rope	Torn	5	10.00	0.15
	Rower Pump	1	Leather bucket	Loosen	1	24.00	0.12
Gournadi	BRRI Pump	2	Diaphragm	Torn	3	65.00	
			Base frame	Broken	3	144.00	
			Wooden base	Decaying	1	36.00	0.55
	Treadle Pump	1	—	—	—	—	0.15
	Rower Pump	1	Leather bucket	Loosen	1	24.00	0.12

Table 3. Irrigation Cost for Different Manual Pumps

Cost item	BRRI pump	Treadle pump	Rower pump
		A. Fixed cost	
1. Depreciation[1]	900	693	1 320.00
2. Interest on[2] investment	440	339.00	387.20
Total fixed cost	1 340	1 032.00	1 707.20
		B. Variable cost	
1. Labour wage[3]	6 030	16 075.00	22 523.34
2. Interest on running cost	482.44	1 286.00	1 801.86
3. R & M[4]	380.00	30.80	35.20
Total variable cost	6 892.44	17 391.80	24 360.40
Total full cost (using hired labour)	8 232.44	8 423.80	26 067.60
Total cost (using family labour)	1 720.00	1 062.80	1 742.40

Note: Two BRRI or 7 Treadle or 8 Rower were needed for irrigating one hectare of rice land.
1/: At 10% salvage value of purchase price Tk. 2 500 for BRRI, Tk. 550 for Treadle and Tk. 550 for Rower pumps, respectively.
2/: At 16% of the capital.
3/: Wage rate at Tk. 35/man-day.
4/: Actual.
1 U.S.$ = Tk. 39/-

Comparative irrigation cost — The prices of the BRRI, the Rower and the Treadle pumps are shown in **Table 3**. Two BRRI or 8 Rower or 7 Treadle pumps were required to irrigate 1 hectare of rice field. At full cost basis irrigation cost per hectare for rice field were Tk. 9 582 for the BRRI pumps, 16 145 for the Treadle and 18 979 for the Rower (**Table 3**). The irrigation cost for the BRRI pump was the cheapest. The rice irrigation by the Treadle and the Rower pumps were much more expensive. Ignoring labour wages, the irrigation cost for one hectare of rice field were Tk. 1 700 for the BRRI pump, 1 063 for the Treadle pump and 1 842 for the Rower pump. At full cost basis per hectare irrigation the cost of rice field for the power pump was Tk. 1 688.

The irrigation costs for the power pumps was cheaper than that of any of the manually operated pumps at full cost basis.

Production of prototypes — Efforts for manufacturing the BRRI pump locally were not satisfactory. Local manufacturers were not interested for its production, because of inexperience and uncertain marketing. Therefore, several manufacturers were selected from Dhaka, but finally, only two manufacturers were able to supply the pumps at reasonable standard. The Rower and the Treadle pumps were procured from the Mirpur Agricultural Workshop.

Socio-economic survey — **Table 4** shows the classification and distribution of farmers according to their land holdings tenure. It was observed that most of the farmers belong to the 0-0.5 ha class. In most of the families in the survey area, the number of adult male is more than that of adult female (**Table 5**). Although, the adultg males dominate family, the number of dependents is high due to unemployments problems.

Farmers who belong to the 0 to 0.5 ha landholding class was high in the villages which used family labour in their agricultural activities. Therefore, the manual pumps could be widely used by this group of farmers in the village.

Table 4. Farmers Land Area Groups in Different Sites

Land holdings (ha)	Chamta		Saitpaika		Karapur		Kalashgramme		Morakati	
	Farm-ers	(%)	Farm-ers	(%)	Farm-ers	(%)	Farm-ers	(%)	Farm-ers	(%)
0-0.5	1	7.14	15	37.50	14	40.00	16	40	18	38.30
0.5-1	3	21.43	13	32.50	7	20.00	12	30	18	38.30
1-1.5	4	28.57	8	17.50	8	22.86	8	20	7	14.89
1.5-2	1	7.14	2	5.00	1	2.86	2	5	1	2.13
2 & above	5	35.72	3	7.50	5	14.28	2	5	3	6.38
Total	14	100	40	100	35	100	40	100	47	100

Table 5. Family Members, Effective Family Labour and Source of Income in Different Survey Sites

Sites surveyed	Adult male/ family	Adult female/ family	Children /family	Total number /family	Effective labour and their percentage/ family		Source of income (%)		
							Agri-culture	Busi-ness	Service
	(No.)	(No.)	(No.)	(No.)	No.	%			
Chamta	4	2	2	8	2	25.00	99	0	1
Shaitpaika	3	2	3	8	3	37.50	92	3	5
Karapur	3	2	2	7	4	57.14	77	18	5
Kalasgramme	2	2	3	7	4	57.14	73	15	12
Morakati	2	2	3	7	3	42.86	73	25	2
Average	3	2	3	7	3	43.93	82.8	12.2	5

Recommendations

The specific recommendations for the pumps are:

BRRI pumps

- Stroke limiting bar (SLB) attached to the fulcrum should be eliminated and a cross bar underneath the pedal would serve its purpose. This will help to overcome the flattening of the stroke limiting bar.
- The size of nut and bolts should be similar or standardized for all pumps for easy repairs or services.
- A diaphragm with longer life should be investigated.

Twin Treadle Pump

- This pump was recommended for use in small landholdings for irrigating vegetables instead of rice.

Rower Pump

- This pump could also be used in small landholdings for irrigating vegetables instead of rice.

General Recommendations

The general recommendations for the pumps are:

- To popularize BRRI pump in different parts of Bangladesh, a 50% subsidy on the price of the pump should be given.
- Proper credit should be made available to the farmers' for buying the pumps.
- Further extension of different manual pumps should be strengthened in different parts of the country with continuos follow up work to get the feed back information from the field for further improvement.

REFERENCES

Ghani, A., T. Islam, K. Humayun and K.A. Haq, 1983. Comparative studyy on different manually operated pumps available in Bangladesh, Agril. Engineering Division, BRRI. Joydebpur, Gazipur.

Islam, S. and M.A. Mazed, 1980. Comparison of performance of different types of pumps (manual pumps only), BARI Agricultural Engineering Division, Report, BARI, Joydebpur, Gazipur. ■■

Tillage Effects on Corn in Relation to Irrigation and Nitrogen

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Abstract

Crops on coarse textured soils suffer from water stress with infrequent wetting and from nutrient stress with heavy and frequent irrigation or rain. These stresses can be alleviated by increasing the rooting volume and/or regulating water and nutrients supplies. Field experiments were conducted to study the interactive effects of tillage, irrigation and N rates on root growth, water and nitrogen use and yield of corn on loamy sand and sandy loam soils. Treatments included combinations of two tillage systems, viz. i) 10 cm-deep conventional tillage (CT) and ii) 35- to 40-cm deep chiselling 35 cm apart with a single tine chisel (DT), three irrigation regimes, viz. i) no irrigation (I_0), ii) 75 mm irrigation at 75 mm evaporation from open pan (I_1) and iii) 75 mm irrigation at 50 mm evaporation (I_2) and two N rates viz. i) 80 kg n ha^{-1} (N80) and ii) 120 kg N ha^{-1} (N_{120}) on both loamy sand and sandy loam soils.

Deep tillage decreased bulk density and soil strength in the tilled zone which caused deeper and denser rooting compared with CT. As a consequence of better rooting, the crop in the deep tilled plots used 77 and 23 mm more water and 19.2 and 27.2 kg ha^{-1} more nitrogen on loamy sand during 1983 and 1984, respectively. Similar trends were observed on sandy loam. Enhanced nutrient and water use in DT led to significant yield increase on both soils during both years. However, tillage effects on grain yield were more pronounced on loamy sand than on sandy loam and in 1984 when rains were less frequent than in 1983 when there were frequent rains early in the season. Irrigation and irrigation X tillage interaction effects were significant during 1984 only.

Introduction

Coarse textured soils are characterized by low water retentivity, excessive permeability and sharp increase in soil strength upon drying. Because of low water storage capacity of root zone and their high potential for leaching of mobile nutrients, crops on these soils are subjected to frequent water and nutrient stresses which reduce yields. The problem is further accentuated by slow growth of roots on these soils due to cmpact subsurface and or rigidity of pores (Cruse et al, 1980).

For proper utilization of nutrients and water by crops and consequent high yields, the zone of nutrient concentration should synchronise with moist zone having actively growing roots. But in these soils the latter lags behind the nutrient rich zone and the moisture gets depleted quickly. The remedy, therefore, lies in accelerating the development of root zone or regulate the supply of water and nutrients or do both.

A number of researchers have documented that subsoiling reduces bulk density and mechanical resistance of soil and affects its pore size distribution (Campbell et al, 1974; Bradford and Blanchar, 1977; Doty and Reicosky 1978 and Chaudhary et al., 1985) and increased root proliferation into sub soil (Kaddah 1976; Camp et al., 1984; Hassan et al., 1984; Chaudhary et al., 1985 and Bennie and Botha, 1986). Also, there are reports that tillage increases water and fertilizer use efficiency (Power, 1983; Eck and Unger, 1985; Sharma, 1985; Doty et al., 1985; Cassel and Edwards 1985 and Gajri et al., 1992a). Lack of information on the interactive effects of tillage, applied N and irrigation regime on root growth, water and nutrient use and yield of corn on sandy soils prompted us to study these aspects on loamy sand and sandy loam soils.

Materials and Methods

Soil Characteristics and Weather

Field experiments were conducted with corn on loamy sand (Typic Ustipsamment) and sandy loam (Typic Ustochrept) soils in 1983 and 1984. The soils differed markedly with respect to soil water retention (**Table 1**). Water retention between field capacity and −1.5 MPa was 108 mm greater in sandy loam than that in loamy sand. Weather data during the growing season are given in **Table 2** and **Fig. 1**.

Treatments

Combination of two tillage systems and three irrigation regimes were randomized in the main plots and two N rates in the sub plots. Tillage systems were: i) Conventional tillage, one pass of discing and two passes of cultivator to disrupt the soil to approximately 10 cm depth followed by culti-packing (CT); and ii) Deep tillage, chiselling 40 cm apart down to 40-45 cm depth with a single tine chisel followed by conventional tillage (DT). The irrigation regimes consisted of: i) no irrigation (I_0); ii) 75 mm irrigation at 75 mm net evaporation (I_1); and iii) 75 mm irrigation at 50 mm net evaporation from a USWB class A open pan after a 75 mm common irrigation 20 days after seeding (DAS) (I_2). Nitrogen rates were: i) 80 kg N ha^{-1} (N80); and ii) 120 kg N ha^{-1} (N_{120}). Each sub-plot measured 10 m × 6 m and the treatments were replicated thrice.

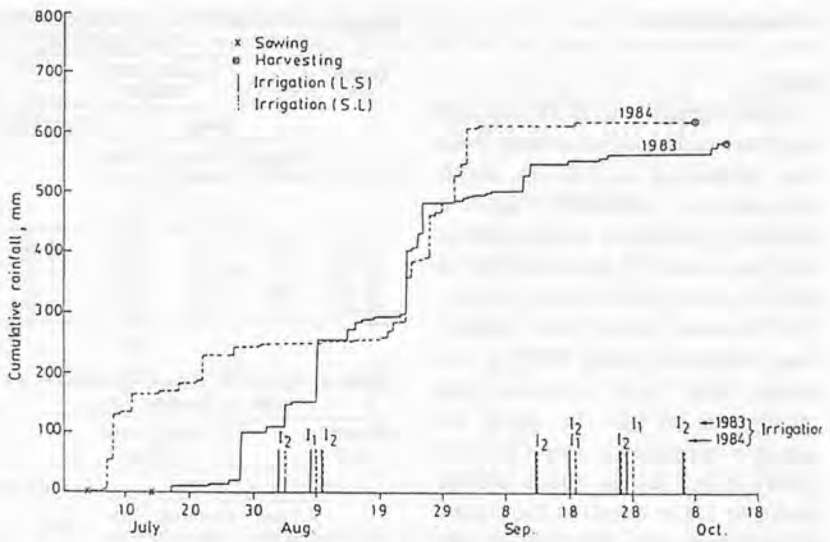

Fig. 1 Rainfall distribution and irrigation events during growing season of corn on two soil types, 1983 and 1984.

Crop Raising

After the harvest of wheat in April the fields were irrigated in early June. Deep tillage was performed in respective plots during the last week of June in a relatively dry soil to get maximum shattering of the sub-soil. Immediately before sowing conventional tillage was done in all the plots to prepare the seedbed after a pre-sowing irrigation in 1983 and a heavy rain in 1984. All plots were fertilized by drilling 50 kg ha^{-1} P_2O_5 from single superphosphate, 25 kg K_2O as muriate of potash and 25 kg $ZnSO_4$ ha^{-1}. Corn was dibbled 22.5 cm apart in 60 cm wide rows. The required N in different treatments was applied by broadcast in three equal splits viz. at seeding, 20 DAS and 40 DAS. Sowing and harvesting schedule for the two years for both soils is given in **Table 3**.

Table 1. Particle Size Distribution and Water Retention Characteristics of Experimental Soils

Soil depth (cm)	Percent soil separates			Water retention (v/v) %	
	Sand	Silt	Clay	Field capacity*	− 1.5 MPa
			Loamy sand		
0-30	88	7	5	17.5	7.3
30-60	87	7	6	18.5	8.0
60-90	88	6	6	17.2	7.8
90-120	90	7	3	14.8	6.3
120-150	91	6	3	14.7	6.3
150-180	91	6	3	14.7	6.2
			Sandy loam		
0-30	75	15	10	24.0	8.9
30-60	68	18	14	24.9	10.1
60-90	68	18	14	24.9	10.1
90-120	68	20	12	24.5	8.7
120-150	68	20	12	24.5	8.7
150-180	74	17	9	24.0	8.8

*Determined in-situ 24 hrs after thorough wetting.

Table 2. Mean Maximum and Minimum Temperature, Sunshine Hours and Open-pan Evaporation during Cropping Seasons

Year	Month	Mean temp. (°C)		Sunshine (h)	Evaporation (mm)
		Max.	Min.		
1983	July	35.1	25.8	8.2	147.2
	August	33.4	25.8	6.0	95.0
	Sept.	34.0	24.0	9.2	103.7
	Oct.	31.2	15.5	9.3	110.8
1984	July	33.6	25.3	8.0	90.2
	August	33.1	25.7	6.7	70.8
	Sept.	32.1	21.6	9.6	66.5
	Oct.	31.8	14.0	10.1	132.4

Table 3. Date of Seeding and Harvest of Corn on Two Soil Types

Year	Soil Type	Date of Seeding	Date of Harvest
1983	Loamy sand	14 July	13 October
	Sandy loam	16 July	20 October
1984	Loamy sand	4 July	6 October
	Sandy loam	6 July	8 October

Observations

Soil

Soil strength in 0-35 cm soil layer at seeding time during 1983 was measured in 0.05 m depth increments, manually with a probing type cone penetrometer (30° angle and 13 mm base dia) at field capacity soil water content. For the same layers bulk density was measured using 0.05 m dia cores. Soil water content was monitored in all the plots by neutron moisture meter (Troxler 2601) using access tubes driven down to 1.8 m depth in the center of each sub-plot. Soil water content in top 0.30 m was measured gravimetrically. Soil samples taken at harvest in 1983 were analysed for NO_3-N content.

Plant

For root sampling, soil cores were taken by 0.15 m depth intervals; with a 0.05 m dia. auger from 8 sites (four on either side of row starting from row base to mid-way between rows) and composited. Soil was washed on 1 mm screen and roots picked up with forceps. Living roots were separated by staining with 1% aqueous solution of Congo red (Ward et al., 1978). Root length was measured by line intercept procedure of Newman (1966). In 1983 roots were determined at 55 and 70 DAS in all replications in I_2 treatment only, but were determined at 25 and 80 DAS in all treatments and all replications in 1984. The number of days to tasselling and silking were recorded from the start of appearance until 50% plants in each plot tasselled or silked. Nitrogen content in plant material was determined with autoanalyser (Warmer and Jones 1970).

Canopy temperatures were measured between 65 and 75 days after seeding (DAS) at 1300-1430 hrs during 1984 with a non-contact instatherm at five randomly selected sites and pooled to obtain a mean value. Stress degree days were computed as the sum of differences between daily mean canopy and air temperatures.

A net area of 6 m × 2.4 m was harvested for grain and stover yields. Observations were also taken on cobs per plant, grain weight per cob and 100-grain weight. Grain yields were adjusted to 15% moisture content.

Table 4. Effect of Tillage Treatments on Soil Bulk Density (Mg m^{-3}) in 0-35 m Soil Layer at Seeding Time

Depth (cm)	Loamy sand Tillage				Sandy loam Tillage			
	Deep			Conventional	Deep			Conventional
	Chisel furrow	Distance from chisel furrow (cm) —8—	—16—		Chisel furrow	Distance from chisel furrow (cm) —8—	—16—	
0-10	1.51	1.53	1.53	1.52	1.47	1.52	1.54	1.54
10-20	1.55	1.61	1.66	1.63	1.55	1.62	1.65	1.63
20-30	1.46	1.53	1.60	1.56	1.52	1.63	1.68	1.63
30-35	1.45	1.52	1.53	1.53	1.46	1.61	1.62	1.62

Table 5. Effect of Tillage Treatments on Cone Index (MPa) in Top 0-35 m Soil Layer at Seeding Time

Depth (cm)	Loamy sand Tillage				Sandy loam Tillage			
	Deep			Conventional	Deep			Conventional
	Chisel furrow	Distance from chisel furrow (cm) —8—	—16—		Chisel furrow	Distance from chisel furrow (cm) —8—	—16—	
0-10	0.46	0.52	0.56	0.55	0.70	0.84	0.85	0.85
10-20	0.47	0.59	0.61	0.81	0.44	0.78	0.86	1.08
20-30	0.37	0.55	0.64	0.82	0.05	0.69	1.01	1.20
30-35	0.08	0.38	0.46	0.80	0.02	0.68	1.19	1.62

Results and Discussion

Soil Physical Properties

DT decreased bulk density in the chisel furrow, more especially at 0.10-0.30 m depth. But 0.08 and 0.16 m away from the chisel marks, bulk density in DT was not substantially different from that in the CT on both soils **(Table 4)**. Interestingly, however, cone index (CI) was decreased by DT even in the mid point between chisel furrows **(Table 5)**. In sandy loam soil CI in 0.20-0.35 m deep layer in the chisel furrow was 0.02 to 0.05 MPa against 1.20 to 1.24 MPa in the CT. The effect of loosening by DT on CI decreased with distance away from the chisel mark.

Root Growth

Since the rooting depth and densities during 1983 were identical for the two timings (55 and 70 DAS), only 70 DAS root length index (RLI, cm root cm^{-2} surface area in the rooted profile) and depth of rooting are given **(Table 6)**. Roots had grown deeper (105 cm) in loamy sand than sandy loam (90 cm). Though, deep tillage had little effect on depth of rooting but substantial differences were observed in RLI on both the soils and at both N rates. Averaged over nitrogen, RLI in the entre profile in DT was more than double the in CT on both soils. Maximum differences in RLI in CT and DT were observed on sandy loam below 30 cm soil depth when the RLI in the former was four times that in the latter.

In 1984, the effect of DT was noticeable even at 25 DAS when

Table 6. Tillage and N Effects on RLI and Depth of Rooting of 70-day Old Corn on Loamy Sand and Sandy Loam Soils

Treatment		RLI (cm root cm^{-2} soil)		Depth of Rooting (cm)
Tillage	N rate	Whole of rooted profile	Below 30 cm depth	
		Loamy sand		
CT	80	8.7	5.1	90
	120	13.7	10.1	105
DT	80	16.4	9.8	105
	120	29.9	14.8	105
		Sandy loam		
CT	80	7.1	1.4	75
	120	6.0	2.0	75
DT	80	11.2	5.1	90
	120	18.9	8.7	90

Table 7. Tillage and Irrigation Effects on RLI and Depth of Rooting of 80-day Old Corn on Loamy Sand and Sandy Loam Soils

Treatment		RLI (cm root cm^{-1} soil)		Depth of Rooting (cm)
Tillage	Irrigation	Whole of rooted profile	Below 30 cm depth	
		Loamy sand		
CT	I_0	4.8	0.2	90
	I_1	5.1	0.9	120
	I_2	5.0	1.4	120
DT	I_0	5.1	1.1	120
	I_1	12.0	5.0	225
	I_2	16.9	5.8	180
		Sandy loam		
CT	I_0	8.4	0.6	135
	I_1	9.7	4.5	180
	I_2	13.4	6.0	180
DT	I_0	9.0	2.9	150
	I_1	10.9	6.0	180
	I_2	17.2	7.9	180

RLI in DT was 0.08 and 0.16 cm^{-2} higher than in CT on loamy sand and sandy loam, respectively. Deep tillage did not affect depth of rooting at this stage. At 80 DAS, irrigation and tillage showed considerable effects both on depth and proliferation of roots (**Table 7**). On the loamy sand, root system in DT had grown 30 cm deeper than in CT in I_0, 105 cm deeper in I_1 and 60 cm deeper in I_2, respectively. However, on sandy loam DT affected depth of rooting in I_0 only. RLI was considerably increased by DT on both soils. These differences were more pronounced on loamy sand than on sandy loam. On the loamy sand RLI (entire profile) in DT was 6, 135 and 238% higher than in CT in I_0, I_1j and I_2, respectively. Corresponding increases on sandy loam were 7, 11 and 28%, respectively. Significantly, the tillage-induced differences in RLI below 30 cm depth were of much larger magnitude. The increase in RLI with DT over CT were 45, 456 and 314% in I_0, I_1 and I_2, respectively, on loamy sand and 383, 33 and 32 per cent, respectively, on sandy loam. Apart from increased rooting depth and RLI, deep tillage caused more uniform distribution of roots in the rooting volume. For example, the RLI in the middle of the rows was much greater in DT than in CT (**Table 8**).

Table 8. RLI Mid-way Between Rows (22.5-30 cm) as Affected by Tillage Under Various Irrigation Regimes in Two Soil Types

Irrigation regime	RLI - cm cm^{-2}					
	Loamy sand			Sandy loam		
	CT	DT	Mean	CT	DT	Mean
I_0	0.4	2.0	1.2	3.6	8.1	5.8
I_1	0.9	4.7	2.8	3.0	8.8	5.9
I_2	2.1	10.7	6.4	7.7	12.4	10.0
Mean	1.2	5.8		4.8	9.8	

Denser rooting in DT compared to CT is attributable to decreased bulk density and soil strength (**Tables 4 and 5**) as root elongation has been shown to be inversely correlated with cone index (Taylor et al, 1966). Greater effects of deep tillage and irrigation on rooting depth in 1984 compared to 1983 were due to infrequent rains in that year during early growth in the former (**Fig. 1**). Frequent wetting by rains and or irrigation negated the deep tillage effects on rooting depth (Gajri et al, 1991).

