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AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.24, NO.3, SUMMER 1993

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

CONTRIBUTORS WANTED

This publication, published quarterly, has an objective to promote agricultural mechanization in developing countries. Its readers consist of so many people in various fields such as farmers, dealers, manufacturers, researchers, government officials, students, etc. not only in Asia but also in the whole world. To enrich contents and to reflect many opinions, we want contributors for Agricultural Mechanization in Asia" Africa and Latin America. Articles, comments, investigations, reports and so on will be received with open arms. If you hope to contribute, contact us without delay.

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7-2 Kanda Nishikicho, Chiyoda-ku, Tokyo, Japan (Tel. 03/291−5717−8, 3671−4)

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YOSHISUKE KISHIDA

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EDITORIAL

Global Network for Agricultural Mechanization

Indeed, why not a global network for agricultural mechanization? Especially, a network that works and gets results.

For some two decades now, AMA has been serving as an international medium for linking the expertise of agricultural engineers, among other professions, with agricultural development utilizing farm machineries. The central idea is to improve the levels of agricultural productivity and at the same time conserve the eco-system. In this way, food availability for everyone will be enhanced and that life for everyone, also, will be more enjoyable under a condition of balanced eco-system.

But in order to crystallize this idea, it is imperative that international cooperation among agricultural engineers, development communication workers and policy makers, among others, in each country be first established through some networking concept. To some extent, this cooperation among countries and societies is being realized even as it really needs a "shot in the arm". This means that a more active and more involved cooperation should be the rule rather than the exception.

That regional cooperation is now in action is evidenced by the fact that the United Nations has taken cognizance of the importance of this move when it established some 10 years ago the Philippines-based Regional Network for Agricultural Machinery (RNAM). And already, the RNAM has started to make some "noise" towards the promotion of agricultural mechanization. For another, a non-governmental entity, the Asian Association for Agricultural Engineering (AAAE), made a debut in 1990 when it was organized during an international conference at the Asian Institute of Technology (AIT) in Bangkok, Thailand. It is heartening to note that the latest count of AAAE membership has grown to 350 in less than three years.

Both the RNAM and AAAE and other Asian societies for agricultural mechanization promise to influence the progress of agricultural mechanization in the Asian region where agricultural productivity, except for a few countries, has not progressed as much as policy-makers and politicians forecast it.

AMA is equally anxious to see other regional organizations develop and grow in many other countries and regions of the world link up with their Asian counterparts in a more meaningful and total effort at promoting agricultural mechanization. As in the years gone by, AMA is eager to promote the linkage among these organizations/societies in the name of accelerating agricultural productivity both on regional and global basis.

AMA, therefore, invites comments from cooperating editors and AMA readers concerning this issue of the need for a global network for agricultural mechanization.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
July, 1993

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Evaluation of Tillage Practices for Soil Moisture Conservation and Maize Production in Dryland Ethiopia

by
Getachew Alem
Research Officer
Institute of Agric. Research
P.O. Box 30361, Addis Abeba
Ethiopia

Abstract

For three consecutive years of significantly varying precipitation, the effectiveness of three tillage practices (seedbed preparation methods); open ridge, tied ridge and flat (traditional), for water conservation and maize production were investigated at the Institute of Agricultural Research Farm at Nazareth, a typical semi-arid dryland environment in Ethiopia. Pre-irrigation has been superimposed on each seedbed to ensure successful crop establishment, and in the meantime to assess its subsequent effects.

Results have indicated that open and tied ridges (improved seedbeds) were found consistently superior over the traditional seedbed in terms of available soil water storage and grain yield. However, the relative effectiveness of these seedbeds depends on the amount and distribution of the seasonal precipitation. Pre-irrigation has shown slight increase in plant height and grain yield but were not statistically significant. Key words: seedbed, moisture conservation, tied ridges.

Introduction

In semi-arid dryland areas, growth, development and, consequently, yield of crops are more highly influenced by the available soil water than any other single factor. In most cases the available soil water is highly associated with the precipitation of the season. Crop stresses most often become severe when the available soil water is reduced considerably during seasons with short or prolonged dry spells. As a result, crop production varies significantly from season to season and yields are always unstable.

In most areas of the Upper Awash and Zewai area (rift valley), the production of maize (*Zea mays* L.), the second most important crop next to tef (*Erograstis tef*, Zucc. Trotter) varies between 8 and 15 qt/ha. Such yield variations depend on the climate of the season. Low and sometimes empty harvests are common experiences and are largely attributable to low and erratic precipitation.

Since 1960, investigations have been carried out elsewhere (3, 5) on seedbed preparation methods in an effort to stabilize crop yields in dryland areas where climatic fluctuation is very high. Experiences in many countries have shown that crop yields were substantially increased using improved seedbeds. In Nigeria, significant yield difference on maize were obtained among different seedbeds; ridges, heaps, beds, furrows and flat (4). Seedling emergence was also found significantly influenced by the different seedbeds due to variation in soil moisture reserves. Tied ridges have increased and stabilized crop yield in the Sahil where rainfall is low and highly variable (7). Peat and Brown (6) showed that tied ridges gave higher yields of cotton relative to other methods in the drier year at Ukiriguru, Tanganyika.

In the dryland and drought prone areas of northern Ethiopia, Mekele and Kobo, where rainfall is low and highly variable, the effect of tied ridges on the grain yield of wheat, sorghum, cow pea and mungbean were also investigated (1, 2, 8). Results have shown that crop yields could be substantially increased using ridges. At fairly good season, yield of wheat (at Mekele) sorghum, cowpea and mungbean (at Kobo) were raised by 318, 78, 58 and 62%, respectively.

Evidences from studies elsewhere and in Ethiopia (although preliminary) suggest that at times of drought, improved seedbeds reduced the risk of crop failure quite appreciably and minimized the incidence of famine. However, in Ethiopia, these techniques have not been thoroughly investigated. Most of the preliminary work was limited to few areas and focused primarily on the relationship between seedbeds and subsequent grain yield alone. So far there are no studies available on the soil moisture conservation performance of seedbeds under varying precipitation.

This paper presents a study on the effects of different seedbeds on water conservation, crop stand stablishments, and grain yield of maize under extremly varying seasonal precipitation.

Materials and Methods

Experimental Site

The experiment was carried out at the Melkassa Research Farm, 17 km South of Nazareth, Ethiopia, on a loam, clay-loam soil of alluvial origin. It is located at an altitude of 1 550 m with a highly variable rainfall that ranges between 500 and 800 mm annually. The rainfall is bimodal in character with a short seasonal rainfall in March-April and a main season rainfall starting from June up to September with a short dry spell approximately one month in between. On the average, the main season constitutes approximately 75% of the total annual rainfall. The seasonal (June to October) climatic data for 1985, 1986, and 1987 is given in **Fig. 1**.

The soils are medium to light texture with a very low organic matter (1.40-2.32%) and high slit content. This soil type extends to most parts of the rift valley between Upper Awash and Zewai area. Based on $-1/3$ and -15 bar metric potentials (36% and 16% soil moisture on dry wt. basis, respectively), the soil has a total water storage capacity of approximately 90 and 43 mm, respectively, for the 20 cm of the soil profile. Due to low organic matter and high silt content of the soil, soil cupping or crusting developed by rain drop impacts are of common occurrences in the research farm and in dryland areas in the rift valley. These conditions reduce infiltration rate and enhances surface runoff.