Water and Nutrient Uptake

Deeper and denser root system with DT extracted more water (**Table 9**) and nitrogen (**Table 10**) from the soil profile. On loamy sand, water use by the crop in 1983 and 1984 was 77 and 23 mm higher, respectively, in DT than in CT; on sandy loam it was 41 and 27 mm more in DT than in CT. It was so because better rooting in DT helped the crop to counter soil

Table 9. Tillage Effects on Harvest Time Residual Water Storage in 180-cm Soil Profile on Two Soil Types during 1983 and 1984

Tillage	Residual Profile Stored Water (mm)			
	Loamy sand		Sandy loam	
	1983	1984	1983	1984
CT	256	203	348	346
DT	179	180	307	319

Table 10. Effect of Tillage and N-rates on Nitrogen Uptake by Corn on Loamy Sand and Sandy Loam Soils

Tillage	N-rate kg ha^{-1}	Loamy sand		Sandy loam	
		1983	1984	1983	1984
		kg ha^{-1}			
Conventional	80	19.1	23.6	60.6	70.8
	120	30.8	31.9	71.0	84.7
	Mean	25.0	27.8	65.8	77.8
Deep	80	34.4	52.2	65.7	112.4
	120	53.9	57.7	84.9	121.0
	Mean	44.2	55.0	75.3	116.7

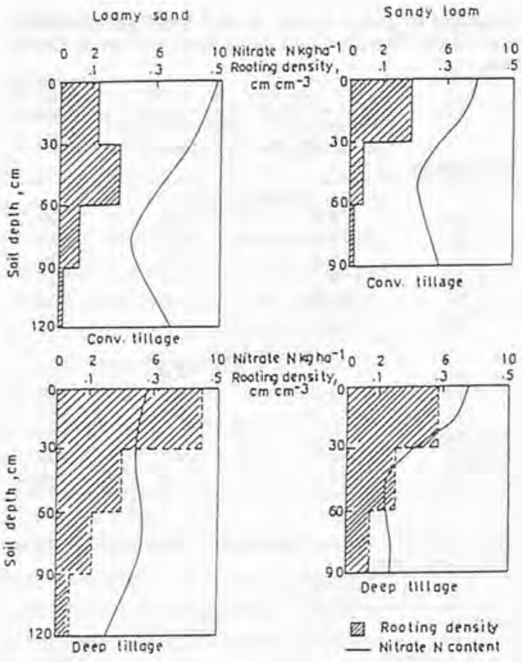

Fig. 2 Tillage effects on rooting density (70 DAS) and residual nitrate-N content profiles at harvest of corn in two soil types, 1983.

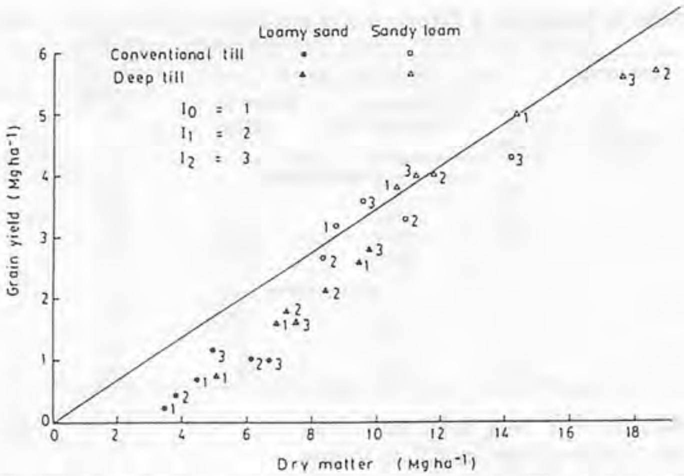

Fig. 3 Grain and dry matter fields of corn as affected by tillage and irrigation.

resistance to water flow through decreased flow path length and greater depth increased the depth of exploitable water (Gajri and Prihar 1985).

Similar to water uptake, N uptake with DT averaged 19.2 kg and 27.2 kg ha^{-1} higher than with CT during 1983 and 1984, respectively, on loamy sand and 9.5 and 88.9 kg ha^{-1} on sandy loam. Nitrogen uptake was also associated with the extent and pattern of root growth as shown by harvest time. NO_3-N profiles and rooting density profiles at 70 DAS **(Fig. 2)**.

Canopy Temperature

Greater water uptake from the soil profile was reflected in plant water status as indexed by stress degree days (SDD = canopy − air temperature during 65 to 75 DAS) **(Table 11)**. The canopy at grain fill stage remained substantially cooler in DT than CT irrespective of the irrigation regime.

Extensive rooting in deep tilled crop helped the crop to extract more water and to maintain more favourable plant water status even if available soil water was reduced (Gajri and Prihar 1985).

Tasseling and Silking

Deep tillage enhanced tasseling and silking on both soils in both years **(Table 12)**. In 1983, time to 50% tasseling in DT and CT averaged 53 and 57 days on loamy sand and 49 and 51 in sandy loam, respectively. In 1984, also 50% tasseling occurred 3 days earlier in DT than in CT on loamy sand and 5 days on sandy loam. Similarly, 50% silks appeared 8 and 4 days earlier on loamy sand and 2 and 4 days earlier on sandy loam in 1983 and 1984, respectively.

Yield

Compared with CT the grain yields were significantly higher in DT on both soils and during both years **(Table 13)**. However, tillage effects were more pronounced on loamy sand than on sandy loam and in 1984, a year of less frequent rains; than in 1983 when there were frequent rains early in the growing season. The crop in DT outyielded that in CT by 132 and 19% in 1983, and 197 and 67% in 1984 on loamy sand and sandy loam soils, respectively. In general, crop responses to deep tillage are greater on low retentive soils

Table 11. Tillage and Irrigation Effects on Stress Degree Day (SDD) in Corn at 65 to 75 DAS, 1984

Soil	Irrigation	SDD	
		DT	CT
Loamy sand	Io	61.2	64.0
	I1	15.0	47.5
	I2	7.5	22.5
Sandy loam	Io	− 1.0	25.0
	I1	−17.5	19.0
	I2	−19.0	−10.0

Table 12. Effect of Tillage on Time (days) to 50% Tasseling and Silking in Corn on Two Soil Types, 1983 and 1984

Soil	Year	Number of days to			
		Tasseling		Silking	
		CT	DT	CT	DT
Loamy sand	1983	57	53	73	65
	1984	55	52	67	63
Sandy loam	1983	51	49	60	58
	1984	52	47	61	57

and under low rainfall (Unger 1979; Arora et al, 1991 and Gajri et al, 1991).

The increase in yield by DT was associated with increase in important yield parameters viz. Cobs plant^{-1} grain weight cob^{-1} and hundred grain weight **(Table 14)**. Also, prolonged reproductive phase **(Table 11)** coupled with higher LAI (data not reported) and better plant water status **(Table 11)** in DT resulted in favourable source — sink relation. Higher harvest index (HI) with DT compared to CT **(Table 15)** also indicates that more photosynthates were translocated to grain in the former.

The crop responded to higher rate of nitrogen on both soils in 1983 and on sandy loam alone in 1984. It appears that substantial amount of applied N might have leached beyond root zone during 1983 when early irrigation was followed by frequent rains. Response to higher level of N on sandy loam in 1984 can be explained in terms of higher soil water retentivity (water supply) (Gajri et al. 1992b).

Yield response to differential irrigation during the two growing seasons is linked with pattern of rainfall. Irrigation levels did not significantly affect maize grain yield in 1983 when there were frequent rains during the grand growth period of the crop. However, in 1984 when the crop received 12 cm rain within four days of seeding and very little rain thereafter till 45 days, differential irrigation affected corn yield significantly. The irrigation × tillage interaction was significant on both soils during 1984. In DT plots, while the yield was significantly affected by irrigation on loamy sand, it was not so on sandy loam. In CT plots on sandy loam, irrigation levels did significantly increase grain yield. In CT plots on loamy sand, significant

Table 13. Grain Yield (Mg ha^{-1}) of Corn as Affected by Tillage, Irrigation and N-rates on Two Soil Types, 1983 and 1984

Tillage	N-rates (kg ha^{-1})	Loamy sand				Sandy loam			
		I_0	I_1	I_2	Mean	I_0	I_1	I_2	Mean
					1983				
Conv.	80	0.36	.23	.39	.33	2.51	2.07	3.03	2.54
	120	0.73	.47	1.18	.80	3.24	2.71	3.59	3.18
Deep	80	1.21	.70	.97	.96	2.51	2.81	3.23	2.85
	120	1.60	1.78	1.62	1.67	3.83	3.97	4.04	3.95
LSD .05									
Tillage			0.37				0.56		
Irrigation			NS				NS		
Fertilizer			.25				.27		
					1984				
Conv.	80	0.12	.69	.64	.48	2.37	2.73	3.38	2.83
	120	.24	1.03	1.00	.76	2.64	3.25	4.30	3.40
	Mean	.18	.86	.82		2.51	2.99	3.84	
Deep	80	.73	2.05	2.55	1.78	4.94	5.04	5.03	5.00
	120	.76	2.18	2.77	1.90	5.04	5.72	5.58	5.44
	Mean	.75	2.12	2.66		4.99	5.38	5.30	
LSD .05			.31				.35		
Irrigation			.37				.43		
Fertilizer			NS				.24		
Tillage × Irrigation			.53				.61		

Table 14. Tillage Effects on Yield Attributes on Two Soil Types, 1983 and 1984

Soil	Cobs plant^{-1}		Grain wt cob^{-1} (g)		Thousand grain weight (g)	
	CT	DT	CT	DT	CT	DT
			1983			
Loamy sand	.54	.71	12.6	22.1	11.8	14.0
Sandy loam	.80	.88	46.6	55.5	19.6	20.0
			1984			
Loamy sand	.41	.69	19.9	34.4	12.5	14.5
Sandy loam	.87	1.00	46.2	71.2	18.2	20.7

Table 15. Harvest Index (kg grain kg^{-1} dry matter) × 100 of Corn as Affected by Tillage, Irrigation, and N-rates on Two Soil Types, 1983 and 1984

Tillage	N-rates (kg ha^{-1})	Loamy sand				Sandy loam			
		I_0	I_1	I_2	Mean	I_0	I_1	I_2	Mean
					1983				
Conv.	80	11.0	8.6	11.6	10.4	32.5	26.0	32.1	30.2
	120	16.3	12.4	11.6	13.4	37.0	32.5	37.1	35.5
					11.9				32.8
Deep	80	21.2	16.1	16.9	18.1	30.8	28.9	33.4	31.1
	120	23.5	24.8	22.1	23.5	36.2	31.8	36.1	34.7
					20.8				32.9
					1984				
Conv.	80	4.0	12.6	11.8	9.5	28.7	27.5	28.3	28.2
	120	6.7	17.7	15.1	13.0	28.1	30.0	30.2	29.4
					11.2				28.8
Deep	80	14.6	24.2	28.5	22.4	34.8	30.8	32.7	32.8
	120	16.8	25.9	28.7	23.8	35.0	30.3	31.4	32.2
					23.1				32.5

response to irrigation was limited to I_1. The absence of response to further increase in irrigation may be due to leaching of nutrients with additional water on this soil and/or smaller plant size (caused by early stresses) which limited the transpirational need of the crop.

It is interesting to noe that when grain yield with 120 kg N ha^{-1} was plotted against corresponding total above ground dry matter and an upper bound line was drawn through the origin **(Fig. 3)**, most of the data points for sandy loam soil were either on or very close to the upper bound line. However, all the data points for loamy sand were much below the line and also showed distinct grouping as DT and CT points. Data points for DT were closer to the line than CT. It shows that deep tillage increased grain yield by increasing dry matter as well as its partitioning into grain fraction (Prihar and Stewart 1990). The postulation that crop on loamy sand suffered from water stress is also supported by the observation that harvest index (HI) of the crop (**Table 15**) failed to reach 30% even with DT and highest irrigation while on sandy loam it exceeded this value without deep tillage and at medium irrigation. Moreover, irrigation almost doubled HI in DT on loamy sand but not so on sandy loam. These observations show that with irrigation practice followed in this study, the crops on loamy sand suffered from intermittent water stresses even in deep tilled plots. In these soils deep tillage must be accompanied by small and frequent irrigations to avoid these stresses.

REFERENCES

Arora, V.K., Gajri, P.R. and Prihar, S.S. 1991. Tillage effects on corn in sandy soils in relation to water retentivity, nutrient and water management and seasonal evaporativity. Soil Tillage Research 21: 1-21.

Bennie, A.T.P. and Botha, F.J.P. 1986. Effect of deep tillage and controlled traffic on root growth, water use efficiency and yield of irrigated maize and wheat. Soil Tillage Res. 7: 85-95.

Bradford, J.M. and Blanchar, R.W. 1977. Profile modification of a Fragiudalf to increase crop production. Soil Sci. Soc. Am. Proc. 41: 127-131.

Camp, C.R., Christenbury, G.D. and Doty, C.W. 1984. Tillage effects on crop yields in coastal plain soils. Trans. ASAE 27: 1729-1733.

Campbell, R.B., Reicosky, D.C. and Doty, C.W. 1974. Physical properties and tillage of Paleudults in the south eastern coastal plains. J. Soil Water Cons. 29: 220-224.

Cassel, D.K. and Edwards, E.C. 1985. Effects of subsoiling and irrigation on corn production. SSSAJ 49: 996-1001.

Chaudhary, M.R., Gajri, P.R., Prihar, S.S. and Khera, R. Effect of deep tillage on soil physical properties and maize yield on coarse textured osils. Soil Tillage 6: 32-44.

Cruse, R.M., Cassel, D.K. and Averett, F.G. 1980. Effect of particle surface roughness on densification of coarse textured osil. Soil Sci. Soc. Am. J. 44: 692-697.

Doty, C.W., Campbell, R.B. and Reicosky, D.C. 1975. Crop response to chiseling and irrigation in soil with compact A_2 horizon Trans. Am. Soc. Agric. Eng. 18: 668-672.

Doty, C.W. and reicosky, D.C. 1978. Chiseling to minize the effect of drought. Trans. ASAE 21: 495-499.

Eck, H.V. and Unger, P.W. 1985. Soil profile modification for increasing crop production. Adv. Soil Sci. 1: 65-100.

Gajri, P.R., Arora, V.K. and Prihar, S.S. 1992(a). Tillage management for efficient water and nitrogen use in wheat following rice. Soils Tillage Res. (in press).

Gajri, P.R. and Prihar, S.S. 1985. Rooting, water use and yield relationship in wheat on loamy sand and sandy loam soils. Filed Crops Res. 12: 115-132.

Gajri, P.R., Prihar, S.S. and Arora, V.K. 1992(b). Interdependence of nitrogen and irrigation effects on growth and input use efficiencies in wheat. Field Crops Res. (in press).

Gajri, P.R., Prihar, S.S., Cheema, H.S. and Kapoor, A. 1991. Irrigation and Tillage effects on root development, watter use and yield of wheat on coarse textured soils. Irrig. Sci. 12: 161-168.

Hassan, A.A., Prihar, S.S. and Rehman, S.M. 1984. Water transmission characteristics and growth of maize as affected by depth of tillage. AMA 15: 31-34.

Kaddah, M.T. 1976. Subsoil, chiseling and slip plowing effects on soil properties and wheat grown on a sandy soil. Agron. J. 68: 36-39.

Newman, E.I. 1966. A method of estimating the total length of root in a sample. J. Appl. Ecol. 3: 139-145.

Power, J.F. 1983. Soil management for efficient water use; soil fertility. p. 461-470. In H.M. Taylor et al. (eds.) Limitation to efficient water use in crop production. Amer. Soc. Agron. Madison WI.

Prihar, S.S. and Stewart, B.A. 1990. Using upper-bound slope through origin to estimate genetic harvest index. Agron. J. 82: 1160-65.

Sharma, B.R. 1985. Response of irrigated fodder oats to nitrogen fertilization as influenced by tillage. Soil Tillage Res. 6: 69-77.

Taylor, H.M., Roberson, G.M. and Parker, J.J. 1966. Soil; strength-root penetration relations for medium-to coarse textured soil materials. Soil Sci. 102: 18-22.

Unger, P.W. 1979. Effect of deep tillage and profile modification on soil properties, root growth and crop yields in United States and Canada, Geoderma 22: 275-295.

Ward, Kathy, Klepper, B., Rickman, R.W. and Allmara, R.R. 1978. Quantitative estimation of living wheat root lengths in soil cores. Agron. J. 70: 675-677.

Warmer, M.H. and Jones, J.B. 1970. A rapid method for nitrogen determination in plant tissue. Comm. Soil Sci. Pl. Anal. 1: 106-14. ■■

Comparative Performance of Mechanical Weeder Alone and in Combination with Herbicide

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Abstract

Field experiments were conducted at the Research Farm, Banaras Hindu University, Varanasi, India, to evaluate the efficacy of mechanical weeding by paddy weeder alone and in combination with herbicide in upland rice. Combined application of Butachlor 1.5 kg/ha + two mechanical weedings, 30 and 45 days after sowing was more effective in reducing weed growth, and maximising grain yield and net return. There was no significant difference in grain yield between three hand weedings and combined application of Butachlor + 2 mechanical weedings, but the net return from three hand weedings was low (US$135.63/ha) compared to combined application of Butachlor + 2 mechanical weedings (US$154.54/ha). Hand weeding thrice, 15, 30 and 45 days after sowing gave low return than three mechanical weedings given at the same time. From the study it can be concluded that combined application of Butachlor + 2 mechanical weedings may be a potential substitute for conventional hand weeding for getting good returns and saving time (man hours).

Introduction

In the eastern part of Uttar Pradesh (India) rice is the main crop of the monsoon season. Of the total rice area in the region, one-third is grown under upland conditions either by broadcasting or drilling behind the plough where severe weed infestation is one of the limiting factors in its cultivation. Losses in grain yield due to weeds in upland rice vary from 40 to 80% and in many cases complete crop failure (Singh and Ram, 1990). Hand weeding is the most common method of weed control in rice but it requires very high labour input. Manual weeding requires 400-600 man h/ha. (Mukhopadhyay *et al.*, 1971). The labour requirement for weeding is variable and depends on weed flora, weed intensity, time of weeding, field conditions at the time of weeding and efficiency of the weeders. Often several weedings were needed to keep the crop weed free. Singh *et al.*, (1981) reported that two hand weedings of upland rice required 1 964 man hours/ha.

Several workers reported about the possibility of weed control by using herbicides alone or in combination with other methods (Sharma *et al.*, 1977; Singh and Chauhan, 1978; Singh and Puran Ram, 1982 and Singh and Reddy, 1983). Many herbicides are effective against many weeds but some weeds which are not affected by herbicides must be eliminated mechanically as the weeds which survive/emerge after the herbicide treatment may grow vigorously due to less competition from other weeds. Mechanical weeder can reduce the time (man hours) required for weeding and the corresponding cost involved compared to manual weeding. With this background, the present study was undertaken to evaluate the efficiency of mechanical weeding (paddy weeder) alone and in combination with other methods of weed control.

Materials and Methods

Field experiments were conducted during the monsoon seasons of 1981 and 1982 at the Research Farm, Banaras Hindu University, Varanasi (India). The soil of the experimental field was sandy clay loam with pH 7.4, having organic carbon 0.38%, available N (197.56 kg/ha), P (32.06 kg/ha) and K (213.50 kg/ha). Rice (cv. Pusa 33) was hand-sown in the furrows using 100 kg seed rate per ha by adopting a row spacing of 25 cm. The

Table 1. Effect of Weed Control Methods on Weed Population and Dry Matter Accumulation in Upland Rice Production

Treatment	Weed population/m² at 70 DAS			Weed population/m² at 100 DAS			Total weed dry matter accumulation/m² (g)	
	Grasses	Sedges	Broad leaved weeds	Grasses	Sedges	Broad leaved weeds	70 DAS	100 DAS
T_1 Unweeded check	245.97	160.33	81.25	240.23	153.33	75.03	209.03	214.90
T_2 One hand weeding at 15 DAS	123.00	89.17	43.67	123.00	83.26	39.43	102.80	105.91
T_3 Three hand weeding at 15, 30 and 45 DAS	40.53	29.40	10.67	37.36	27.76	9.60	43.26	44.88
T_4 Three mechanical weeding at 15, 30 and 45 DAS	52.23	42.20	19.36	34.27	39.70	18.2	56.25	58.25
T_5 Butachlor @ 1.5 kg/ha as pre-emergence	59.06	46.66	15.26	55.53	43.03	14.47	61.82	59.14
T_6 Butachlor @ 1.5 kg/ha + Propanil @ 1.0 kg/ha as post emergence	44.70	32.53	11.03	41.20	30.77	10.87	47.95	47.54
T_7 Butachlor @ 1.5 kg/ha + one hand weeding at 30 DAS	42.43	30.13	10.26	39.20	28.93	9.70	45.15	45.72
T_8 Butachlor @ 1.5 kg/ha + two mechanical weeding at 30 and 45 DAS	40.50	32.8	9.4	37.20	31.16	8.93	44.56	44.61
SEm ±	0.28	0.28	0.15	0.17	0.29	0.15	0.14	0.14
CD at 5%	0.81	0.82	0.45	0.51	0.86	0.43	0.43	0.42

Table 2. Effect of Weed Control Methods on Yield Components, Yield and Net Return in Upland Rice

Treatment	No. of effective tillers/m²	No. of grains/panicle	1000-grain weight (g)	Grain yield (q/ha)	Straw yield (q/ha)	Net return ($/ha)	Cost of treatment ($/ha)
T_1 Unweeded check	44.37	32.86	17.41	13.47	21.73	28.56	75.06
T_2 One hand weeding at 15 DAS	89.20	51.52	18.09	26.96	31.76	110.09	87.86
T_3 Three hand weedings at 15, 30 and 45 DAS	175.86	66.68	19.45	33.79	41.04	135.63	113.45
T_4 Three mechanical weedings at 15, 30 and 45 DAS	143.50	59.69	18.85	30.90	35.08	136.40	89.46
T_5 Butachlor @ 1.5 kg/ha on pre-emergence	143.66	59.19	18.82	30.32	35.36	132.68	86.65
T_6 Butachlor @ 1.5 kg/ha + Propanil @ 1.0 kg/ha on post emergence	171.17	64.17	19.16	32.61	39.93	146.87	93.78
T_7 Butachlor @ 1.5 kg/ha + one hand weeding	173.86	66.02	19.36	32.95	40.29	143.87	99.45
T_8 Butachlor @ 1.5 kg/ha + two mechanical weedings at 30 and 45 DAS	172.40	65.88	19.33	33.65	40.73	154.54	94.65
SEm ±	1.27	0.15	0.02	0.45	0.25		
CD at 5%	3.72	0.41	0.06	1.35	0.76		

pre-emergence herbicide was applied just after sowing and post-emergence herbicide at 20 days after sowing (DAS) using a spray volume of 800 l/ha. Hand-weeding was done with the use of push type hand hoe (Khurpi) as per treatment and mechanical weeding was done using paddy weeder developed at the University. Details of treatments and pooled data on weed and yield parameters are shown in **Tables 1** and **2**.

Results and Discussion

The major weed flora of the experimental field consists of *Echinochloa colonum* (L.) Link, *Echinochloa crusgalli* (L.) Beauv., *Cynodon dactylon* (L.) Pers. and *Dactyloctenium aegyptium* (L.) Beauv. (Grasses), *Cyperus rotundus* L., *Cyperus iria* L. *Fimbristylis miliacea* (L.) Vahl. (sedges), *Commelina benghalensis* Linn, *Cynotis axillaries* Schalt., *Euphorbia hirta* L., *Corchorus acutangulus* Lamk., *Phylanthus niruri* Lin., *Eclipta alba* Hassach., *Amaranthus viridis* Lin. and *Trianthema monogyna* Linn. (Broad-leaf weeds).

The data presented in **Table 1** indicate that weed control treatments had significant influence on grasses, sedges and broad-leaved weed population during both stages of observation. In general, weed population was maximum at 70 DAS compared to 100 DAS in all the treatments. It is evident from the data that all weed control methods significantly recorded lower weed population than weedy check. The minimum grass weed population was recorded in three manual weedings which was at par with Butachlor + 2 mechanical weedings and significantly superior to the rest of the treatments at 70 DAS. At 100 DAS, three mechanical weedings had significantly lower grasses than all other treatments which was closely followed by combined application of Butachlor + 2 mechanical weedings and three hand-weeedings. The sedges population was minimum in the three mechanical weedings followed by combined application of Butachlor + one hand weeding at both stages of observation.

The combined application of Butachlor + 2 mechanical weedings significantly lowered broad leaved weed population than all other treatments both at 70 and 100 DAS. Almost a similar trend was observed in the case of weed dry matter accumulation also. The lower weed dry weight in the above treatments was mainly due to lower weed population.

The data presented in **Table 2** on yield and yield components indicate that the highest grain yield was obtained with three hand-weedings but was at par with combined application of Butachlor + 2 mechanical weedings, Butachlor + one hand weeding and Butachlor + Propanil. The higher grain yields in these treatments may be due to better weed control which influenced the yield components viz., number of effective tillers/m^2, number of grains per panicle and 1000-grain weight and high yield **(Table 2)**. It was also observed that three mechanical weedings were at par with lone application of Butachlor. A similar trend was observed in the case of straw yield.

The data pertaining to the economics of different treatments indicate that all the weed control treatments resulted into more net returns for weedy check, inspite of high cost under treatments **(Table 2)**. The treatment three hand weedings (15, 30, 45 DAS) although had higher grain yield but failed to maintain the same in terms of net return. The combined application of herbicide either with manual or mechanical weeding recorded more than their separate applications. In separate applications mechanical weeding (thrice) was more profitable than hand weeding thrice despite having significantly lower grain yield. The combined application of Butachlor + 2 mechanical weedings had maximum net returns (US$154.54/ha) indicating the potential of combined application of herbicide with mechanical weeding for maximising net returns. Another advantage is the tremendous savings in time (i.e., man hours) compared to hand weeding.

REFERENCES

Mukhopadhyay, S.K., B.C. Ghosh and H. Maity. 1971. Weed problem in upland rice and approaches to solve them by use of new herbicides. Oryza, 8: 269-274.

Sharma, H.C., H.B. Singh, G.H. Frieson. 1977. Competition from weeds and their control in direct seeded rice. Weed Research 17 (2): 103-108.

Singh, C.M., S.C. Cho and J. Moody. 1981. The efficiency of rolling weeder in controlling weeds in dry seeded rainfed rice (*Oryza sativa*). Paper presented at the cropping systems. Tuesday Seminar, 24 Feb. 1981, I.R.R.I., Las Banos, Philippines.

Singh, G. and R.S. Chauhan. 1978. Weed management in upland paddy. Ind. J. Weed Sci. 10 (1): 83-86.

Singh, S.P. and Puran Ram. 1982. Weed control through herbicides in direct seeded rice under intensive and minimum tillage. In Abstr. Ind. Soc. Weed Sci. Conf. HAU, Hissar, p. 12.

Singh, R.P. and S. Ram. 1990. Effect of weed control methods in direct seeded upland rice. Ind. J. Weed Sci. 22 (1&2): 86-88.

Singh, R.P. and B.G. Reddy. 1983. Effect of integrated weed control treatments on weed growth and 'N' depletion pattern in direct seeded rice. In Abstr. Ind. Soc. Weed Sci. conf. Institute of Agricultural Sciences, B.H.U., Varanasi-221105, pp. 4. ■■

Mechanization of Sesame Harvesting in the Sudan

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Abstract

Trials in mechanizing sesame harvest in Sudan started in the late 1950s and early 1960s. Various types of machines have been used ranging from binders to conventional combines with some modifications to perform the operations of cutting, threshing and cleaning of the crop. The need for mechanizing the harvest process was recognized from the fact that over 70% of the cost of production goes to manual harvest and expansion in production is constrained by shortage of labour during the critical harvest period. Problems in mechanical harvest of sesame originate from the habit of growth of the plant that contributes to non-uniformity in maturity and drying of pods. From the work reviewed and results of trials conducted by the author, it was clear that mechanical harvest of sesame is technically feasible and that some progress has been achieved in reducing crop losses from 28% to 18%.

Introduction

Sesame (*Sesamum indicum* L.) is an economically important oilseed crop in the Sudan. It is grown in large scale in many parts of the country. The annual production amounts to 50% of the production of Africa and 13% of the world total production (Khidir, 1981). **Table 1** shows areas, production and average yield of sesame in the mechanized and traditional sectors of agriculture for the period 1987-1989. The main constraints facing commercial production are low yields, pests and diseases and shattering of seeds from mature dry pods. This shattering characteristic makes harvesting processes difficult and costly. The costs of manual harvest constitute about 70% of the total cost of production (Khidir, 1981). Furthermore, the harvest operation is highly timed and has to be completed within a very short period - two weeks after the crop reaches physiological maturity.

Table 1. Area, Production and Average Yield of Sesame

Sector	1987-88			1988-89		
	Area (ha)	Production (MT)	Average yield (t/ha)	Area (ha)	Production (MT)	Average yield (t/ha)
Mechanized	434 000	121 000	0.28	292 000	56 000	0.19
Traditional	526 000	112 000	0.21	865 000	222 000	0.26
Total	960 000	233 000	0.24	1 157 000	278 000	0.24

Source: Mechanized Farming Corporation, Annual Report (1989).

The indeterminate habit of growth of the plant contributes to non-uniformity in maturity and drying of pods. Early harvest results in reduction in yield due to some upper pods still green and delayed harvest, until the top pods ripe, leads to splitting of lower pods and shattering of seeds.

Kaushall et al. (1969), reported by Khider (1981), found that the optimum time for harvesting sesame plants, i.e., when oil content is highest (53.4%), is when the pods turn yellow. Earlier harvest reduced oil content and crop yield and later than optimum leads to crop losses without any increases in the oil content of seeds.

Harvesting and Threshing Methods

Various methods and techniques have been used to harvest sesame. These methods range from manual to partial and complete mechanization.

Manual

The plants are cut with a sickle just below the lowest pod, tied in small bundles and stacked together for drying. After 10-15 days, the bundles are turned upside down, the seeds are shaken out of the pods and collected on a mat. For complete threshing, the bundles are beaten by hand to remove any attached seeds. Hand winnowing with seives is practised for cleaning seed of dirt and foreign material. The loss of seeds occurs during the period of drying and threshing operations. Khider and ELHag (1981) (unpubl.) using polythene sheet for collecting seeds reported total crop loss of 12%.

Mechanical Harvest

Mechanical harvesting of sesame is becoming extremely important in the Sudan since hand harvest becomes more difficult due to the rapid expansion in areas under production and the scarcity and high cost of labour coupled with the timely operation of harvest.

Partial to complete mechanization of sesame harvest has been tried using a variety of machines with different levels of success.

Partial Mechanization

Partial mechamization is achieved by mechanically cutting and binding the plants in bundles when they are physiologically matured. The bundles are then collected by hand and stacked together for drying. After drying the seeds are shaken out of the pods manually.

The first trial of partial mechanization was conducted in the late 1950s and early 1960s using the Danish Seiga reaper/binder machine which cut the crop, bound and tied it in bundles of various sizes. The machine was front-mounted and PTO-operated. Although the trial was promising, there were some technical problems due to irregularities in the orientation of the cut material. As plants were of different heights some tended to fall in opposite direction and blocked the path of those held upright before they reach the knotting mechanism. However, the machine performed better when the plants were tall and of uniform height. Furthermore, the output of the machine was too low (0.63 ha/h) for large scale production.

In the 1970s two other makes of binders (Italian and Yugoslavian) were tried by the Mechanized Farming Corporation but the performance was also unsatisfactory (Mahmoud, 1979). The construction of the machines was too week to handle the tough crop. Abdel-Mageed in (1987) tried a Polish rear-mounted PTO operated binder (Warta 2) at the Simsim Project in Eastern Sudan. The machine cut and knotted the plant efficiently. As a result, the two problems of orientation and knotting mechanism experienced in previous binders were solved. The machine was introduced by the Farmers' House Co. in Gedarif area in relatively large scale. The only draw-back was the low output as it covered 1.3-2.0 ha/h.

Complete Mechanical Harvest

The poor field performance of binders in operations and output coupled with partial mechanization of the harvest process focused the attention on direct combining of the crop using combine harvesters. For direct combining of the crop, the plants and pods need to be dried for threshing. If the plant is left to reach such degree of dryness, the pods will open and the seeds are cutting mechanism of the combine. Therefore, attempts were made to use specially modified combine headers.

In 1972-74 Khider and ELHag (unpubl.) carried out experiments using a combine harvester with collecting trays attached ahead of the cutterbar. They found difficulty in accurately assessing the magnitude of crop losses as plants were not grown in well defined rows.

In 1976 another approach was tried through a joint project between Sudan/United Nations Development Program (UNDP) and the University of California aimed towards complete mechanization of harvest and threshing with minimum crop losses. The approach was essentially as follows:

a) The plants were sprayed with a desiccant (diquat-reglone) to achieve a rapid and uniform drying of the plants and pods. Reglone was selected because it was effective with relatively low cost.

b) Use of a combine harvester with a cutting mechanism that causes minimum shaking of plants before cutting. To achieve minimum disturbance to plants, the cutting knives were driven by hydraulic motors instead of the conventional reciprocating drive mechanism.

c) Collecting trays were attached ahead of the cutterbar to minimize seed losses.

The pre-requisite for the success of the operation was that plants have to be grown in definite row spacings. Another problem was that the application of the desiccant (diquat) should be at suitable climatic conditions, i.e., relative humidity above 30% at the time of spraying. The trials were continued for three seasons (1976-1978) at Abu-Naama and Wad Medani research stations. The performance of the machine was very low at the rate of 0.8 ha/h with average crop losses of 24.0% and 10% impurities. In 1982 CLAAS of Germany and ICI conducted trials for direct combining of sesame at Agadi State Farm (560 km south of Khartoum). They used the conventional reciprocating cutterbar with collecting trays and an air-conveying system to blow-in the shattered seeds falling on the trays. The desiccation of the plants was achieved with diquat (reglone) applied 2-3 weeks before the date of harvesting the crop. The results obtained questioned the cost-benefit of the diquat application as seed recovery from combine harvesting without diquat application was similar to combine harvesting when diquat was applied. The justification for using diquat was to enhance the start of harvest of part of the crop area in large scale production so as to extend the harvesting season. In order to attain maximum clean seeds, special cleaning sieves were used. Athough the findings were difficult to explain, the trials showed that the crop can be successfully combine harvested. During the period (1986-87) intensive direct combine harvest trials were conducted jointly by CLAAS and Combine Harvester & Eng Company in the Sudan. These experiments were carried out at Agadi State Farm with the objectives of minimizing crop losses and to determine the necessary modifications required on the special header to handle the shattering varieties of sesame with minimum losses.

In the first season (1986), a comparative study was conducted between the 1982 header and the 1986 header. Each of the two headers was fitted with a number of collecting trays mounted ahead of the conventional cutterbar. The main difference between them was that the 1986 header was fitted with an air-conveying system which consisted of a centrifugal blower and air-conveying ducts to direct air towards the collecting trays and deliver shattered seeds to the machine. The results are shown in **Table 2**. They indicate crop losses of 28.2% and 18.7% for the 1982 and 1986 headers, respectively. They also show that the air-conveying system recovered 9.5% of crop losses.

The trials of the second season (1987) were conducted to confirm the results obtained with the air-conveying system header in 1986. Another objective was to locate areas of higher crop losses with the header. The results as shown in **Table 2** indicate crop losses of 17.7%. These losses could be attributed to the machine and cultural practices.

Machine Losses

1) *Collecting tray losses* — The triangular shape of the collecting trays mounted on the front part of the header pushed the standing crop and caused shattering of seeds. This part of the header represented the area of the highest crop losses. If the components of this part are redesigned in such a manner as to have gentle and smooth guidance of the crop to the cuttig mechanism, the magnitude of losses could be reduced considerably.

2) *Cutterbar losses* — The vigorous vibrations of the knife sections against the guards caused some seeds to miss the collecting trays and fell on the ground. The losses in this part of the header can be reduced to minimum if a cutterbar of double-knives, with minimum vibrations, was used instead of the conventional cutterbar.

3) *Auger losses* — a) The relatively high speed of the cross-auger used in harvesting grain crops is not suitable for small light seeds of sesame as some seeds were thrown out of the machine. b) The spiral steel vanes on the auger had a crushing action on the delicate seeds of sesame. and c) The retracting fingers used to convey the heads of grains were not suitable for conveying the small pods of sesame to the threshing mechanism as some pods were left on the feed-table.

Cultural Practices

For mechanical harvest, the crop has to be grown in definite row spacing of 53 cm on dead straight rows. This requires high precision drills and well trained and experienced operators. The irregularities in row spacings led to some crop losses.

Table 2. Crop Losses of Sesame, 1982, 1986/87

	Header without Air-conveying	Header with Air-conveying	
Trial No.	Losses in kg/ha (1982)	Losses in kg/ha (1986)	(1987)
1	44.0	35.0	65.3
2	66.0	23.0	57.7
3	88.0	68.0	78.5
4	53.0	62.0	64.7
5	98.0	44.0	82.0
Total	349	223	348.2
Average	69.8	46.4	69.64
Losses (%)	28.2	18.7	17.7

Note: Potential yield (1986) was 247.3 kg/ha.
Potential yield (1987) was 392.7 kg/ha.

Conclusions

From the work reviewed and results of trials conducted by the author on mechanization of sesame harvest, it was clear that mechanical harvest of shattering varieties of sesame is technically feasible and that some progress has been achieved in reducing crop losses.

During the period 1960-1987 various methods and techniques of harvesting sesame were tested ranging from partial mechanization with binders to complete mechanization with combine harvesters with modified headers. The trials indicated a critical need for research and development in mechanical sesame harvest. Although some work has been done in the Sudan by CLAAS of Germany and Combine Harvester & Engineering Co. it is felt that more design work should be carried on the modified air-conveying header. Suitable varieties of sesame need to be developed and machine-crop interaction should be further studied.

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Energetic Fuel from Paddy Straw

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Abstract

Briquettes could be formed when a combination of molasses and cowdung mixed with ground paddy husk in the proportions of (25% + 10%), (15% + 15%) and (10% + 25%) were used. The smoothness of briquettes goes on decreasing with the increase in percentage of cowdung. The density and bulk density of briquettes increased with the increase in percentage of molasses.

Introduction

Food and energy are the two main requirements of mankind. The demand for these basic needs is going to increase with the ever increasing population all over the world. The increased demand for food has been met to a large extent through the introduciton of high yielding varieties of cereal crops, farm mechanization and modernization of agriculture. But there is a great shortage of all types of mineral fuels as well as wooden fuels. Moreover, the prices of these fuels are very high and beyond the reach of many people.

The world energy consumption in 1975 was 8 002 million mt of coal equivalent, which increased to 12 500 million mt in 1985 and 18 850 million mt in 1990. It is expected to increase to 27 400 million mt of coal equivalent in the year 2000. This is precisely the reason that scientists all over the world are working hard on the optimum utilization of the existing resources of fuels.

In India, the availability of all types of agricultural wastes was about 200 million mt per year in 1985, which rose to 250 million mt in 1990. One of the important agricultural wastes is paddy straw. India is the second largest country in paddy production (next to China) in the world. During 1990, the paddy production in the country was estimated at 96 million mt.

About 5% of paddy straw which is very poor quality feed is used as a cattle feed, 2% has domestic use in making roofs of mud-houses and animal sheds, 1% as bedding for poor men and livestock houses, 5% as raw material for making paper and card board and 7% as packing material for fruits, chinaware, equipment and other fragile commodities and the rest, 80%, is burnt in the fields which is a nuisance to the environment causing unpleasant atmosphere, which gives harmful effects to man, animal, crop and other living and non-living objects. The use of paddy husk as fuel seems to be very promising. But using this as such a fuel for domestic stores (*chullah*) is problematic. It gives slow combustion, non-uniform burning, heavy smoke and very low application efficiency, i.e., 4-5%. The fresh paddy straw has 35-40% moisture and 10-12 MJ/kg energy but if dried to 15-16% moisture content can give energy up to the extent of 15-16 MJ/kg.

Since paddy straw is a very loose and light material, it is a problem in handling, transportation and storage. But by compaction if briquettes are made from this paddy straw, it will not only be easy and cheap in its handling and storage, but gives good fuel to domestic *chullahs*, bakery furnaces, brick kilns and steam boilers. Its calorific value will also increase from 15 to 18 MJ/kg, efficiency from 5% to 20%. Techniques were developed by different scientists and engineers to compress various agricultural wastes into cylindrical briquettes by applying various amounts of pressure with or without using some binding material. These techniques are grouped into two classes: high pressure techniques and low pressure techniques.

In high pressure techniques, these is need for very high power i.e., 25-35 hp to apply pressurised compaction. There is no need for any external binding material. The lignin of biomass itself acts as binder. But in low pressure techniques, there is need for some binding material like molasses, bentonite clay, cowdung, cerdex-265, sodium silicate, etc.

The briquettes may be solid cylinders, hallow cylinders, or cuboidal prisometic shapes. Some may be spherical and pellet form if made by manual pressing with hand or die-pressing with hand.

Review of Literature

Rodger (1936) explored the possibility of utilizing the agricultural waste as fuel in the form of briquettes. He prepared briquettes from wheat straw, oat straw and pea straw and ascertained their thermal properties. He observed that the combustion efficiency of wheat straw briquettes was greater than those of other types of briquettes.

Chancellor (1962) formed wafers of hay with different types of loading and observed that wafer formation was more efficient by static loading as compared to impact loading. The durability and density of wafers prepared with the application of static loading was high.

Matsuo *et al*, (1977) prepared wafers from paddy straw at different moisture contents and observed that wafering was facilitated at moisture content of 25% of the straw and a die temperature of 70°C.

Susawa (1978) recommended the use of a plunger type machine for column shaped wafers of a 50-80 mm diameter and 30-60 mm density and roller type die for rectangular shaped wafers of 30-40 mm cross-section and 40-80 mm length. The specific density and bulk density of wafers formed at a pressure of 500 kg/cm^2 varied from 0.6 to 1.0 gm/cm^3 and 0.37 to 0.60 gm/cm^3, respectively.

Singh (1981) used universal testing machine for applying static load in briquette preparation. A mild steel plunger was used to transfer the load from the universal testing machine.

Singh and Singh (1982) used a universal testing machine of 100 mt load capacity for compression of briquettes in a die. A cylindrical mild steel die of 25 mm diameter and 150 mm length with a 224 mm piston made of mild-steel rod was used to apply compressive load.

A commercially used large capacity briquetting machine was developed and manufactured by the Nippon Hulliate Machine Co. Ltd., Japan in 1985. This machine is capable of producing 260 kg/hr briquettes using an electric motor of 30 hp. The compression was done by impact loading.

Sehgal *et al*, (1988) designed and developed a prototype briquetting machine using chopped paddy straw (65%) mixed with molasses (5%), sodium silicate (5%) and black oil (5%). The briquetting machine was driven by a 3 hp electric motor.

Physical Properties of Briquettes

Bruhn (1955) prepared pellets from a mixture of hay and clay and studied the effect of pressure on the density and durability of pellets. The density of pellet varied from 800.95 to 961.14 kg/m^3 at 562.48 to 703.10 kg/cm^2 pressure range.

Butler and Mccolly (1959) conducted an experiment on pellets of hay. Bentonite, Cerdese-265 and black strap molasses were used as binding agents and increasing the pellet density. They found that the density of pellets bear linear relationship with the log of pressure applied. The pellets of length to diameter ratio approaching unity have better flow characteristics and greater bulk characteristics and greater bulk density. The relationship was as follows:

$$d = k, \ln (p/k_2)$$

Where
d = pellet density in Lbs/ft^3
P = Pressure in Lbs/ft^2
K_1, K_2 are parametric constants.

Smith *et al*, (1977) conducted experiments on briquettes of wheat straw at different pressures and temperatures. The result showed that wheat straw could be compressed and stabilized to a density of the order of 10 times that of normal of 20-60 Mn/M^2 after heating to a temperature of 80-140°C.

Matsuo *et al*, (1978) prepared the wafers of chopped straw after treating with alkaline solution. They observed that 5 to 15% sodium hydroxide solution incrased the strength of wafers by 50%.

Singh and Singh (1982) observed that a compressive force of 300 kg/cm^2 was adequate to convert paddy straw mixed with binder into satisfactory briquettes. Molasses were found superior over other binders.

The pressure and quantity of binders decreased with a decrease in particle size of the raw material. The bulk density of pellets was 62% of the specific weight of the pellets.

Singh and Kashyap (1983) formed briquettes from paddy husk by using the proportion of molasses or sodium silicate between 10% and 25% in ground paddy husk. The density of the briquettes varied from 0.902 to 1.364 gm/cm^3.

O'Dogherty and Wheeler (1984) conducted experiments on the compression of straw in closed dies. At densities of 250 kg/m^3 the wafers were durable and could be formed at pressure of 12-30 MPa. The optimum moisture content for wafer formation was 10 to 20% (w.b.). Rapeseed straw formed the densest wafers and barley straw the least dense.

Singh *et al*, (1986) established pressure density relationship for different forages and their mixtures. Pure legume hay produced the most dense wafers and the grass hay the least dense, with mixtures having intermediate values. The grass wafers formed at pressures up to 40 MPa were not stable, whereas the legume wafers formed at 20 MPa and that of grass — legume mixtures (1 : 1) formed at 30 MPa were stable to withstand handling. The optimum moisture content for forming stable wafers ranged between 12 and 15% (w.b.).

O'Callaghan and Faborode (1987) conducted experiments on briquetting of fibrous materials. They concluded that wafers from chopped materials required more energy and also were more unstable. For example, the straw at 8.3% m.c. (w.b.), chopped material consumed 28-31 MJ/mt of energy, while unchopped material has consumed only 18-27 MJ/mt of energy and giving more durability under high pressure loading for unchopped materials.

Description of Briquetting Machine

The briquetting machine consists of an overhanging screw shaft, a barred housing and an extruder die pipe. The barred assembly has been housed over the screw shaft and mounted on a stand. The free end of the screw shaft as well as the extruder were tapered with 5° angle up to a length of 34.4 cm. where a 5-cm diameter is coupled with screw shaft to guide out the briquettes. The screw shaft is coupled directly with a reduction gear unit (10 : 1) and is driven by a 3-hp electric motor. A feeding hopper is provided at the upper end of the tapered screw extruder. The extruder, hopper, reduction gear unit and the electric motor are fixed on an angle-iron stavel to make a complete assembly of briquetting machine.

Feasibility Test for Making Briquettes from Paddy Straw

With the help of 3.00 hp briquetting machine, the feasibility of making briquettes from paddy straw (chopped or ground) mixing with some proportion of binding materials i.e., molasses and cowdung was tasted.

The paddy straw was chopped using wheel type fodder chopping machine which gave a mean size of 6.2 cm. The straw was also ground in hammer mill giving mean particle size of 0.1725 cm with fineness modulus of 4.052.

Determination of Fineness Modules and Particle Size

The fineness modules determined by using a set of Tyler standard screen sieves for sieve analysis of ground paddy straw using a Rotap shaking machine for five minutes and the weight of material retained on each sieve was determined. The result of the analysis is shown in **Table 1**.

Fineness modules

$$= \frac{\text{Total of fineness numbers}}{100}$$

$$= \frac{405.2}{100} = 4.052$$

Average particle size:

$$D = 0.0104\ (2)^{FM}$$
$$= 0.0104\ (2)^{4.052}$$
$$= 0.1725 \text{ cm.}$$

Feasibility Trials for Making Briquettes

Feasibility trials were conducted to optimise the procedure for making briquettes from paddy straw and to find the optimum properties of binding materials, i.e., cowdung and molasses. Four trials were conducted as follows:

Trial 1 consisted of mixing molasses and cowdung in the proportions of (25 + 10), (15 + 15),

Table 1. Analysis of Fineness Module

Mesh size	Size of opening (mm)	Material retained (g)	Material retained (%)	Fineness Number
3	6.592	25	10.0	10 × 7 = 70.0
4	4.699	35	14.0	14 × 6 = 84.0
8	2.362	40	16.0	16 × 5 = 80.0
14	1.168	53	21.2	21.2 × 4 = 84.8
28	0.589	42	16.8	16.8 × 3 = 50.4
48	0.295	35	14.0	14 × 2 = 28.0
100	0.147	20	8.0	8.0 × 1 = 8.0
Pan	—	—	—	0 × 0 = 0
Total		250	100	405.2

(10+25) per cent with chopped straw (6.2 cm) and subjected to compression in the machine (prototype briquetting machine driven by 3 hp motor).

Trial 2 consisted of ground straw (0.1725) with fineness modules 4.052 without binding material. The ground straw was soaked in water and 4 different samples of straw at moisture content of 44.50%, 35.00%, 25.20% & 14.90% were taken. The samples were then subjected to compression in the prototype machine.

Trial 3 consisted of ground straw of same size having cowdung as binding material, in the proportions of 10, 20, 30%, respectively. The samples were pressed in the machine.

Trial 4 consisted of mixing molasses and cowdung in the proportions of (25+10), (15+15), (10+25)% with the ground paddy straw of same size and subjected to compression in prototype briquetting machine.

Results and Discussion

In Trial 1, molasses and cowdung were mixed in different proportions with chopped paddy straw. The machine was not able to crush the straw. No briquettes were formed. It was, therefore, necessary to grind the paddy straw for making briquettes with high durability and density.

In Trial 2, briquettes could not be formed by compressing wet ground paddy straw even up to 44.50% moisture content (w.b.). The briquettes were also not formed even at lowest moisture content i.e., 14.90% (w.b.).

In Trial 3, mixing of cowdung in ground paddy straw ranging between 10 to 30% was done, but no briquette formation could be made.

In Trial 4, molasses and cowdung in proportions A = (25+10), B = (15+15) and C = (10+25) percent mixed with ground paddy straw. The briquettes were formed in each case.

Physical Properties of Briquettes

Moisture content — The moisture content for the composition A, B and C of briquettes was 10.61%, 9.53% and 8.63% (w.b.). It is clear that with increase in molasses proportion, moisture content also increased.

Physical dimensions — The briquettes were in the shape of a regular cylinder with mean diameter of 4.254, 4.258, 4.368 cms and length 14.19, 13.78, 12.82 cms for A, B, C type briquettes, respectively. The standard deviation from the mean for the diameter increased with the decrease in the percentage of molasses added. it also increased with an increase in the percentage of cowdung. A vernier calliper was used to measure the dimensions of the briquettes.

Briquette density — The density of briquettes increased with an increase in the percentage of molasses but decreased with an increase in percentage of cowdung. The mean density of briquettes of composition A, B, C were 0.728 g/cm^3, 0.6982 g/cm^3 and 0.6094 g/cm^3, respectively.

Bulk density — To determine the bulk density of briquettes, a rectangular container 23.5 cm × 11.5 cm × 9 cm was fabricated. It was filled with dried briquettes by pouring from a height of 60 cms above the top of the container. The filled container was dropped five times from the height of 15 cms to allow proper settling of briquettes. The bulk density was determined by dividing the weight of briquettes by the volume of the container.

The bulk density of briquettes decreased with a decrease in percentage of molasses and same trend was followed with an increases of the cowdung component. The bulk density of briquettes of composition, A, B

Table 2. Various Compositions of Molasses and Cowdung Mixed with Ground Paddy Straw

Material	Percent Composition			Actual Composition (weight in g)		
	A	B	C	A	B	C
Ground paddy straw	65	70	65	1100	1100	1000
Molasses	25	15	10	275	165	100
Cowdung	10	15	25	110	165	250
Total	100	100	100	1485	1430	1350

Table 3. Moisture Content Mean Density and Specific Weight of Briquettes

Properties	Briquette A	Briquette B	Briquette C
Mean moisture content (w.b.) %	10.61	9.53	8.63
Mean density (g/cm^3)	0.7290	0.6982	0.6085
Specific weight (g/cm^3)	1.019	1.024	1.026

Table 4. Bulk Density of Briquettes of Various Compositions

Composition	No. of Briquettes	Weight of Briquettes (g)	Volume of Container (cm^3)	Bulk Density (gm/cm^3)
A	11	1 425	2 432.25	0.5829
B	11	1 325	2 432.25	0.5529
C	10	1 170	2 432.25	0.4810

Table 5. Mean and Standard Deviation of Length and Diameter of Briquettes

Composition	Length		Diameter	
	Mean Deviation	Standard Deviation	Mean Deviation	Standard Deviation
A	2.4008	2.8178	0.0490	0.0527
B	0.9536	1.6830	0.0625	0.0650
C	1.6504	1.8811	0.0751	0.0817

and C were 0.5829 g/cm^3, 0.5529 g/cm^3 and 0.4810 g/cm^3, respectively.

Specific weight — A measuring cylinder of one litre capacity was taken with a diameter bigger than the diameter of the briquette. It was filled with water up to two-thirds volume. Each briquette was put in a plastic bag. A metal rod of 1.6 mm diameter with a ring at one end was used to control the briquette from inside the plastic bag. The briquette was lowered into the water, level of water rose and the volume of water displaced was determined. The specific weight was determined as follows:

Specific weight (g/cm^3)
= [Wt of briquette in air (gms)] / [(Original volume of water in cm^3) − (Volume of water displaced cm^3)]

The specific weight of the briquettes increased with an increase in the percentage of cowdung but decreased with an increase in percentage of molasses component. The mean specific weight of the briquettes for composition A, B, and C were 1.019 gm/cm^3, 0.24 gm/cm^3 and 1.1026 gms/cm^3, respectively.

The mean bulk density for these three compositions was nearly 55% of the mean specific weight of all the briquettes.

Average feed rate — The average feed rate of the machine was 12.5 kg/h.

Durability and stability — When the briquettes were allowed to fall freely from a height of 50 cms, they remained intact and strong without any breakage.

REFERENCES

Bruhn, H.D. (1955). Pelleting grain and hay mixture. Agril. Engg. 36 (5): 330-31.

Butler, J.L. and H.F. McColly (1959): Factors affecting hte pelleting of hay. Agril. Engg. 40 (8): 442-46.

Chancellor, W.J. (1962): Formation of hay wafers with impact loads. Agril. Engg. 43 (13): 136-38.

Malhotra, R. (1987): Combustion efficiency of paddy straw as affected by particle size. Unpublished B. Tech Project Report, PAU Ludhiana.

Matsuo , M. *et al.* (1977): Studies on wafering of rice straw. Jr of Society of Agril. Machinery, Japan 39 (1): 47-52.

O'Callagham, J.R. and M.O. Faborode (1987): Optimising the compression for briquetting of fibrous agril. materials. Jr. of Agril. Engg Research 38 (4): 245-262.

O'Dogherty, M.J. and J.A. Whealer (1984). Compression of straw to high densities in closed cylindrical discs. .Jr of Agril. Engg. Research 29 (1): 61-72.

Rodger, J.B. (1936): Thermal and Physical Proportion of fuel briquettes made from Agril. & other waste products. Agril. Engg 17 (5): 199-204.

Sehgal, V.K. *et al.* (1988): Wafering & Pelletisation of paddy straw and other agril. wastes. Annual Report of Ludhiana Centre presented at XVI Annual Workshop held at Gujrat Agril University, Junagarh, pp. 12-31.

Singh, A. & Y Singh (1982): Briquetting of paddy straw. AMA, Japan 13 (4): 42-44.

Singh, D (1981): A study on the suitability of paddy husk briquettes for burning. Unpublished M Tech thesis, PAU Ludhiana.

Singh D & M.M. Kashyap (1985): Mechanical & Combustion characteristics of paddy husk briquettes. Agril. wastes Elsevier Applied Science Publishers. Vol. 13: 189-196.

Singh, J. *et al.* (1986): Effect of pressure & Moisture content on density and stability of wafers of different forages. Jr. of Agril Engg. ISAE 23 (1): 89-98.

Smith, I.E. *et al* (1977): Briquetting of wheat straw. Jr. of Agril. Engg. Research 22 (2): 1105-1111.

Susawa. K. (1978): Rough Wafering-Techniques in Japan. JARG 12 (1): 17-21.

Singh, D and M.M. Kashyap (1983). Paddy husk briquettes — a feasibility study. Jr. Institution of Engineers. pp. 64. ■■

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Mechanization of Sesame Harvesting in the Sudan

REFERENCES

1. Abdel Mageed M.O. (1978), Technical Report on Farmer's House Warts-2 Polish Binder. Mechanized Farming Corporation-Khartoum-Sudan.
2. Current Agricultural Statistics (1989), Agri.Stat.Dept.Ministry of Agriculture Khartoum-Sudan.
3. Khalid E.S. & ELGhali A.G. (1987), Assessment of Sudan Mechanical Harvesting of sesame. Technical Report-SimSim Dryland Project AGDEV CO/MFC, Khartoum-Sudan.
4. Khider M.O (1981), Harvesting of Sesame. FAO (abstract) plant production adn protection, Paper No.29.
5. Mahmoud E.S. (1987), Mechanical Harvest of Sesame. Technical Report No (2) Combine Harvesters & Engineering Co. Ltd. Khartoum-Sudan.
6. Mahmoud M.A. (1979), The past, present and Future of Mechanical Harvesting of sesame in the Sudan. Agri. Research corporation, WadMedani-Sudan. ■■

Energetics of Major Crops in Mixed Cropping System

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Introduction

Agriculture plays a pivotal role in the economy of Pakistan. It provides livelihood, directly or indirectly, for nearly 70% of the population, contributes over 70% of the country's foreign exchange earnings and generates around 26% of the gross domestic product.

The rural population uses less than 20% of the total energy consumed in Pakistan. The domestic fuel requirements of the rural households are mostly met by non-commercial fuels like fuel wood, animal dung and farm wastes. The agriculture sector as a whole, accounts for about 16% of the total electricity consumption. All domestically consumed LSD (low speed diesel) is used to run tubewells. About 601 thousand tonnes or about 23.5% of the total consumption of high speed diesel (HSD) is used in rural areas for agriculture operations. Almost all the kerosene oil utilized in the rural areas is in the domestic sector and that too for lighting purposes only.

Continuing changes are occurring in farming methods and technology. New technological developments such as high yield crop varieties, fertilizer, pesticides and tractorization have caused a substantial increase in demand for commercial energy. In the production of any crop, energy is derived from a number of sources like animate (manpower, draught power), chemical (fertilizer, pesticide) and commercial (diesel, electricity, etc.). Within the agriculture sector, there are wide variations in the level and pattern of energy use among various crops. Unfortunately, however, little information is readily available about the energy output — input relationships in Pakistan agriculture. Therefore, the present study was conducted to see the level of resource use and pattern of energy input on major crops grown in the mixed farming system of the Punjab province.

Methodology

This study was confined to the mixed cropping system zone which has unique characteristics with regard to climate, cropping patterns, rainfall, and soils. Its height from sea level is about 250 m. Annual rainfall varies from 200 to 400 mm. Climate, in general, is semi- and subtropical continental with mean maximum temperature 42°C. Soil type is haptic yermosols. Sugarcane, cotton and maize are the major crops during the Kharif (summer) season, while wheat is the important crop during the rabi (winter) season. Over 92% of the total farm area is irrigated.

From within the mixed cropping system, Toba Tek Singh district which represents more or less the average conditions of the area was chosen as the study site. Toba Tek Singh district lies between 31.17 north latitude and 72.30 east latitude. The total population of this district is 1 127 thousands, of which 16.5% is urban and 83.5% rural. In all, 153 farmers from a cluster of four villages consisting of Chak No. 316 G.B., 315 G.B., 407 J.B. and 409 J.B. were randomly selected for the study.

Information on crops was obtained from the respondents for various agricultural activities. Information so collected was converted into man hours, bullock pair hours, liters of diesel, kilo watt hours (KWH) of electricity, kilograms of different fertilizers, amount spent on pesticides etc. Finally, these heterogeneous units of various inputs were converted into a single unit i.e., kilocalories, by employing the standardized conversion factors (Ahmad, 1989).

Results and Discussion

Tables 1 to **4** list the energy input and output per hectare on

Table 1. Energy Input and Output per Hectare in the Mixed Cropping System for the Production of Cotton

Production Resources	Units	Physical Units	Energy Units Kcal	Percent of total
Manual Labour				
Family & Permanent hired labour	h.	192.34	48 085	1.41
Casual hired labour	h.	217.59	54 398	1.60
Bullock Labour	h.	38.15	175 490	5.15
Tractor				
a. owned	h.	6.33	402 537	11.82
b. hired	h.	0.64	40 699	1.20
Tubewell				
a. owned	h.	2.13	74 550	2.19
b. hired	Rs.	1.90	66 500	1.95
Plant Protection	kg.	842.78	769 027	22.58
Seed	kg.	15.79	83 892	2.46
Manure	kg.	3 350	241 200	7.08
Fertilizer				
a. N	kg.	68.35	1 275 206	37.45
b. P	kg.	41.66	173 597	5.11
Energy used/ha			3 405 181	100.00

Yield of Primary Crop = 946.89 kg
Yield of Secondary material = 946.89 kg
Energy use/unit of primary output = 3 596.2 kcal/kg

Table 2. Energy Input and Output per Hectare in the Mixed Cropping System for the Production of Sugarcane

Production Resources	Units	Physical Units	Energy Units Kcal	Percent of total
Manual Labour				
Family & Permanent hired labour	h.	388.56	97 140	1.98
Casual hired labour	h.	277.55	62 388	1.27
Bullock Labour	h.	80.28	369 288	7.52
Tractor				
a. owned	h.	0.62	39 427	0.80
b. hired	h.	0.54	34 340	0.70
Tubewell				
a. owned	h.	14.03	419 050	8.53
b. hired	Rs.	5.93	207 550	4.23
Plant Protection	kg.	—	—	—
Seed	kg.	3 344.33	1 237 402	25.20
Manure	kg.	9 820.00	707 040	14.40
Fertilizer				
a. N	kg.	86.51	1 614 017	32.87
b. P	kg.	29.48	122 843	2.50
Energy used/ha			4 910 485	100.00

Yield of Primary Crop = 12 090.00 kg
Energy use/unit of primary output = 406.16 kcal/kg

Table 3. Energy Input and Output per Hectare in the Mixed Cropping System for the Production of Maize

Production Resources	Units	Physical Units	Energy Units Kcal	Percent of total
Manual Labour				
Family & Permanent hired labour	h.	293.90	73 475	2.64
Casual hired labour	h.	45.12	11 280	0.41
Bullock Labour	h.	50.43	231 978	8.34
Tractor				
a. owned	h.	2.50	158 980	5.72
b. hired	h.	1.83	116 373	4.18
Tubewell				
a. owned	h.	1.53	53 550	1.94
b. hired	Rs.	1.68	58 800	2.11
Plant Protection	kg.	—	—	—
Seed	kg.	41.81	145 666	5.23
Manure	kg.	8 270	595 440	21.40
Fertilizer				
a. N	kg.	65.97	1 230 802	44.25
b. P	kg.	25.23	105 133	3.78
Energy used/ha			2 781 477	100.00

Yield of Primary Crop = 1 530.12 kg
Yield of Secondary material = 3 060.24 kg
Energy use/unit of primary output = 1 817.82 kcal/kg

Table 4. Energy Input and Output per Hectare in the Mixed Cropping System for the Production of Wheat

Production Resources	Units	Physical Units	Energy Units Kcal	Percent of total
Manual Labour				
Family & Permanent hired labour	h.	86.68	21 670	0.63
Casual hired labour	h.	44.01	11 003	0.32
Bullock Labour	h.	81.00	372 600	10.78
Tractor				
a. owned	h.	4.15	263 907	7.63
b. hired	h.	3.83	243 557	7.04
Tubewell				
a. owned	h.	1.88	65 800	1.90
b. hired	Rs.	4.62	161 700	4.68
Plant Protection	kg.	—	—	—
Seed	kg.	103.73	340 649	9.85
Manure	kg.	1 520	109 440	3.16
Fertilizer				
a. N	kg.	91.87	1 714 019	49.57
b. P	kg.	36.84	153 512	4.44
Energy used/ha			3 457 857	100.00

Yield of Primary Crop = 2 256.79 kg
Yield of Secondary material = 4 513.58 kg
Energy use/unit of primary output = 1 532.20 kcal/kg

major crops. Energy used per unit of primary output was calculated as the emphasis is generally placed on the production of the main product by the farmers.

The energy input for cotton was 3 405 thousand kcal/ha or 3 596 kcal/kg of cotton. Fertilizer was the most important item in terms of contribution to total energy. It made up 42.5% of the total energy input. The next important energy item was the plant protection which accounted for 22.6% of total energy used. Tractor accounted for 13.0%, organic manures 7.1%, bullock labour 5.2% and tube-well 4.1%, while seed and manual labour each claimed about 3% of the total energy input.

Energy input per hectare for sugarcane was 4 910 thousand kcal or 406.16 kcal/kg of sugarcane. Like cotton, fertilizer was the most important energy input in sugarcane. It contributed 35.3% to the total energy input. Seed, manure and tube-well shared 25.2, 14.4 and 12.8% of total energy input for sugarcane, respectively. Bullock labour accounted for 7.5% of the total energy input, while manual labour and tractor made negligible contributions to total energy used in sugarcane.

For maize, energy input was 2 781 thousand kcal/ha or 1 817.82 kcal/kg of maize. Three inputs, i.e., fertilizer, organic manure and tractor were the main items which made major contribution towards total energy investment for maize crop. Their shares were 48.0, 21.4 and 9.9%, respectively, in the total energy input in maize.

Energy required per hectare of wheat was 3 458 thousand kcal or 1 532.2 kcal/kg of wheat. Fertilizer made up the largest share i.e., 54.0% followed by tractor (14.7%), bullock labour (10.8%), seed 9.9% and tubewell (6.6%).

Table 5. Energy Used Compared with Other Countries on Various Crops (kcal per kg of Output)

Crop	Pakistan Punjab*	India**			Nepal	
		Et_1	Et_2	Et_3	Tarai	Hills
Wheat	1 532	538.73	453.65	441.78	2 388.00	2 149.20
Cotton	3 596	4 093.92	3 833.10	4 164.10	—	—
Sugarcane	406	35.50^P	33.31^P	32.31^P	107.46	—
		33.19^R	28.10^R	30.81^R	—	—

* Observed in this study.

** For wheat Et_1 stands for flood irrigation, Et_2 for border irrigation and Et_3 for check base in irrigation.
For cotton Et_1 stands for ridge and furrows, Et_2 for long bed furrow and Et_3 for beds and channels.
For sugarcane Et_1 stands for sowing on furrows and covering furrows, Et_2 for sowing on flat bed, earthing up 20-25 days after sowing and Et_3 for sowing on flat than earthing up.

P = Planted, R = Ratoon.

Energy Use in Some Selected Countries

When the level of energy use per kg of output of different crops in Pakistan — Punjab was compared with that of India and Nepal (**Table 5**), it was found that for wheat production the energy input in Pakistan — Punjab was much higher than in India (Mittal and Dhawan, 1989), but was substantially lower than for Nepal (Shrestha et al., 1989). For cotton crop, energy use per kg of output was lower in Pakistan — Punjab than in India. However, energy use in sugarcane was substantially higher in Pakistan — Punjab than for India.

Summary

The present study was conducted in the mixed cropping system of the Punjab province. The results of the study indicate that energy input per ha was 3 405, 4 910, 2 781 and 3 458 thousand kcal for cotton, sugarcane, maize and wheat crop, respectively. Energy required per kg of produce for these respective crops were 3 596, 406, 1 817 and 1 532 kcal. Fertilizer was the most important source of energy in terms of contribution to total energy, while the relative contribution of other energy inputs varied among different crops.

The energy input per kg of output in Pakistan — Punjab was higher than in India but lower than Nepal. Energy use per kg of cotton was lower in Pakistan Punjab than in India. However, energy input per kg of sugarcane was higher in Pakistan — Punjab than in India or Nepal.

REFERENCES

Ahmad, Bashir; 1989. Resource Use and Energy Input on Major Crops in the Punjab. Department of Farm Management, University of Agriculture, Faisalabad.

Mittal, J.P. and K.C. Dhawan, 1989. Energy Parameters for Raising Crops under various Irrigation Treatments in Indian Agriculture, Agriculture Ecosystems and Environment, Vol. 25, pp. 11-25.

Shrestha, B.L., G. Singh, and V.M. Salokhe, 1989. Energetics of selected crops in Nepal, ASAE/CSAE, Paper No. 895012. ■■

Expert System for Crop Production Machinery System

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Abstract

The complexity and magnitude of the machinery selection problem in the analysis of crop production systems have led to numerous efforts to develop models as a decision aid. The Crop Production Machinery System (CPMS) model developed at Michigan State University is a computer interactive model developed based on the concept of expert systems which allows the user to interact with the program. The computer program consists of the Machinery Selection Model and the Machinery Cost Analysis Model. The Machinery Selection Model is used to predict the size of tractors and implements required to complete the farm operation during a specified duration of time and to determine the compatibility of tractors and implements by properly matching the available tractor power. The Machinery Cost Analysis Model is used to estimate the cost of production for the tractors and implements selected. The CPMS program was created to enable users to easily carry out a sensitivity analysis. This paper also describes the machinery selection input data and the selection algorithm based on a capacity and power match.

Introduction

Tractor and machinery selection is an important part of machinery management. The main aim of tractor and machinery selection studies is to complete a certain field operation during a specified time and at a minimum total cost (Ghassan Al-Soboh et al. 1981). Wu and Persson (1986) stated that the matching of machine width and tractor power has an important effect on the time and fuel requirements per unit land area. The use of oversized implements results in a loss of productivity and fuel efficiency. In practice, farmers depend on their experiences or recommendations of other farmers or machinery dealers when matching tractors and implements. The success of many farm-level production systems depends on wise selection of machinery systems.

The number of crops in a rotation, different tillage systems, different land size for different crops in a crop operation, and the use of the same implement with different speed, depth and tractive efficiency complicate the selection of machinery. The complexity and magnitude of the machinery selection problem in the analysis of crop production systems have led to numerous efforts to develop models as a decision aid. Currently, many agriculture specialists are developing expert systems which will be more effective and comprehensive in dealing with agronomic problems (Downs et al. 1990). Expert systems allow users to become more knowledgeable about a problem as they interact with the program. Beside helping the user make proper decisions, the system can provide education through explanatory and feedback features. The importance of expert systems for machinery management was well described by Oskoui et al. (1990). Jones et al. (1987) used expert system concept in an overall systems approach for solving agricultural problems. Downs et al. (1990) developed an expert system and knowledge base to provide information that a farmer would need in making a typical management decision for tractor-implement systems. Kotzabassis et al. (1990) developed a software package to serve as an expert decision aid for cost effective farm machinery selection and management.

Objectives

The objectives of the project were:
1. To develop a machinery selec-

tion model to determine near optimum machinery sets for various production systems.

2. To develop the machinery cost analysis model to evaluate machinery costs after a complete set of implements and tractors is selected. The machinery cost analysis must be able to evaluate machinery costs when: (a) the use of machinery is shared in several enterprises; (b) the same machinery is used under different conditions (e.g., speed, depth, field efficiency, tractive efficiency); and (c) machinery costs are compared for different situations such as farm size and production practices.
3. To develop a machinery selection simulation model and machinery cost analysis simulation model that is user friendly and a microcomputer-based program. Beside helping the user make proper decisions, the system must provide education through explanatory and feedback features. It must include programs for the users to create external data files.

This paper describes only the machinery selection algorithm. As such, it does not include the machinery cost algorithm.

Crop Production Machinery System Model

The Crop Production Machinery System (CPMS) model developed at Michigan State University is a computer interactive model developed based on the concept of expert systems which allows the user to interact with the program. The user enters the required inputs and the program will carry out an interactive search. This interactive computer model identifies and searches for the number and type of crops used. For each crop the program identifies and searches for the number and size of the tractor used, and for each tractor, the program identifies and searches for the number and type of implements used.

The CPMS simulation model was developed to evaluate machinery systems for crop production. The computer program consists of the Machinery Selection Model (MSM) and the Machinery Cost Analysis Model (MCAM). The former model is used to predict the size of tractors and implements required to complete the farm operation during a specified duration of time and to determine the compatibility of tractors and implements by properly matching the available tractor power. The MSM also computes the field time required for the machinery set to complete the tillage and planting operations. The MCAM, on the other hand, is used to estimate the cost of production for the tractors and implements selected in the MSM. Machinery requirements (number and size of each) and costs are determined for each crop production system with two alternative tillage systems, conservation or conventional tillage systems. The users will have the choice of five different locations in Michigan, three soil textures, different farm sizes, and a maximum of five crops in a single rotation.

The CPMS program was created to enable users to easily carry out a sensitivity analysis. Even in using the external data files, the users can change the parameters or values in the main program. Changing the dates of operation, mode of operation, tillage systems, type and number of crops, or size and soil texture of the farm affects the tractor and implement selection. The sizes, ages and purchase prices of tractors and implements along with the fuel price, oil price, labor wage rate, interest rate, and the type and number of crops in a crop rotation affect the tractor and implement cost analysis.

Tractor and Implement Matching

The design of the CPMS simulation model involves calculations of machine productivity and costs. The size of implements, speed of operation, and field efficiency are required to determine the implement effective field capacity or the time required to complete the field operations. Typical ranges in operating speed and field efficiency for most types of machines are given in the ASAE STANDARDS (ASAE, 1990). The field time required for each operation is determined by dividing the total crop area by the effective field capacity of the operation. This result is compared with the available field time within the specified calendar date constraints. Suitable work time available is generally hard to obtain because of the long period of time required to obtain such data. A model developed by Rosenberg et al. (1982) can be used to generate probabilities of suitable work days (pwd) from weather data for a specified location.

The implement drawbar power requirement or draft is an important factor to determine if the tractor can pull the implement. ASAE STANDARDS (ASAE, 1990) presents draft and power requirements equations for most field machines for varioius soil types. Factors often included in the equations are implement speed, depth and width of cut. The ability to predict draft, power and fuel requirements for tillage operations is an important consideration in selecting tillage and planting systems.

Machinery Selection Input Data

A primary function of the main program is to initialize most of the user's inputs. The user's inputs consist of:
(1) Geographical locations
(2) Soil texture
(3) Type of tillage system
(4) Number and choices of crops in crop rotation
(5) Land area for each crop in the rotation
(6) Farm operation calendar dates
(7) Choices of known or computed first tractor size
(8) Choices of known or computed implement sizes

Location

The users have the choice of five different locations in Michigan. These locations are Kalamazoo in Southwest, Adrian in Southeast, East Lansing in Central, Bad Axe in East, and Seney in the Upper Peninsular of Michigan. The suitable days information for these locations was obtained from the weather data computer simulation work carried out by Rosenberg et al. (1982). The predicted portion of days suitable for field work, the number of working days and the number of hours per day are used to determine the field time available for operations. The probability of working days (pwd) varies with the months of operations and the locations. This program is designed such that other locations can be added if the pwd are known.

Soil Texture

The choice of soil texture consists of fine, medium and coarse soils. Soil texture is used to determine the drawbar power required by the implements for a farm operation and combines with location to determine the suitable day probabilities. The equations for implement draft for different soil textures are obtained from the ASAE STANDARDS (ASAE, 1990) and FMO, (1987). The program selects the draft equations based on the choice of soil texture and the implement to be used. The draft is used to determine the required drawbar power of the implement. The required drawbar power of an implement is compared with the available drawbar power produced by the tractor to find their compatibility.

Tillage System

The user has the choice of two tillage systems, the conventional tillage system and the conservation tillage system. The conventional tillage system uses a moldboard plow for primary tillage whereas the conservation tillage system uses a chisel plow. Other implements used in the model for both systems include a disk harrow, field cultivator and row crop planter or grain drill. In the program, users will have the choice of using all or any of the implements in the tillage system selected.

Crops and Crop Rotation

The user has the choice also of using corn, soybeans, field beans, wheat oats in various crop rotation combinations. Increasing the number of crops in a crop rotation reduces the machinery cost by increasing machinery utilization. The number of crops also affects the field time of operation and implement field time. The type of crop determines the type of planting equipment to be used and also assits in determining the type of tillage system to be carried out.

Farm Size

The user has to specify the farm size by entering the land area for each crop in the rotation. The farm size affects the field time required by each implement to complete its field operation within the time constraints. Subsequently, it is used to determine the number and size of tractors and implements to be used. The farm size is also used to determine the approximate minimum size of implements to complete the farm operation.

Calendar Dates of Farm Operation

The user has two options on the mode of farm operation. The first option is an individual farm operation of primary tillage, secondary tillage and planting. This option allows for the individual farm operations to be in different seasons. The second option is a continuous farm operaiton covering from the primary tillage through the planting operation. A continuous farm operation is usually carried out in one season. The user is required to enter the beginning and ending dates of the farm operation, and the number of hours per day available. The number of days and the hours available per day for the farm operation are used along with the pwds to calculate the available field time for that operation. The available field time of operationis used to compare with the field time required by the implements to determine if the operation is completed within the date constraints.

Machinery Selection Algorithm

The selection of a farm

machinery set by the selection algorithm is based on a capacity and power match. The implements are sized to match the power available from the tractor and also sized to complete the job in the time alloted to each operation. Capacity matching is complicated by the fact that many operations are interrelated by time. When two or more operations are done in sequence, time devoted to one operation takes time away from another. Similar operations may also be done parallel to one another when there are two or more crops in a crop rotation.

The first step of the tractor and machinery selection algorithm is to determine the minimum and maximum implement sizes for a particular operation. The minimum implement size is the smallest implement which is able to complete each field operation within the time interval specified. The maximum implement size is the largest implement which can be pulled by the associated tractor. In the process of determining the minimum implement size, the program also calculates the tractor size. The recommended minimum and maximum implement sizes are to be used as a guide to select the appropriate commercial sizes of the implement in the main program. **Figs. 1** to **6** show the diagrams of the machinery selection algorithm. **Figs. 1** and **2** show the algorithm where the inputs are initialized. The user inputs the choice of locations, choice of soil texture, choice of implements and type and number of crops to be planted. For each crop the user is required to enter the land size and dates of operation. **Figs. 3** and **4** show the algorithm where the program calculates the minimum and maximum implement and tractor sizes.

The CPMS program can deal with a variety of tractor and machinery availability situations.

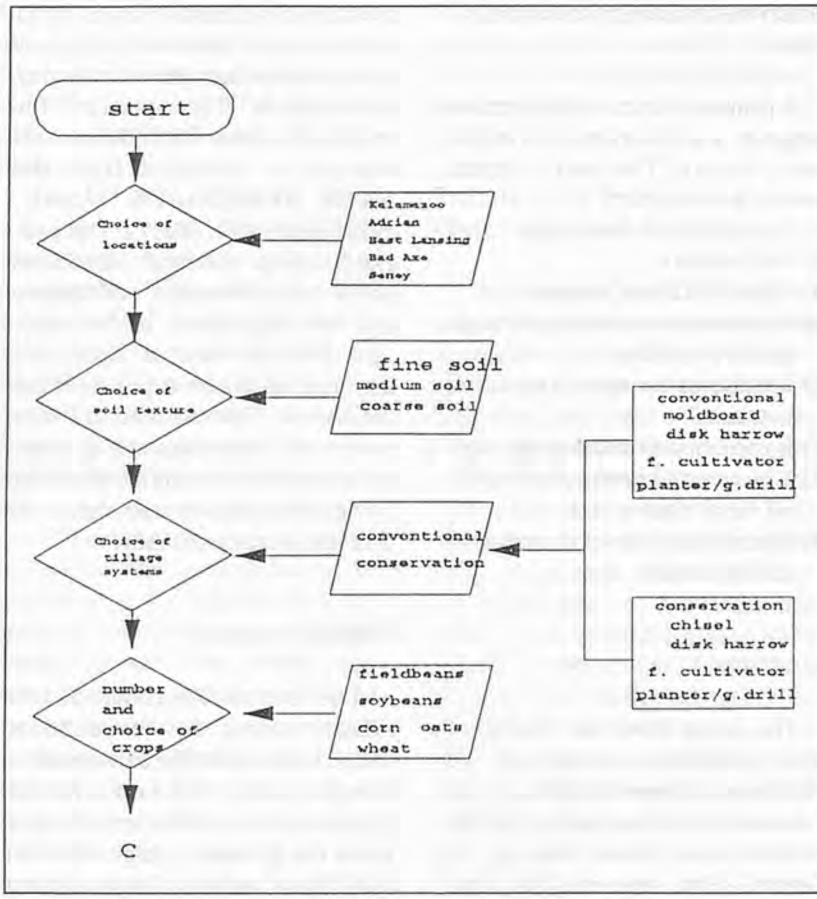

Fig. 1 Machinery selection algorithm.

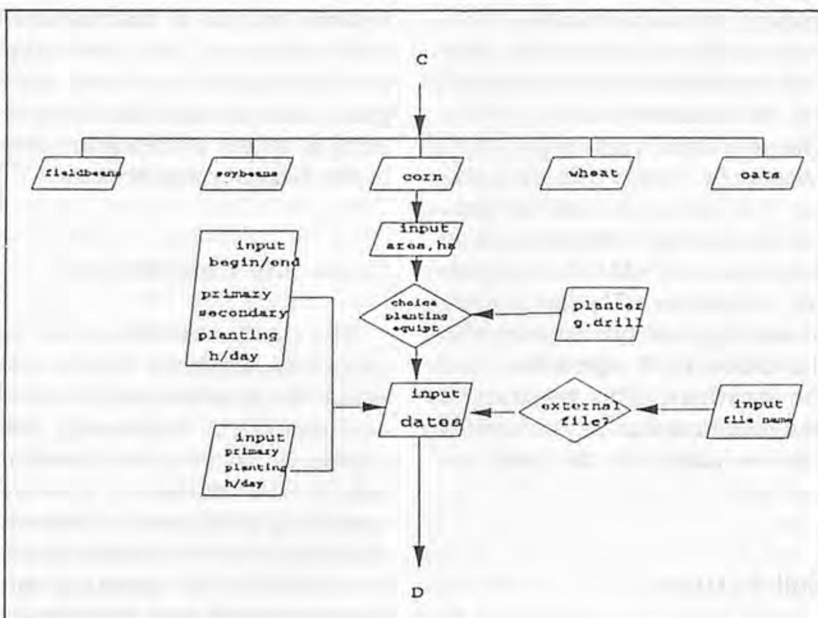

Fig. 2 Machinery selection algorithm (cont'd.).

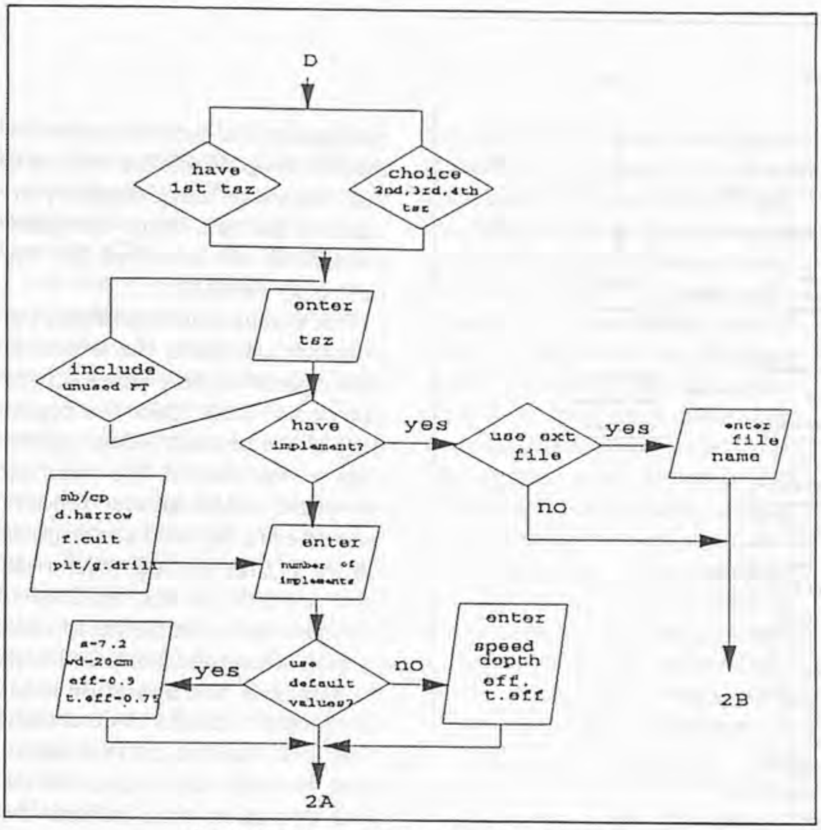

Fig. 3 Machinery selection algorithm (cont'd.).

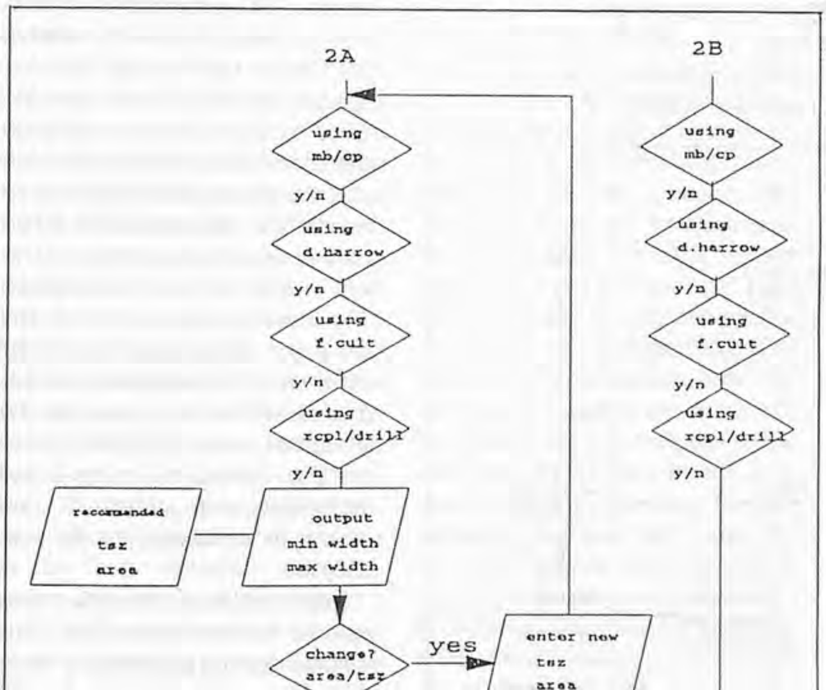

Fig. 4 Machinery selection algorithm (cont'd.).

If the user has a set of implements, but no tractors, the program can determine tractor sizes which are properly matched with the implements' power requirements. If the user has tractors but no implements, the program can determine implement sizes which are properly matched with the tractors' available power. The program can determine if the system's capacity is sufficient to complete all field operation within the time constraints for either of these situations. If the user has neither implements nor tractors, the program can select a tractor and implement set which is sized to complete all field operations within the time constraints.

The second part of the algorithm is the implement analysis program. In this part of the program, the user has to enter commercial implement and tractor sizes. Selecting the recommended tractor and implement sizes ensures compatibility between the tractor and implements, and that the operation is completed within specified date constraints. **Figs. 5** and **6** show the algorithm to compare the power and field time requirements of the implement with the available tractor power and available field operation time.

The drawbar power required by the implement is compared with the drawbar power of the tractor. Once the drawbar power requirement is met, the program then calculates the field time required by the implement to complete the farm operation. The field time required by the implement to complete the operation is compared with the available field operation time. Once the field time requirement is met, the program then proceeds to the next selected implement. After the drawbar power and field time requirements for all implements selected for the first tractor and for the first crop operation are met, the program

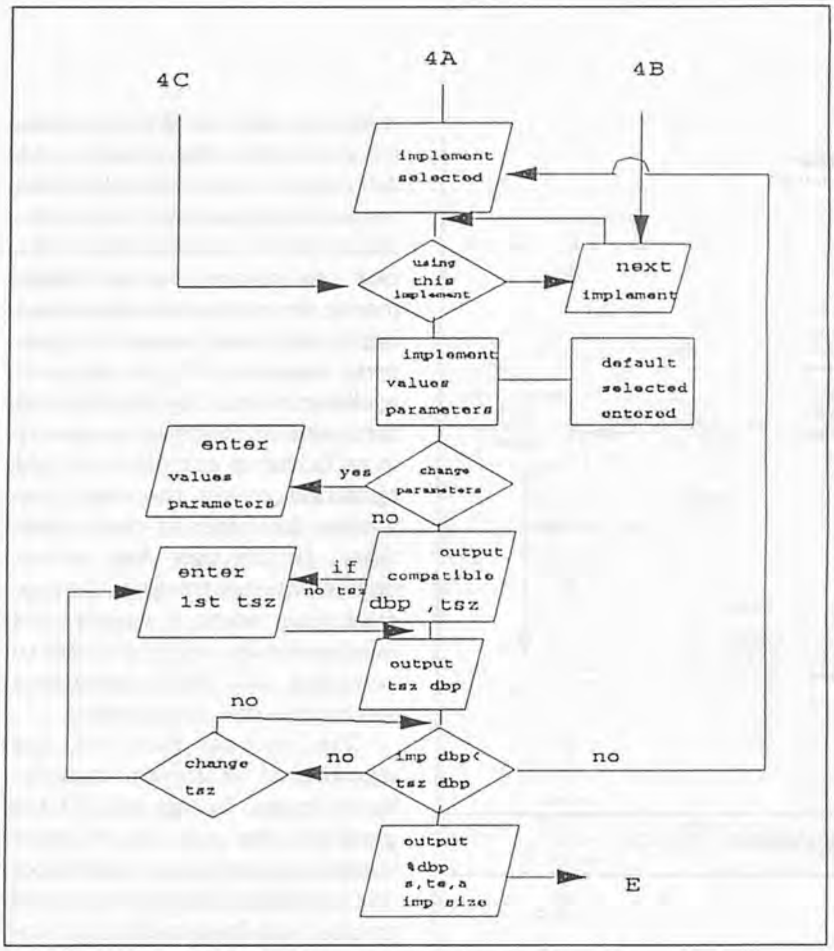

Fig. 5 Machinery selection algorithm (cont'd.).

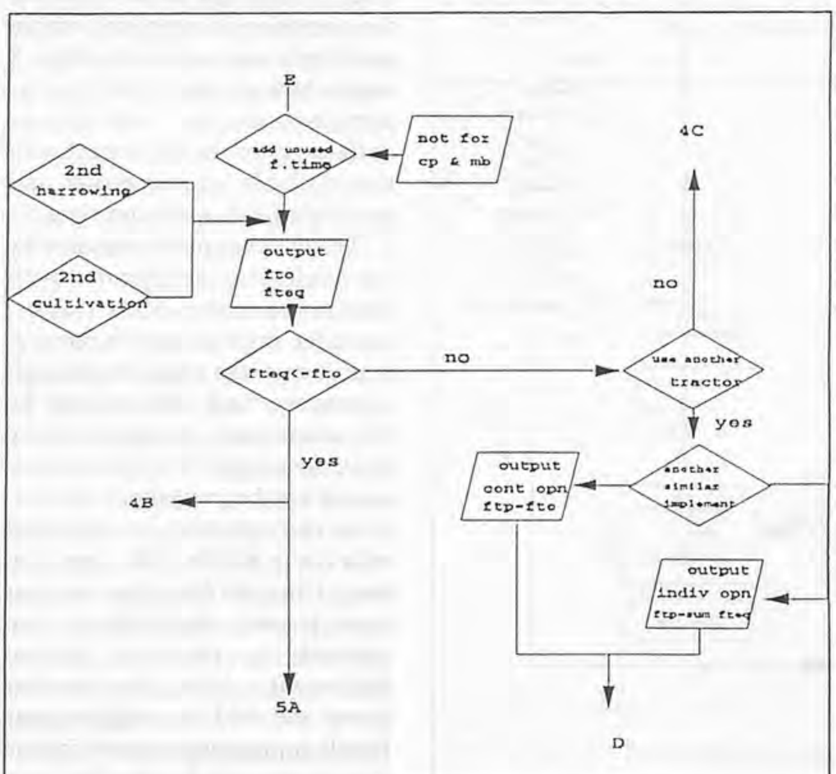

Fig. 6 Machinery selection algorithm (cont'd.).

proceeds to the second tractor for the first crop. If another tractor is not required, the program proceeds to the next crop. The same procedures are observed for the next crop operation.

For a continuous operation, the program calculates the available field operation time based on the number of days from the beginning of the primary tillage operation to the end of the planting operation, on the number of hours worked each day, and on the pwds for each time period. The field time required by ech implement and cumulative implements used by each tractor are compared with the available field operation time. The program checks to determine if the field time for the first implement is lower than its available field operation time before the program proceeds to the next implement. The program then continues to check for the cumulative field time of the first and the next implements. If the field time required by an implement is higher than the available field operation time, the program will indicate to the user that the implement is too small to complete the farm operation within the time constraints. This situation indicates what the user needs to increase the size of one or all of the implements selected or distribute one or more of the operations to an additional tractor. The choices of using larger implements or an additional tractor can be evaluated by the cost analysis.

Individual farm operation uses separate dates of operation. This program feature is useful for those operations which are carried out in two different seasons. For example, this allows the user to schedule primary tillage in the fall and secondary tillage in the spring. For the individual farm operation, the user is advised not to overlap the dates of the operations, especially for implement operations using the same tractor. Overlap in the dates of operations is allowed for operations using different tractors because they can operate simultaneously. The user has the option to use the unused field time remaining from the first implement operation to be added to the available field operation time for the next implement operation. The user must be careful not to add the available field time of an earlier operation to the later operation if the two operations are carried out in different seasons. The user can use two implements such as a field cultivator and disk harrow for the secondary tillage operation for the same crop. In this case, the program asks if the available field time unused by the primary tillage operation is to be added to the available field operation time for the secondary tillage operation. The new available field time of the secondary tillage operation is used for both the disk harrow and the field cultivator. The total time required by the disk harrow and field cultivator is compared with the available field operation time.

The CPMS program compares the field time required by each implement with the field time available for that farm operation. If the implement field time is more than the available field operation time, the program will allow the user the options of not using the implement with that tractor operation, increasing the implement size or ground speed, or completing the farm operation using a similar implement with another tractor. The user has the second option of choosing a larger implement or increasing the speed of operation to decrease the required implement time. Other parameters such as operation speed, operation depth, field efficiency and tractive efficiency can be changed.

Selecting the machinery for farms which produce several crops is a complex problem. The field time matching is more complicated, and the users must be careful in choosing the dates of operation. The program allows the overlap of operation dates of a similar operation for different crops but does not allow the same ending dates of a similar operation for different crops. The ending operation date of the later crop must come after the ending date of the earlier crop. The program uses the ending date of operation for the earlier crop as the beginning date of operation for the next crop if the beginning date of the later crop falls between the beginning and ending dates of operation for the earlier crop. The beginning and ending dates of operation are important in calculating the available field operation time. The program automatically adds the unused field time from the operation of the earlier crop to the same operation of the later crop.

Two different approaches were taken to solve the problem of continuous and individual farm operations for a multiple crop farm. For the continuous operation, the field time required by all implements is added for each tractor used. The total implements' field time is compared with the available field time of operation. The unused field operation time for each tractor operation from the first crop is carried forward to the next crop operation. In the next crop operation, the user has the option of using or not using the available unused field operation time from the previous crop. Users must not use the unused field time from a previous crop if the dates of operation for both crops do not overlap, especially if the planting operation of the later crop requires a specific beginning date to avoid planting a crop too early.

For the individual farm operation, the field time required for each implement will be compared with the time available for each operation. The unused implement field time from a crop operation is or is not added automatically to the similar operation of the later crop depending on whether or not the dates of operation overlap. For the crops with overlap in the dates of operation the program automatically adds the unused field time left by the previous crop operation to the similar operation of the next crop. The program does not add those times where the operation dates of both crops do not overlap. This avoids the unused time left by a similar operation that was carried out in a different season.

Conclusion

The CPMS model consists of the Machinery Selection Model and Machinery Cost Analysis Model. The Machinery Selection Model is used to determine the compatibility of the tractors and implements, to properly match the available power, and to complete the field operations during a specified duration of time. The tractor size is calculated based on the drawbar power required by the implement. The required implement drawbar power is compared to the available tractor drawbar power. The field time required by the implements to complete the farm operation is compared to the available field operation time. The best size and combination of implements are those implements that could utilize the maximum available power from the tractor and the available field operation time. The concept of expert systems used for this program will easily allow the user to carry out a sensitivity analysis. The model was also created to be used with external data files. The model was able to compare different farm sizes, tillage systems, and crop production system with respect to costs and machinery requirements.

REFERENCES

ASAE D230.4 1990. Agricultural Machinery Management Data. ASAE Standards. St. Joseph, MI 49085.

ASAE EP391.1 1990. Agricultural Machinery Management. ASAE Standards. St. Joseph, MI 49085.

Downs, H.W., Randal K. taylor and Abdulrahman Al-Janobi. 1990. A Decision Aid for Optimizing Tractor-Implement Systems. ASAE paper No. 90-1569. ASAE, St. Joseph, MI 49085.

FMO (Fundamentals of Machine Operation). 1987. Machinery Management. Deere and Company. Moline, IL.

Ghassan Al-Soboh, A.K. Srivastava, T.H. Burkhardt, and J.D. Kelly. 1981. A Mixed-Integer Linear Programming (MILP) Machinery Selection Model for Navybean Production Systems. TRANSACTIONS of the ASAE 29 (1): 81-84, 89.

Jones, J.W., Pierce Jones, and P.A. Everett. 1987. Combining Expert Systems and Agricultural Models: A Case Study. TRANSACTIONS of the ASAE 30 (5): 1308-1314.

Kotzabassis C., B.A. Stout and H.T. Wiedemann. 1990. Farm Machinery Selection and Management Expert System. ASAE paper no. 90-7018. ASAE St. Joseph, MI 49085.

Oskoui K.E, O.M. Morgan and W.B. Voorhees. 1990. Manage: — An Expert System for machinery management. ASAE paper no. 90-1643. ASAE St. Joseph, MI 49085.

Rosenberg, S.E., C.A. Rotz, J.R. Black, and H. Muhtar. 1982. Prediction of Suitable Days for Field Work. ASAE paper no. 82-1032, ASAE, St. Joseph. MI 49085.

Wu, Z., W.L. Kjelgaard, and Sverker P.E. Persson. 1986. Machine Width for Time and Fuel Efficiency. TRANSACTIONS of the ASAE 29 (6): 1508-1513. ■■

A Comparative Study on the Effect of Rice Threshing Methods on Grain Quality

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Abstract

A comparative study was conducted to investigate the performance of four available rice threshing methods, namely, by pedal thresher, bullock treading, drum beating and manual treading on threshing output, grain damage percentage and unthreshed grain of paddy. Sixteen sets of data were analyzed and results thus obtained show significant differrence (at 1% level by LSD) among the treatments on threshing output (kg/h), damaged and unthreshed grain percentage.

The study reveals that pedal thresher gave higher threshing output (103.4 kg/h) than other methods irrespective of rice varieties except Nizersail. Among the four threshing methods, manual treading performed better in respect to grain damage compared to other methods. Although the damage percentage of grain due to pedal threshing was higher than manual treading, it was not statistically significant.

Introduction

Bangladesh is an agricultural country. Rice is the staple food of the people. About 10.25 million ha of land is used for rice cultivation. Rice grows in four different seasons i.e., Aus (March to August), Broadcast Aman (April to November), T. Aman (July to December) and Boro (January to mid April). DAE (1990) reported that the total production of paddy from 10.25 ha of land was 27.06 million t from both high yielding and local varieties. The yield of local variety is very low. With the increasing population pressure, the production of local varieties can not meet the food requirement of the country.

The introduction of high yielding rice varieties to the farmers was a deliberate effort to increase the domestic rice production. The Bangladesh Rice Research Institute (BRRI) has developed some high yielding varieties (BR1 to BR23). Some paddy kernels are very difficult to separate from the panicle and some are easily shattered at the time of threshing.

Threshing is the detachment of paddy kernels from the panicle of the rice plant. The separation of grains from the papnicle occuurs due to the rubbing action, impact and stripping. The rubbing action occurs when paddy is threshed by trampling by man, animal or tractors. Impact action takes place during drum beating but both impact and striping action is followed by pedal thresher and power thresher.

Moreover, the thresher may be classified into two types based on feeding system: hold on and through in method.

In Bangladesh, the common methods of paddy threshing are manual treading, bullock treading, drum beating, beating by flail, pedal thresher and power thresher. The use of mechanical and power thresher is yet very limited.

The small volume of paddy bundles are threshed by the farmer immediately. But in case of large quantity they stack the paddy bundles for several days and gradually complete the threshing.

Late threshing of stacked materials sometimes causes both quantitative and qualitative loss due to warm and moist environment inside the stack.

For the bullock treading **(Fig. 1)**, all the paddy bundles are spread throughly on the threshing floor. Usually two to six bullocks and one man are used for treading the paddy stalk for hours. From the mud floor a measurable quantity of grains may be lost. Sometimes the grains are embeded into the soil due to the pressure of the body weight of the working animals. Hoofs of animals also occasionally may cause damage on grains during threshing.

During rainy days, people use mud floor for threshing the paddy by bullock treading method which results in maximum deterioration of grain comapred to other seasons.

The beating system is widely practised by the farmers in the country **(Fig. 2)**. But during threshing, grains are split and due to beating action, internal cracks may develop and may cause loss of grain. When the small quantity of paddy is to be threshed, usually farmers use their feet for threshing which is known as manual treading **(Fig. 3)**.

Mechanical threshing is very rare in Bangladesh. Pedal threshers are used in some districts. This type of mechanical threshing reduces the labour requirement and improves the quality of paddy (Samajpati and Sheikh, 1981).

It was observed that rice loss in the use of the pedal thresher was low when compared to losses incurred during the traditional practice of hand-beating followed by ox treading. The loss in hand beating alone was about 3.5% more than that with the pedal thresher (FAO, 1986).

A comparative study was conducted by Campbell (1976) on the threshing output of different threshers as shown in **Table 1**. The threshing loss of paddy with different threshers in Turkey ranged from 2.88% to 4.5% due to the use of improper thresher (Pinar, 1987).

The traditional threshing methods of paddy are common in rice growing countries. A high capacity thresher is not attractive to farmers and contractors. However, very small threshers are in use. IRRI (1986) reported that in Thailand threshing is done by beating or treading, animal treading, power tiller treading and tractor treading.

The threshing output of paddy using pedal thresher and IRRI-designed threshers were 80-100 kg/h and 250 kg/h, respectively, (IDRC, 1976).

In Bangladesh, farmers generally lack knowledge and information about proper threshing machine or method. As a result huge quantities of threshing materials are stacked for a long time and thus significant quantities of grains deteriorate in the stack.

Although the pedal thresher is an appropriate technology for rice threshing, its use is limited in the country. The pedal thresher **(Fig. 4)** needs two workers and a small area for threshing. It can be manufactured in local workshops with local materials. The cost of the machine is about Tk. 1 800.00 (US$50). Information on various threshing methods or machines is important for farmers in selecting the proper thresher.

Table 1. Output of Different Rice Threshers

Type of threshing	Horse power (hp)	Threshing output (kg/h)
Hand beating	—	17.20
Treading with bullocks	—	140
Pedal thresher	—	40-54
Table thresher	3	207
Drum thresher (Engine powered)	4	250

SOURCE: Campbell (1976).

Fig. 1 Bullock treading method.

Fig. 2 Beating method of threshing.

Fig. 3 Manual treading method.

Fig. 4A Pedal thresher method.

Fig. 4B Pedal thresher method.

The present study was undertaken to make a comparative study on available existing rice threshing methods in terms of their suitability and efficiency.

Materials and Methods

The four traditional existing threshing methods and four rice varieties were selected for the study. The experiment was conducted at the Comilla Regional Station of the BRRI during *aman* season in 1990. The rice varieties were: BR11, BR212, BR23 and Nizersail. The threshing methods were: bullock treading, pedal thresher, drum beating and manual treading. For this study, 20 bundles of paddy from each variety were taken at random. Three bullocks and two persons were engaged during animal treading. For the other three threshing methods, all operaitons were done by two workers also. Threshing time was recorded by a stop watch. The threshing capacity percent damage on grains and unthreshed grains were likewise recorded.

Results and Discussions

The performance of the farm threshers: i.e., bullock treading (BT); pedal thresher (PT); drum beating (DB); and manual treading (MT) on the threshing output of various varieties of paddy are shown in **Table 2**. The average threshing capacities of BT, PT, DB and MT were 67.45, 103.4, 75.83 and 27.14 kg/h, respectively. For the rice varieties used in the study, there was a high degree of threshing output when paddy was threshed by pedal thresher except the Nizersail variety (55.43 kg/hr). Possibly the low moisture content of grain and straw and uneven panicle arrangement within the bundles took more time to thresh with the PT and thus resulted in low threshing output compared to other methods. Usually, the threshing capacities of different methods depend on grain-straw ratio of the paddy crop, moisture content of grain, ambient weather condition of working day, physical strength of the workers and the feeding rate of materials to different processing methods. From the experiment it was observed that the variety and threshing method have significant effect on threshing output at 1% level **(Table 3)**. Campbell (1976) reported the threshing output of pedal threshers to be 40-54 kg/h. The IDRC (1976) reported that the threshing output of pedal thresher was 80-100 kg/h.

The average threshing output of pedal thresher, 103.40 kg/h thus obtained from the study was about two times higher than Campbell's finding and little higher than IDRC's report.

The average percentage damage

Table 2. Effect of Threshing Method and Variety on Threshing Output (kg/ha), T. Aman 1990

Variety/Method	BR11	BR22	BR23	N.sail	Mean
B.T.	75.69cA	71.00cA	50.90cB	72.20bA	67.45
P.T.	105.80aC	139.65aA	112.23aB	55.93cD	103.40
D.B.	82.87bA	78.73bA	58.15bB	83.55aA	75.83
M.T.	33.30dA	24.43dBC	20.70dC	30.13dAB	27.14
Mean	44.42	78.45	60.50	60.45	

C.V. = 4.82; LSD at .01 level = 6.553.
Small and capital letters used in column and row, respectively.
Similar letters in column and row have no different significantly.
B.T. = Bullock Treading, P.T. = Pedal Thresher,
D.B. = Drum Beating, M.T. = Manual Treading.

Table 3. Analysis of Variance of Threshing Output (kg/hr) of Four Different Methods with Four Popular Rice Varieties

Source	Degree of freedom	Sum of square	Mean square	Snedecor's F. ratio (Calculated value)
Variety	3	3 154.479	1 051.493	122.4344*
Method of threshing	3	35 802.901	11 934.300	1 389.6133*
Variety × method of threshing	9	10 507.585	1 167.509	135.943*
Error	32	274.823	8.588	
Total	47	49 739.788		

Coefficient of variation (C.V.) = 4.28%.
*Significant at 1% level.

Table 4. Effect of Threshing Method and Variety on Grain Damage, T. Aman, 1990

Method	BR11	BR22	BR23	N.sail	Mean
B.T.	1.05aC	3.08aB	3.86aA	3.90aA	2.97
P.T.	0.37cC	0.86cB	1.52bA	0.83cB	0.90
D.B.	0.50bcD	1.73bA	1.27cB	1.08bC	1.15
M.T.	0.64bB	0.42dCB	1.23dA	0.30dD	0.65
Mean	0.64	1.52	1.79	1.52	

C.V. = 4.81; LSD value at .01 level = .1581
Small and capital letters used in column and row, respectively.
Similar lettters in column and row have no different significance.

Table 5. Analysis of Variance of Damaged Grain (%) of Four Different Threshing Methods with Four Popular Rice Varieties

Source	Degree of freedom	Sum of square	Mean square	Snedecor's F. ratio (Calculated value)
Variety	3	11.194	3.731	805.711**
Method of threshing	3	40.298	13.433	2 900.437**
Variety × method of threshing	9	10.757	1.195	258.080**
Error	32	0.148	0.005	
Total	47	62.398		

Coefficient of variation (C.V.) = 4.81%.
** = significant at 1% level.

on grains varied from 0.65 to 2.97, were except for BR11 where PT provided 0.37% (**Table 4**). But in the case of BR22 and Nizersail, MT had less damage, 0.42 and 0.30%, respectively. However, at the same time PT had 0.86 and 0.83% damage for those varieties due perhaps to the high rpm (revolution per minute) of the machine. The variety and threshing methods have significant effect on grain damage at 1% level of significance (**Table 5**).

During the experiment it was observed that there were some unthreshed grains left in the straw (**Table 6**). The average unthreshed percentages of grains for BT, PT, DB and MT methods were 4.12, 0.10, 0.35 and 1.55%, respectively. For all the varieties under study, there was a low percentage of unthreshed grain when paddy was threshed by the pedal thresher. The variety and threshing method influenced the percentage of unthreshed grain at 1% level (**Table 7**).

The threshing output using the pedal thresher was higher than other methods except Nizersail. On grain damage, manual treading had better results than the other methods whereas the pedal thresher was next in position to manual treading.

Table 6. Effect of Threshing Method and Variety on Unthreshed Grain Percentage, T. Aman, 1990

Variety/Method	BR11	BR22	BR23	N.sail	Mean
B.T.	2.61aD	4.53aB	4.30aC	5.02aA	4.12
P.T.	0.08dB	0.21dA	0.06dB	0.05dB	0.10
D.B.	0.25cB	0.56cA	0.35cB	0.25cB	0.35
M.T.	1.03bB	2.12bB	2.27bA	0.79bC	1.55
Mean	0.99	1.86	1.75	1.53	

CV (%) = 2.96; LSD0.01 = 0.10
Small letters compare in a column and capital letters compare in the rows.

Table 7 Analysis of Variance of Unthreshed Grain of Four Different Threshing Methods with Four Rice Varieties

Source	Degree of freedom	Sum of square	Mean square	Snedecor's F. ratio (Calculated value)
Variety	3	5.289	1.763	860.023*
Method of threshing	3	121.370	40.457	19 734.877*
Variety × method of threshing	9	9.898	1.100	536.487*
Error	32	0.066	0.002	
Total	47	136.623		

Coefficient of variation (C.V.) = 2.96%.
* = Significant at 1% level.

Conclusions

The study shows that threshing with a pedal thresher performed better compared to the other traditional methods in respect to threshing output, grain damage and unthreshed grains. This is useful information for farmers in other growing countries.

REFERENCES

Directorate of Agriculture and Extension, 1990. Krishi Diary, Krishi Information Service, Farm gate, Dhaka.

FAO, 1986. Farm and village level post harvest rice loss assessment, Termination statement prepared for the Govt. of Bangladesh.

IDRC, 1976. Rice post harvest technology. p. 371.

IRRI, 1986. Small farming equipment for developing countries. p. 396-97.

Pinar, Y. 1987. Grain losses at harvesting and threshing of paddy in Turkey. AMA, vol. 18 No. 4. pp. 61-64.

Samajpati, J.N. and Sheikh, M.S.A, 1981. Paddy post harvest technology in Bangladesh. AMA, winter, pp. 39-42.

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Animal Traction and Sustainability of Dryland Farming Systems in Africa

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Abstract

This paper examines the economic perspectives for the use of animal traction farm technologies for dryland farming systems in Africa. The paper is structured around three main hypotheses relating to opportunities for and constraints to improving potential economic gains from animal traction. The analysis has shown that the perspectives for increasing animal traction economic viability and sustainability in dryland areas of Africa lie mainly in the efficient use of the displaced labour resulting from the use of the technology for intensification of the land use systems. This intensification process should, however, be coupled with advances in biological technologies and the wider use of animal traction weeding implements. Also, the alternative uses of the animals over most of the year should be encouraged so as to spread the fixed costs of the animals and implements. Finally, appropriate adjustments in both technical and institutional structures that accompany the technology must be made.

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Introduction

Dryland farming, the mode of food production in many parts of Africa, relates to agricultural systems in which adequate water supply is the determining factor. The drylands of Africa are inhabited by over 200 million people, most of whom are small-holder farmers.

A distinctive characteristic of the dryland farming systems in Africa is low productivity which underscores the continuing declining performance of agriculture in many African countries. Among the several bottlenecks, labour is a key constraint to productivity of the farming systems whose main inputs are land and labour (Singh, 1988; Panin, 1992). Majority of the farmers rely mainly on hand cultivation. Animal traction, a technology perceived by its proponents as being "appropriate" to small-holders was introduced into many African countries over several decades ago with limited success. The history of its introduction has been covered by Sargent et al. (1981), and Munzinger (1982).

In recent years, however, interest in the technology as a possible means for small-holders to increase their farm productivities has been rekindled among both researchers and policy makers in Africa as well as international oraganizations. This is a result of bad experience with tractor mechanization and the increasing deteriorating economies of most countries in the continent. For example, it was reported by Dibbits and Sindazi (1990) that the policy and strategy of the Zambian Government with regard to mechanization is now geared to animal traction for the small-holder farming community. Also, in Botswana, the continuing importance of animal traction in the economy and government strategies for enhancing small-holder profitability is well spellt out in the country's national development plan (MoA, 1991).

The renewed interest in the technology has prompted many governments and international donor organizations to animal traction-related programmes. Nevertheless, still only 15% of total arable land in Sub-Saharan Africa (SSA) is being cultivated with animal traction technologies (ILCA, 1981). Also, the technology accounts for only 10% of the total power use in the region. This puzzles many development officials and researchers about its "appropriateness" within the African dryland farming systems.

The low utilization of the technology by farmers warrants further consideration in discussions about its economic implications for small-holder farming systems. This does not imply that economic factors are the only ones involved in farmers' decisions for or against the adoption and use of the technology. However, it needs to be stressed that these are very crucial in the context of long-term sustainability of the technology within the farming systems.

Basically, farm innovation must meet four criteria before it can be considered a likely candidate for acceptance and overall effectiveness. It must be politically practical, socially acceptable, and economically feasible, as well as technically effective. These criteria may or may not weigh equally in evaluating feasibility. However, failure in meeting any one of the criteria signifies a low probability for the success of the technology.

Within the broader framework of the factors affecting animal traction farm technology this paper focuses on its economic implications on the farming systems. It does so by contrasting the potential benefits with available information from economic studies on animal traction farming systems. This study is based on three main hypotheses:

1. The widespread adoption of animal traction in dryland areas of Africa is largely constrained, among other factors, by the inability of the technology to substantially reduce farm investment and production costs.
2. The use of animal traction may lead to increases in cultivated areas but these may not be substantial enough to bring about the much needed increases in total food production per farm, and
3. The enhanced profitability of animal traction will mainly depend on the alternative uses of the displaced labour and other uses of the traction animals.

Characteristics of Animal Traction on Dryland Farming Systems

The main effects of animal traction on agricultural production are a characteristic of that which is associated with agricultural machinery. Its use can have far-reaching effects on the farming structure as well as on the welfare of the farming and non-farming communities.

Animal traction can be described as being "cost-saving" or "output-increasing" technology. It is commonly viewed as "cost-saving" if its dominant role can replace labour inputs. On the other hand, its effect is assumed to be "output-increasing" when its use is directed in such a way that its labour substitution is discouraged but rather provides an incentive for increasing total labour input and proportionately greater output expansion.

From the outset, a unique feature of a technological change as generally perceived in economics must be clarified. A technological change, is some alterations in the means of/or procedures in production (Yudelman, 1971). As such it is an alteration in part of an integrated system of economic activity. Therefore, one would not expect its effects to be completely uniform throughout that whole system.

What is crucial for the adoption and sustainability of any farming technology is that its use should result in an improvement of the welfare of the adopting farmers and the society as a whole. This calls for its overall benefits to exceed its costs. In considering its effects on the farming system, the technology should not be treated in isolation since new technology is almost invariably specific to or more associated with particular input, products, locations or production structures.

Economic Considerations of Farmers' Adoption

Economic Viability of Animal Traction Investment

While animal traction technology has the potential to increase farm productivity of small-holders, the technological change is not without costs. An important burden in the context of transforming traditional agriculture is the rise in capital needs of the farming households. This change involves the demand for a set of new capital inputs. Hence, the adopting farmer faces a greater financial burden than can be imagined under the traditional hand-cultivation systems because the former's fixed and variable costs are significantly higher.

As frequently cited in the literature, the initial capital requirement of animal traction is usually high relative to average farm incomes. According to Sargent et al. (1981), the extra financial burden reflecting the rise in the capital needs of actual and potential animal traction farmers is a major hindrance to the spread of the technology among small-holder farmers in Africa. For example, Phillip et al. (1990) report that the unaffordability of farmers to purchase draft animals and equipment is among the most important identified constraints hindering the development of animal traction in northern Nigeria.

Just as any economic activity, investing in animal traction technology ultimately would require sacrifices of other investment activities at both farm and societal levels. Therefore, for its adoption to have much chance of success and be sustainable in the long term within the dryland farming systems, it must be economically viable. Thus, its potential benefits must exceed its costs. The costs of animal traction constitute interest and depreciation on initial investment in animals and implements and the costs of feeding, housing and tending the animals.

Cost and Labour-saving Effect

The primary impact of animal traction on dryland farming, which also serves as the main motive of its proponents, is associated with its "labour input savings" per unit of output as crop area per unit of labour increases.

As observed by several authors, animal traction technology significantly reduces human labour input per area in all farm operations in which it is directly employed. Yet, there is an inconclusive evidence on its impact on annual total labour input per ha, an important determining factor for its adoption.

For example, Lasitter (1982) and Francis (1988) found that animal traction households in Burkina Faso and in Northern Zambia used 17% and 36% less total labour input per hectare, respectively, than their how counterparts. Panin (1988), on the other hand, reported the contrary in his studies in Nothern Ghana. There, the use of animal traction increased per hectare labour input by 10% over hoe households. A general observation made by Starkey (1990), is that the technology may be labour swithching rather than saving.

One of the most important considerations affecting labour effect of animal traction technology on the farming systems is the amount of use made of the technology. Using the technology near the limit of its technical capacity helps to spread the common costs. But as it is the case in many dryland farming areas in Africa, the technology is underexploited among farmers.

The current use of the technology is mainly associated with ploughing/ridging the period of which is usually short. Mean use over the year for ploughing/ridging, for example, is estimated to be 151 h per pair in Zambia (Francis, 1988) and 159 h in Ghana (Panin, 1988), representing an average period of 25 work days assuming the animals are worked for 6 h a day.

The use of the technology for weeding-the most labour intensive and limiting operation under many taditional farming systems (Norman, 1973; Olukosi, 1986; Panin, 1987), is scanty. As reported by some writers, only few traction farmers use the technology for weeding. This is inspite of the fact that weeding with animal traction tends to increases labour productivity (Jaeger, 1986). Lassiter (1982) reported that roughly 7% of total acreage under animal traction using households in Burkina Fasso was weeded with the technology.

In many areas, e.g., Mozambique, animal traction weeding is not practised and there are no ox-drawn implements for this operation (Ramanaiah and Munguambe, 1988). Imperfect access to credit as reported by Kumwenda and Kunkwenzu (1988) in Mali for the purchase of weeding and other implements and lack of information about their use explain the unpopularity of weeding with draft animals among farmers.

Yield Effect

As evident from literature on technological change, yield effect of mechanisation is usually negligeble (Donaldson and McInerney, 1973; Pingali et al. 1987). Major increases in output which arise from mechanization are mostly attributable to other yield increasing factors such as fertilizer, high-yielding seed variety with mechanization playing a catalystic role in the process.

Table 1. Yield Effects of Animal Traction Technology over Hand Cultivation by Crop and Country (%)

Crop	Ghana	Burkina Fasso
Maize	+37.0	+11.0
Millet	− 0.6	− 6.0
Sorghum	− 5.0	− 7.0
Groundnuts	+10.0	+28.0

Source: Ghana, Panin (1988).
Burkina Faso, Singh (1988).

Surveys on small-holder farming systems in Africa reveal mixed results for animal traction effects on per hectare yields (Barrett et al, 1982; Delgado and McIntire, 1982; Sargent et al. 1981; Panin and de Haen, 1989). However, a critical analysis of some of the available survey data tends to lend support for the above observation on mechanization effect on yield. As shown in **Table 1**, mostly crops such as maize and groundnuts for which animal traction demonstrates positive effect are those which normally receive either fertilizer application or better weed management.

The yield effect on millet and sorghum, the dominant crops in dryland farming areas in terms of acreage and utilization, is very modest or negative. This is because these crops are normally not fertilized (Panin, 1988; Singh 1988), and relatively less attention with regards to weed management is paid to them.

Area Effect

Invariably, all comparative studies of animal traction vis-à-vis hand cultivation systems conclude that animal traction farmers cutivate larger farm size than those relying only on manual cultivation. Increases of more than 50% are commonly cited (Lassiter, 1982; Singh, 1988; 1988; Panin and de Haen, 1989).

Nonetheless, the area effect of the technology is often disputable because the large differences in farm size tend to diminish as the number of workers per household is taken into consideration. This implies that the difference in acreage mainly reflects a difference in scale. Evidence presented in **Table 2** shows that in a comparison of animal traction users with non-users, no significant increases in cultivated areas could be attributed to the use of animal traction technology.

Also, the findings of Barret et al. (1982), Delgado and McIntire (1982) show no significant increase in acreage with animal traction except when variations in family size are ignored. The inferences that can be drawn from these studies and general conclusion from the technology's impact on yield cast doubts about the conomic potential of animal traction in dryland farming areas in SSA.

Table 2 Household Size and Cultivated Acreage (ha) by Country

Country	Number of Household Members		Cultivated Area per Household		Cultivated Area per Active Worker	
	NAT*	AT**	NAT	AT	NAT	AT
Burkina Faso	7.42	11.72	4.00	6.40	1.17	1.26
Ghana	10.75	14.53	3.56	5.58	1.01	1.05
Zambia	4.70	10.10	2.75	5.62	0.79	1.34

Source: Burkina Faso, Lassiter (1982); Ghana, Panin (1988); Zambia, Francis (1988).
*NAT = non-animal traction users; **AT = animal traction users.

Profitability and Sustainability Perspectives of Animal Traction Farming Systems

It seems clear from the previous discussion that profitability of animal traction farming systems are constrained by various pressures on resources available to the farmers and society as a whole.

The inability of technology to effect substantial yield increases on a given acreage implies that it will only make economic sense for farmers to adopt its use if the potential savings in labour input per unit of output will be more than enough to compensate for its costs. This under-normal-circumstances can be fulfilled in environments where labour is scarce and costly as well as the availability of abundant arable land. In other words, the higher the wage rates in an area (cost of labour) and the more accessible enough arable land is to majority of the populace, the greater the potential benefits from animal traction will be.

Under the current African situation where the rate of population growth is rapid and high resulting in unemployment, low rural wage rates and fragmentation of farm land into smaller sizes, one would wonder if the cost-saving factor would warrant the adoption of animal traction lest making it profitable. Of course, in the context of dryland farming in Africa it can be argued that animal traction is, inevitably an important innovation due to the labour "bottlenecks" during the cultivation period. This fact is not to be disputed.

While it is difficult to discern any consistant pattern of animal traction effect on total farm labour input that are of current significance to its adoption success and sustainability is how the technology can enhance efficient use of farm labour to increase farm productivity and its profitability. The possible solution to this can be sought from how the displaced labour time resulting from the use of the technology on any farm operation is utilised as well as the alternative uses of the animals. In other words, it can be argued that the profitability of the technology will depend largely on the alternative uses of the displaced labour and the traction animals.

The alternative uses of the displaced labour, among other things, include using it on the household farm to increase crop production and/or for non-farm activities to generate extra farm household income. The animals, on the other hand, can be used for activities such as carting of water and goods, grinding, etc.

On-farm Uses of Displaced Labour to Increase Crop Production

The household's crop production can be increased either through intensification or extensification of land use. The optimum results achievable under each practice will, among other factors, depend on the labour available ot the household. Due to its labour substitution effect, animal traction using households stand a better chance to accomplish one of the methods than other households relying on hand implements alone. The displaced labour can be used on the same piece of land or for expansion of the cropped area to increase total crop production.

Raising Crop Production Through Intensification of Land Use

The displaced labour can be used to complement the labour input on the same piece of land owned by the household and thereby raising its total labour input relative to households without animal traction. As a result of the increased labour, the households can timely and properly execute other yield enhancing agronomic practices which under normal situations are constrained by the available labour in non-traction using households.

Examples of the agronomic practices include timing of plant-

Table 3. Effects of Intensification and Extensification of Land Use on Crop Production

Item	HHHs*	Extensifying ATHs**	Intensifying ATHs
Area (ha)	3.60	5.50	4.50
Area/worker (ha)	1.01	1.21	0.83
Labour (h/ha)	568.00	562.00	688.00
Output (kcal/ha)	2 861.00	3 045.00	3 650.00***
Increase over hand technique (%)		6.00	28.00

Source: Panin (1988).
*HHHs = households using hoes; **ATHs = animal traction households
*** = significant at 95% confidence level.

ing, plant population, seedbed preparation, application of organic manure and chemical fertilizers, mulching and through weeding. These operations when properly and timely performed do have a positive bearing on yield since they increase the fertility of the soil.

With increased fertility of the soil, productivity of land can be expected to be higher for farms on which the operations are performed. Thus, animal traction households are in a better position to achieve higher crop yield per unit land through intensification of land use than those without animals **(Table 3)**.

Also, diversification of crops on the same unit of land is an important component of the intensification process. Animal traction enables farmers to plant different crops within the normal short rainy season period which constrains manual cultivation system. Through this practice it is expected that the total aggregate output will be higher for animal traction farmers. Research results on intercropping farming systems show that total output per unit of land of mixed cropping is higher than output of the same unit of land planted with a sole crop (Steiner, 1980). The findings of Panin (1988) confirm this even though the impact of animal traction on the cropping patterns was very minimal.

The data presented in **Table 3** lend support for this intensification process. As shown in the table, animal traction households that intensified their labour use per hectare relative to the non-traction households proportionately realized higher land productivity. The increase in productivity over that of non-traction households amounted to 28%.

Raising Crop Production Through Extensification of Land Use

The intensive use of labor on the same piece of land owned by a household which has just been discussed is more common among households with limited arable land. But for farmers with abundant land, the labour time saved can be used to expand the cultivated areas. In this case, the increases in total crop production result mainly from the output of the extra land brought under cultivation. Again, this situation is supported by the data in **Table 3**, as well as the findings of other surveys (Barret et al., 1982; Francis, 1988).

The attainment of higher crop production through the extensification process may be short-lived because of increasing population growth which may reduce the land resident ratio. With mounting pressure on available land, the traditional fallow system of restoring soil fertility may disappear. The subsequent effect of this will be decreased soil fertility which, in turn, may adversely affect crop output unless new agronomic methods are introduced.

Furthermore, the increase in total output resulting from extensification process relative to that of intensification is marginal. This is due to the fact that the whole extensification process may be affected by the total available household labour. As such only a marginal amount of new land measured on area per worker basis can actually be brought under cultivation. **Table 2** reveals an increase of only 6% for the extensifying animal traction farmers over those without traction as compared to 28% from intensification process.

Increasing Household Income from Non-farm Activities

Animal traction households may also derive revenues from sources other than farming activities. This involves the redeployment of displaced farm workers in other economic sectors to earn income. The success of this is, of course, limited, particularly by the available job openings and the skills of the workers.

Also, in practice, it appears that in the traditional farming set ups, the technology does not fully substitute for the farm workers but merely reallocates duties (Starkey 1990). This combined with other factors at moment makes the possibility of generating extra income through the use of displaced labour to look bleak.

Increasing Household Income Through Alternative Uses of Traction Animals

The fixed cost of keeping the animals can substantially be reduced if the animals are used more often throughout the year for other non-conventional activities such as water and firewood fetching, grinding and carting of goods to generate extra income. While the use of animals for these activities is gaining an increasing importance, research studies often fail to adequately quantify their monetary returns.

The animals themselves can be sold after their useful lives. It is documented that the replacement values of the animals are higher than their purchase prices because the animals increase in weight during their working lives (Lassiter, 1982; Barett et al., 1982; Panin, 1988). However, it is worth nothing that none of the studies which report higher replacement values reveal the accumulated cost over time for keeping the animals. This lapse places doubt on the actual benefit from sales of the animals. Again, most small-holder farmers are interested in the money at hand rather than what is to be earned in the future from sales of the animals considering other risks involved in keeping the animals.

Conclusion

The foregoing analysis shows that possible solutions to improve on the adoption chances of animal traction among small-holder farmers as well as its economic viability lie in the efficient utilization of the displaced labour. From the various utilization options available, it is clear that intensification of the labour use on the same piece of land to increase crop production is the best alternative. Adherence to this process will also have a positive effect on our natural resources. It will offset the constraints imposed on increased crop production by an inelastic supply of land and also ensure that land is properly managed and conserved.

As it is well known, animal traction technology in isolation, without attention to other factors, does not appear to be a viable technical "package" for the dryland subsistence agriculture. Therefore, the inensification process should incorporate the use of biological technologies so as to bring a threshold increases in land productivity and the wider use of animal traction weeding implements. A major hinderance to intensification of land use in the traditional farming systems is the common property rights governing land use systems in many areas of Africa. These need urgent attention from various institutions or governments to address the situation. The constraints imposed on its wider adoption among small-holder farmers by unaffordability to purchase the traction animals and equipment may be offset by the establishment of credit facilities.

Furthermore, avenues for alternative uses of the animals should be exploited in the various farming areas and farmers should be encouraged to do so. This, of course, is subject to how easily farmers can have access to the required implements.

REFERENCES

Barret, V., G.Lassiter, D.Wilcock, D.Baker, and E.Crawford (1982). Animal Traction in Eastern Upper Volta: A Technical, Economic and Development Paper No.4. Michigan State University, East Lansing.

Delgado, C., and J. Mclntire (1982). Constraints on Oxen Cultivation in the Sahel. America Journal of Agr. Econ. 64: 188-96.

Dibbits, H.J. and M. Sindazi (1990). Constraints on Oxen Cultivation in the Sahel. America Journal of Agr. Econ. 64: 188-96.

Dibbits, H.J. and M. Sindazi (1990). Historical and Present Constraints to the Use of Animal Traction in Zambia. pp 444-449 in: Starkey, P.H. and Faye A. (eds), Animal Traction for Agricultural Development. Proceedings of the Third Workshop of the West Africa Animal Traction Network held 7-12 July 1988, Saly, Senegal. Published by the Technical Centre for Agricultural and Rural Cooperation (CTA), Ede-Wageningen, The Netherlands. 479p. (E/F).

Donaldson, G.F., and J.P. Mclnerney (1973). Changing Machinery Technology and Agricultural Adjustment. America Journal of Agr. Econ. Vol 55, No. 5.

Francis, P.A. (1988). Ox Draught Power and Agricultural Transformation in Northern Zambia. Agricultural Systems 27:35-49.

ILCA (International Livestock Centre for Africa)(1981). Animal Traction in Sub-Saharan Africa. ILCA Bulletin 14, IICA, Addis Ababa, Ethiopia.

Jaeger, W.K. (1986). Agricultural Mechanization: The Economics of Animal Draft Power in West Africa Westview Press, Inc.; Praeger Publisher, Boulder, Colorado.

Kumwenda, W., and E. Kunkwenzu (1988). Research on the Use of Draught Animal Power and Mechanisation in Mali. pp 24-29. in Namponya, C.R. (ed). Animal Traction and Agricultural Mechanization Research in SACCAR Member Countries. Proceeding of a Workshop held in Maputo, Mozambique, 8-12 August 1987. SACCAR Workshop Series No. 7.

Lassiter, G.C.(1982). The Impact of Animal Traction on Farming Systems in Eastern Upper Volta Ph.D. dissertation. Dept. of Agr. Eco., Cornell University, Ithaca, New York.

MoA (Ministry of Agriculture, Botswana)(1991). Botswana's Agricultural Policy: Critical Sectoral Issues and Future Strategy for Development. Agricultural Information Section, Gaborone, Botswana. 51p.

Munzinger, p.(ed) 1982. Animal Traction in Africa. GTZ, Eschborn, Germany, 490p.

Norman, D.W. (1973). Economic Analysis of Agricultural Production and Labour Utilization Among the Hausa in the North of Nigeria. African Rural Employment Paper No.4., Dept. of Agr. Econ., Michigan State University, East Lansing, Michigan.

Olukosi, J.O. (1986). Income Generation and Distribution Among Farmers in Two Villages; The Case of Two Villages in Kwara State. Samaru. Miscellaneous Paper No. 144, Institute for Agricultural Research, Samaru, Nigeria.

Panin, A. (1987). The Use of Hoe and Bullock Traction for Crop Cultivation in Northern Ghana. An Empirical Economic Analysis. ILCA Bulletin. No. 29:2-8, IICA, Addis Ababa, Ethiopia.

Panin, A. (1988). Hoe and Bullock Farming Systems in Northern Ghana: A Comparative Socio-Economic Analysis. TRIOPS Verlag Langen, F.R.Germany.

Panin, A. (1992). Animal Traction and Farm Labour Use: A Case Study of Three Villages in Northern Ghana. Agricultural Mechanization in Asia, Africa and Latin America (AMA), Vol.23 NO.3, pp. 65-69, Tokyo, Japan.

Panin, A., and H. de Haen (1989). Economic Evaluation of Animal Traction: A Comparative Analysis of Hoe and Bullock Farming Systems In Northern Ghana. Quarterly Journal of international Agricultural. Vol. 28:1 pp. 6-20.

Phillip, D.O.A, G.O.I, Abalu, Aganga, A.A. and Aduku, A.O (1990). Animal Traction in Northern Nigeria: A Survey of Constraints and a Model of Prospects in Starkey, P.H. and Faye A. (eds), Animal Traction for Agricultural Development. Proceedings of the Third Workshop of the West Africa Animal Traction Network held 7-12 July 1988, Saly, Senegal. Published by the Techinical Centre for Agricultural and Rural Cooperation (CTA), Ede-Wageningen, The Netherlands. 479p. (E/F).

Pingali, P.L., Y. Bigot, and H. Binswanger (1987). Agricultural Mechanization and the Evolution of Farming Systems in Sub-Saharan Africa. John Hopkins University Press, Baltimore.

Ramanaiah, K.V., and A.V. Munguambe (1988). Increasing Efficiency of Draught Animal Power in Mozambique pp 34-37. Namponya C.R, (ed). Animal Traction and Agricultural Mechanization Research in SACCAR Member Countries. Proceedings of a Workshop held in Maputo, Mozambique, 8-12 August 1987. SACCAR Workshop Series No. 7.

Sargent, M., J. Lichte, P. Matlon; and R. Bloom (1981). An Assessment of Animal Traction in Francophone West Africa. East Lansing, Michigan State University, Dept. of Agr. Econ., African Rural Economy Working Paper No. 34.

Singh, R.D. (1988). Economics of the Family and Farming Systems in Sub-Saharan Africa: Development Perspectives. Boulder, Colorado, Westview Press.

Starkey, P.H. (1990). Animal Traction for Agricultural Development in West Africa:Production, impact, profitability and constraints. Starkey, P.H. and Faye, A. (eds), Animal Traction for Agricultural Development. Proceedings of the Third Workshop of the West Africa Animal Traction Network held 7-12 July 1988, Saly, Senegal. Published by the Technical Centre for Agricultural and Rural Cooperation (CTA), Ede-Wageningen, The Netherlands. 479p. (E/F).

Steiner, K.G. (1980). Intercropping in Tropical Smallholder Agriculture with special Reference to West Africa. Eschborn, F.R. Germany.

Yudelman, M. (1971). Technological Change in Agriculture and Employment in Developing Countries, O.E.C.D. ■■

ERRATA

Vol. 25, No. 2, Spring 1994 "**Mounted Implement for Sugarcane Stool Destruction**" page 47, The name of the authors should read:

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ABSTRACTS

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

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Dynamic Simulation of Tractor Suspension System: Aribi, K., Lecturer; Salleh, Lecturer, Farm Div., Univ. of Agriculture Malaysia, 43400 Serdang, Selangor, Malaysia.

The computer-simulated suspension system of tractor could be obtained by applying the dynamic characteristic equations and using relevant data of various dampers, masses and springs.

The assumptions used for the suspension system based on a 2 degrees of freedom.

With softwares available, suspension dynamic characteristics can be easily simulated and seen on a screen.

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Implications and Prospects of Combine Harvesting Technology in Pakistan: Younis, M, Lecturer; Iqbal, M., Asst. Prof., Dept. Farm Machinery and Power; Azhar, A.H., Res. Officer, Dept. Irrigation and Drainage; Sabir, M.S., Assoc. Prof., Dept. Farm Machinery and Power, University of Agriculture, Faisalabad, Pakistan.

This paper reports the present status of adoption of combine harvesting technology by the farming community, implications and future recommendations to adopt the efficient mechanical technology for timely harvesting of cereal crops and reduce grain losses. Combine population has the increasing trend due to non-availability of sufficient labour and uncertain weather conditions during harvesting periods. Fragmentation of land into small pieces is also a major constraint in the adoption of this technology. By the year 2000, the total number of combines has been estimated to be 43224 in order to harvest the crops on time. For adoption of this latest technology in its true sense, custom hiring system is recommended to be expanded to provide adequate and timely services to the small-sized and medium-sized farmers who cannot afford to own expensive farm machineries.

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Development and Testing of Flail Mower As Attachment to Prime Mover of Self-propelled Paddy Reaper: Tajuddin A., Assoc. Prof.; Balasubramanian M., Prof. & Head; Swaminathan, K.R., Dean, Zonal Research Centre, College of Agrl. Eng., Tamil Nadu Agrl. Univ., Coimbatore-641 003. India.

A flail mower was developed as attachement to the prime mover of a self-propelled IRRI model paddy reaper for clearing land from bushy plants like parthnium and for allied operations. The flexible cutting elements of the mower are capable of cutting plants even in stoney or uneven land surface. The attachment costs $250, excluding the cost of the prime mover. The operational cost of the machine is only one-third of the cost of conventional methods of clearing land using manual labour.

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Utilization of Resources by Head and Tail Farmers Under Irrigated Rice Condition: Hossain, Md. Ismail, Senior Scientific Officer, Agril. Econ. Div., BARI, Joydebpur, Gazipur.

The study has shown that "tail" farmers (those farthest away from irrigation water source) were at a disadvantage in receiving their share of irrigation water. This means that the use of their labour and other resources such as fertilizer and farm chemicals were not fully compensated. In comparison, their "head" counterparts (farmers nearest the source of irrigation water) benefitted more by realizing higher crop yields per unit area, hence higher returns to irrigation and labour inputs than the tail farmers.

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Effect of Irrigation Schedules on Grown and Yield of Soybean Crop: Kalwar, G.N., Prof.; Jamre, G.H., Assit. Prof., Dept. of Agronomy, Sindh Agric. Univ., tandojam, Pakistan. Bukhari, S., Prof.; Mahar, S., Assoc. Prof., Dpet. of Farm Power and Machinery, Sindh Agric. Univ., Tandojam, Pakistan.

The experiments were conducted in order to determine the effect of irrigation schedules on growth and yield of soybean (*Glycine max* (L) Merr) at the Malir Experimental Farm, Sindh Agriculture University, tandojam, with Sultanpur silt loam soil at 23.5% soil moisture.

The results show highly significant differences in irrigation schedules and soil fertility levels. Full season irrigation produced maximum tiller density, height, pods, grain weight and grain yields under a regime of high soil fertility level. The plant population was adversely affected due to inadequate irrigation.

The experiment also show that withholding irrigation water during the stage of plant growth, initial flowering and pod initation meant a reduction in the number of pods per plant, grains per plant and grain weight.

The grain yield decreased by 28.3% when the crop did not receive irrigation water at branching, pod initiation and pod completion stages. Moisture stress at any growth stage of the crop reduced grain yield as blooming, pod formation and pod filling stages were most critical periods for water stress in soybean crop.

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Improved Blade for Groundnut Digger: Gupta, R.A., Asst. Res. Scientist, Office of the Res. Scientist, Agric. Eng., Gujarat Agric. Univ., Junagadh Campus, Junagadh, Gujarat, India.; Parmar, M.T., Res. Scientist (Dry Farming), Main Dry Farming Res. Station, Targhadia, Gujarat Agric. Univ., Rajkot, Gujarat, India.

Four blades of groundnut digger with different shapes, i.e., Convex-I, Convex-II, V-shaped and double stepped were developed at the Main Dry Farming Research Station, Targhadia, Rajkot, Gujarat, India. Their performance was compared with the straight and regular blade which is locally available and used by the farmers in the region. From the field trials it was found that with the use of double stepped blade, the loss of groundnut pods can be reduced by 47.5%. Draft requirement was reduced by 25.0%. As the draft is reduced more area per unit of time can be covered. The double stepped blade worked at uniform depth because of its shape hence, jerks on the neck of bullocks were minimised and the bullocks felt more comfortable while working in the field. A farmer can harvest a net sum of Rs. 388.67/ha by using this blade.

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Simulation of Parboiled Paddy Drying: Khan, Md. K., Lecturer, Dept. of Agril. Processing and Food Engineering, College of Agric. Eng. and technology, Bhubaneswar, India; Singh, R., Prof.; Sandhu, S.S., Dept. of Processing and Agric. Structures, P.A.U., Ludhiana, India.

A series of thin-layer drying tests were performed in a controlled temperature laboratory type dryer within the temperature and relative humidity ranging from 65 to 120°C and 9 to 36%, respectively. A second order quadratic equation was fitted into the experimental data to represent the drying behaviour. The parameters of the developed thin-layer drying equation were related to the air temperature, relative humidity and the initial moisture content. A simulation model was developed to predict the drying time in a deep bed of parboiled paddy consisting of thin layers stacked upon one another. The experimental results from the multilayer drying tests were compared with the simulated results based on the model. Good agreement was obtained between the simulated and experimental results.

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Energy Requirements of Selected Nigerian Agricultural Traditional Manual Tasks: Nwuba, E.I.U., College of Agric., Ahmadu Bello Univ., Zaria, Nigeria. Now in Dept. of Agric. Eng., Anambra State Univ. of Technology Enugu, Nigeria; Nwuba, L.A., Institute of Education, Ahamadu Bello Univ., Zaria, Nigeria. Now in Dept. of Animal Science and Aquaculture, Anambra State Univ. of Technology Abakaliki Campus, Anambra State, Nigeria.

Energy requirements of tilling, ridging, weeding, bush slashing, wood cutting and *shadoof* water lifting were studied using Nigerian popular traditional tools. Four subjects were calibrated on a bicycle ergometer in seasonal environments. The subjects were then engaged in various tasks, in turn, under similar environmental conditions. Their heart rates were measured and the energy requirements read from the calibration graphs.

It was found that all the traditional manual tasks studied were high-energy demanding and could not be continued for prolonged periods of time without rest stops. The study shows that bush slashing required 5 kJ/min, wood cutting required 6.50 kJ/min, *shadoof* water lifting 6.56 kJ/min, weeding 7.10 kJ/min while tilling and ridging demanded 7.7 and 10.0 kJ/min, respectively.

It was also found that the work rates for the tasks increased sinificantly in hot seasonal environments.

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Some Physical Properties of Cowpea as Related to Mechanical Threshing of the Entire Plant Shoot: Nwuba, E.I.U., Dept. of Agric. Eng., Ahmadu Bello Univ., Now in Dept. of Agric. Eng., Anambra State Univ. of Technology, Enugu; Arinze, E.A.; Braide, F.G., Dept. of Agric. Eng., Ahmadu Bello Univ., Zaria, Nigeria.

Selected physical properties of cowpea were applied in the design of a whole shoot cowpea thresher. The physical properties were measured for 7 popular varieties of cowpea and the whole shoot threshing was tried with the 7 varieties in a cowpea pod thresher. The pod thresher was then redesigned for whole shoot threshing.

It was found that the breaking of cowpea stalk in the threshing chamber decreased with cowpea grain size. The cowpea varieties differed significantly in their grain size which ranged from 6.36 to 9.18 mm in length, 5.24 to 7.44 mm in width and 4.0 to 5.82 mm in thickness. The pod pericarp thickness was found to be significantly different and closely related to grain size and shatter losses.

Five sieve sizes of 7 mm, 8 mm, 8.5 mm, 9 mm and 10 mm and concave sizes of 8.5 and 10 mm were recommended for different grain sizes. The spikes on the threshing cyclinder were 12 mm apart and the cylinder was provided with knives to cut the fluffy stalk. A stalk evacuating chute was provided at the threshing chamber. A power requirement of 12 W per kg/h of material, a blower air flow of 486 m/min and a cylinder speed of between 350-450 m/min were recommended at a concave clearance of 26 mm.

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Tractor on Board Data Acquisition System for Measuring Tractor Performance: Ismail, W.I. bin Wan, Universiti Pertanian Malaysia, 43400 Serdang, Selangor Darul, Ehsan, Malaysia; Burkhardt, T.H., Michigan State University, East Lansing, Michigan 48824, USA.

The implement draft and fuel requirements are two important factors in determining tractor and machinery selection in machinery management. Microcomputers were increasingly utilized in the acquisition and processing of implement-tractor performance data. The tractor-on-board data acquisition system was developed to ease infield data collection using the established equations from the ASAE Standards. The data acquisition system consists of DjTPMII to measure the engine speed, ground speed and tractor front and rear wheel rotation speeds; an Emco PDP I fuel flow transducer to measure the fuel consumption; and strain gauges to measure the draft of implements. The signal from each sensor is passed through a signal conditioner and through an analog-to-digital converter. The data were stored as ASCII code in RAM of a microcomputer which was later transferred to a floppy disk. The engine RPM, front and rear wheel revolutions, tractor ground speed and fuel consumption were verified before field experiments were carried out. The experimental outputs were compared and validated using the computer model outputs.

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Field Evaluation of Hydraulic Rams: Bhoi, K.L., Assoc. Res. Scientist, Main Dry Farming Research Station, Gujarat Agric. Univ., Targhadia, Rajkot, Gujarat State, India; Ram, S., Prof; Chauhan, H.S., Prof., Dept. of Irrigation and Drainage Eng., G.B. Pant Univ. of Agric. and Tech., Pantnagar, India.

The hydraulic ram (hydram) is a device to raise part of the volume of water available at some height to a greater height. The device is being successfully used for lifting water from rivers to irrigate upland terraces in hilly areas in India. The performance of a few hydrams installed in Kumaon and Garhwal hills of U.P. State, India, was studied. The hydram discharges were observed ranging from 1.051 to 0.272 ℓ/s at the magnification factor (m.f.) of 3.5 to 14.5 in the case of 10 cm × 5 cm hydram, 2.37 to 0.828 ℓ/s at the m.f. of 4.0 to 8.9 in case of 15 cm × 7.5 cm hydram and 3.538 to 1.5 ℓ/s at the m.f. of 8 to 12 in case of 20 cm × 10 cm hydram. The study shows that the weight of the waste valve equal to 0.056 kg/cm^2 and 0.023 kg/cm^2 for the hydram size of 15 cm × 7.5 cm and 10 cm × 5 cm, respectively, and the weight of delivery valve equal to 0.021 kg/cm^2 of the area of the valve plate for the hydram size 10 cm × 5 cm resulted in higher discharges and efficiencies of the hydram than the weights provided by hte manufacturer.

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Sustainability of Efficient Mechanization for Agricultural Production in a Developing Economy (Akwa Ibom State of Nigeria in Focus): Essien, Obot E., The Head, Dept. of Agric. Eng., School of Agriculture, P.M.B. 1001, Abak, Akwa Ibom State, Nigeria.

This article is based on investigations conducted between 1986 and 1991 on the availability and conditions of physical facilities expected to be utilized for mechanization of agriculture in Akwa Ibom State—a humid tropical zone of Nigeria, while potentials for mechanization are great, physical facilities like workshops, tractors and implement, harvesting, processing and irrigation equipment are still very low. While the ratio of functional to available tractors grew between 23 and 80%, in 1987 and 1991, tractors, growth rate was about 3% of potential number required; downtime or percentage loss of tillage time went up between 16 and 66 percent, and monthly production efficiency (i.e., percentage of monthly fulfilled orders) for locally fabricated processing machines ranged between 25 and 60. Reasons prevailing were poor infrastructural equipment for repairs and maintenance, lack of spare part inventory and sloppy service funding. However, improvement lies with accepting better service, spare-part and workshop management strategies. ■■

Gerald Thierstein Receives Kishida International Award

The 1994 ASAE Kishida International Awards is presented to Gerald E. Thierstein, P.E., in honor of his dedication to the application of appropriate technology and agricultural practices in the developing world and to the development of the international agricultural engineering profession.

The award was presented by ASAE, the Society for engineering in agricultural, food, and biological systems, during its International Summer Meeting, June 19-22, at the Hyatt Regency at Crown Center, Kansas City, Missouri. Initiated in 1978, the award serves to recognize outstanding contributions to engineering-mechanization-technological related programs of education, research, development, consultation, or technology transfer that have resulted in significant improvements outside the United States.

Presently living in Fort Collins, Colorado, Thierstein recently retired from the Department of Biological and Agricultural Engineering at Kansas State University. He devoted more than 25 years of his career to agricultural engineering in developing countries. His primary interests have been in the areas of appropriate technology and education. His career has taken him from South America to Southeast Asia, and included assignments in the Caribbean, East Africa, the Middle East and South Asia.

Thierstein started the first agricultural engineering program in East Africa at Egerton University, Kenya, and taught and supervised graduate students at Mekerere University in Uganda and the American University of Beirut in Lebanon. Short term training of technicians and supervision of graduate students from many countries were important components of his work at the International Crops Research Institute of the Semi-Arid Tropics (ICRISAT) in India. Another important training aspect of his work in most countries was to improve the skills of agricultural machinery operators.

In every instance, Thierstein demonstrated concern about the technical needs of small-scale farmers, assisted with design and development of equipment suitable for local manufacture, and encouraged local people in the development of their own ideas. Several of his developments are being manufactured in various countries.

Gail Janssen Elected President of ASAE

Gail E. Janssen, P.E., chairman of the board and chief executive officer of F&M Bancorporation, has been named President of ASAE, the Society for engineering in agricultural, food, and biological systems.

Janssen was inaugurated at the Society's International Summer Meeting, June 19-22, at the Hyatt Regency at Crown Center, Kansas City, Missouri. As president of the Society, he is primary spokesperson for more than 9,000 members in 50 states, 10 provinces and 100 countries. He will hold the position of president for one year, then serve on the Executive Committee for one year in the position of Past President.

In his position with F&M, Janssen is responsible for 15 banks with 40 offices servicing 38 Wisconsin communities. He is also chairman of the board of Badger Northland, Inc., a manufacturer of agricultural equipment; and a director of a food processing firm and a construction company.

Prior to entering the finance field in 1977, Janssen devoted his career to agriculture and agricultural engineering. He operated a dairy farm for eight years before earning two bachelors degrees from the University of Wisconsin in 1960 and 1962 — one in agriculture, the other in mechanical engineering. After graduating, Janssen became the farm electrification advisor for Wisconsin Public Service Corporation in Green Bay. From there, he moved to Gehl Company in West Bend, where he progressed from design engineer to assistant chief engineer.

A member of ASAE since 1962, Janssen has devoted time and effort to numerous Society offices including those of ASAE treasurer and director of finance, and as chair and vice-chair of both the Wisconsin Section and the former Illinois-Wisconsin Region. An ASAE Fellor, he is a Trustee of the ASAE Foundation, a charter member of the Wisconsin Section, and a member of the Presidents' Club.

William Johnson Receives Mccormick-Case Gold Medal

William H. Johnson, P.E., Professor Emeritus in the Agricultural Engineering Department at Kansas State University, is the recipient of the 1994 Cyrus Hall McCormick-Jerome Increase Case Gold Medal.

The award was presented by ASAE, the Society for engineering in agricultural, food, and biological systems, during its International Summer Meeting, June 19-22, at the Hyatt

Regency at Crown Center, Kansas City, Missouri. The McCormick-Case Gold Medal has been presented annually since 1932 to honor outstanding inventive and entrepreneurial achievements.

Johnson was honored for his productive leadership in ASAE and his outstanding contributions to the agricultural engineering profession. His accomplishments in research, education and administration are notable. At the Ohio State University, Johnson's research contributed significantly to the development of minimum tillage — now a universally accepted process — and motivated studies that resulted in a reduction in losses in wheat, corn and soybeans.

At Kansas State University, where Johnson administered the Agricultural Engineering research program, he initiated a Ph.D. program in agricultural engineering and integrated extension faculty into the department. His efforts resulted in improved enrollment and significantly increased contract research. Recently, he was inducted into the KSU College of Engineering Hall of Fame.

Richard Godwin Elected ASAE Fellow

Richard J. Godwin, CEng., is professor and head of Agricultural and Environmental Engineering, and director of Research with Silsoe College at Cranfield University, England, has been elected a Fellow of ASAE, the Society for engineering in agricultural, food, and biological systems. He was honored at the Society's International Summer Meeting, June 19-22, at the Hyatt Regency at Crown Center, Kansas City, Missouri.

Election to Fellow is one of the highest distinctions an ASAE member can achieve. Elected annually by ASAE's Board Directors, Fellows are chosen for their unusual professional distinction and extraordinary qualifications. A minimum of 20 years of active practice of engineering or teaching of engineering with demonstrated distinction in performance for at least 5 of those years is required for nomination. Election to Fellow is a distinction earned by only about two percent of the ASAE membership.

A member of ASAE since 1970, Godwin currently holds the offices of international director and co-chair of President Scott's initiative for globalization. He has served on the Society's International Committee and the Soil Dynamics Committee. Recently, Godwin was recently named president of the Institution of Agricultural Engineers in the United Kingdom.

Wayne Coates Elected Director ASAE International Department

Wayne Coates, P.E., an associate professor in the office of Arid Lands Studies at the University of Arizona, has been elected Director of the International Department of ASAE, the Society for engineering in agricultural, food, and biological systems.

He was installed at the Society's International Summer Meeting, June 19-22, at the Hyatt Regency at Crown Center, Kansas City, Missouri. His term will run for two years. As International Director, Coates will represent ASAE members in over 100 countries. The Board of Directors develops policy for the nonprofit, technical, scientific and educational Society.

At the University of Arizona, Coates teaches and conducts research in the area of agricultural machinery design and testing. His development of equipment used in the production, processing, and harvesting of new crops has resulted in trips to international destinations for consultations and presentations of the results of his research.

A member of ASAE for 21 years, Coates recently completed a term as a District Director. He chaired the Service to International Members Committee, and is the ASAE representative on the Consortium of Affiliates for International Programs Committee of the American Association for the Advancement of Science. He is past-chair of ASAE's Arizona Section and the former Pacific Region, and is a member of the International Executive Committee and the International Affairs and Relations Committee, as well as several other ASAE committees related to research.

The ASAE Board of Directors Approved a Recommendation to Rejoin CIGR

The ASAE Board of Directors approved a recommendation to rejoin CIGR, at the existing fee rate, for a period of three years, with a long term view of a continuing relationship. This decision will be reviewed annually by the ASAE Board with a recommendation from a Review Group consisting of: 1) ASAE international Director (serving as chair of the group); 2) Chair of the ASAE International Executive/Steering Committee; 3) Chair of the ASAE International Affairs and Relations Committee; 4) Chair of the ASAE International Meetings and Conferences Committee; and 5) the following ASAE members who are in leadership positions in CIGR, the ASAE representative on the CIGR Executive Board; and all other ASAE members who serve on the CIGR Executive Board who can attend the meetings of the Review Group.

The following Criteria are:

1) How well CIGR plans and develops its ideas to be a facilitator of international communications (given budget constraints) to include provision for: a) an international newsletter; b) a calendar of events; and c) an expanded network system;
2) Evidence that the CIGR leadership has adopted and developed: a) the role model as a facilitator for network partnership linkages; and b) a realistic approach to budget constraints pending the possible withdrawal of existing sponsorship for the secretariat.

EIMA - International Agricultural Machinery Manufacturing Exhibition

Nov. 5-9, 1994
Bologna, Italy

From 5 to 9 November 1994, EIMA will celebrate its 25th anniversary, a most important milestone in the progress of a still young specialized exhibition for agricultural and green area mechanization which has been held, since its inception, on the Bologna Fairgrounds.

EIMA came into being in 1969 as a result of the foresighted institution of a group of Italian manufacturers, associates of UNACOMA, and the unrelating efforts of the Secretary General of the Association at that time. From its beginning EIMA assumed the formula of a high quality exposition, marking its distinction from traditional agricultural fairs, both for display layout and target emphasis. Over the last 10 years, the average number of exhibitors has been 1 450-1 500, and that attendance from 70 000-80 000 persons, 10% of which coming from 100 countries all over the world.

For further information contact:
Secretary General, EIMA-00161 Roma, Via Lazzaro Spallanzani, 22/A
Tel: 06/44231370, Fax: 06/4402722

MANTECH '94 — International Exhibition & Seminars on Manufacturing Technologies

Nov. 5-10, 1994
Pragati Maidan, New Delhi, India

Asia Premier Manufacturing Technology Show

MANTECH '94 is being organized by FICCI, the apex body of chambers of commerce and industry in India, with the active support of all the key Ministries of Government of India.

MANTECH '94 will provide an excellent opportunity for:

- entering into multi-billion dollar Indian market
- exhibiting the state-of-the-art technologies
- assessing the technology requirements in the Asian region
- transferring technology to India and other Asian countries
- identifying and finalizing arrangements for setting up production base in India and in third countries
- participating in technology seminars.

Spectrum of Technologies

MANTECH '94 will display latest technologies and equipments in various manufacturing fields including:

① Agritech
② Chemicals
③ Communications
④ Electronics
⑤ Energy Conservation
⑥ Environment protection
⑦ Food Processing
⑧ Instrumentation
⑨ Mining
⑩ Petrochemicals
⑪ Power
⑫ Railway Equipment

A Forum for Businessmen — An Impetus for Globalization

A series of Seminars organized concurrently during the Exhibition, will encourage intensive dialogue between technology suppliers and technology seekers. The seminars will also provide a platform for interactive discussions, one-to-one meets and exchange of ideas on manufacturing technologies.

Participation Costs (International Sector)

- Open space US$ 75 per sq mt
- Covered bare space US$200 per sq mt
- Built up stand with package of facilities US$350 per sq mt

Minimum space of a built up stand is 12 sq. mts. For open/covered bare space it is 50 sq mts.

Last date for Booking is August 31, 1994

For further information contact:
Federation of Indian Chambers of Commerce and Industry
Federation House, Tansen Marg, New Delhi-110001. Tel: 91-11-3319251-61
Fax: 91-11-3320714, 3721501, 3721504.

The International Symposium on Water Quality Modeling

April 2-5, 1995
Hyatt Orlando, Kissimee, Florida, U.S.A.

This conference will focus on new modeling concepts, parameter evaluation and data base development, validation studies, application examples, and G.I.S. applilcations. The conference will provide a forum for information exchange of state-of-the-art technology in water quality modeling.

Sponsored by: American Society of Agricultural Engineers

Cooperating Organizations: USDA-ARS, USDA-CSRS, American Society of Civil Engineers

For other informations contact: John Hiler, Meeting & Conferences Manager, ASAE, 2950 Niles Road, St. Joseph, Michigan, 49085-9659. Tel: 616.429.0300. Fax: 616.429.3852.

Fifth International Microirrigation Congress

April 2-6, 1995
Hyatt Orlando, Orlando, Florida, U.S.A.

This international conference will focus on the newest developments in research, equipment, adoption and usage of microirrigation systems worldwide. Special programming will be designed to identify and prioritize challenges and opportunities. Researchers, consultants, designers, managers, manufacturer's representatives and users of microirrigation systems are encouraged to participate.

Sponsored by: The American Society of Agricultural Engineers

Cooperating Organizations: The Irrigation Association, Florida Irrigation Society, Soil and Water Conservation Society, American Society of Agronomy, Soil Science Society of America, ASCE, American Water Resources Association, USCID, USDA-ARS, USDA-ES, USDA-SCS, Water Environment Federation.

For other information contact: John Hiler, Meetings & Conferences Manager, ASAE, 2950 Niles Road, St. Joseph, Michigan 49085-9659. Tel: 616.429.0300 Fax: 616.429.3852.

1995 International Agricultural Mechanization Conference

April 10-13, 1995
Beijing, China

For further information contact: Ms. He Zhongling, Chinese Academy of Agricultural Mechanization Science No. 1, Beishatan, Deshengmn Wai, Beijing 100083, China Tel: 86-1-2017131, Fax: 86-1-2017326

7th International symposium on Agricultural and Food processing Wastes

June 18-20, 1995
Chicago, Illinois, USA.

For further information contact: Dr. James Converse, Agricultural Engineering Department, 460 Henay Hall, Madison, WI 43705 USA.

Sustainable Development Intriguing Topic Focus

Engineering for Sustainable Development will be the focus of the ASAE International Summer Meeting, June 19-22, 1994, in Kansas City, Missouri, at the Crown Center Complex. Discussions will define the challenge of sustainable development and identify a set of action principles that engineering in these disciplines supports to meet this challenge.

According to ASAE President Norm Scott, "Sustainable development is perceived to be the dominant economic, environmental, and social issue of the 21st Century." The 1994 ASAE International Summer Meeting provides an opportunity for over 1,000 engineering professionals to address "The Role of the Engineer in Sustainable Development." An ASAE task force has suggested six principles which will serve as the focus of the discussion, and provide a conceptual guideline for discussion and implementation. These principles are:

- Engagement in shaping decisions
- Sustainable development education for ASAE members and the public
- Integrated systems thinking and synthesis
- New environmental/economic measures and analysis
- Sustainable technologies and processes
- Expanded partnership opportunities

Speakers for a special Forum on Monday, June 20, include Rodney Sobin, analyst, Office of Technology Assessment, who will address "Industry, Technology and the Environment." **Don Roberts**, vice president CH2M Hill and president of the World Engineering Partnership for Sustainable Environment, who will discuss "The Engineer's Role in Sustainable Development." And **Margot McDonald**, California Polytechnic State University, who will present information on "Creating Sustainable Communities." Following the Forum, all attendees will be involved in focus groups centering around "Engineering for Sustainable Development." ■■

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.

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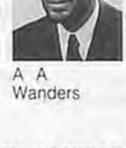
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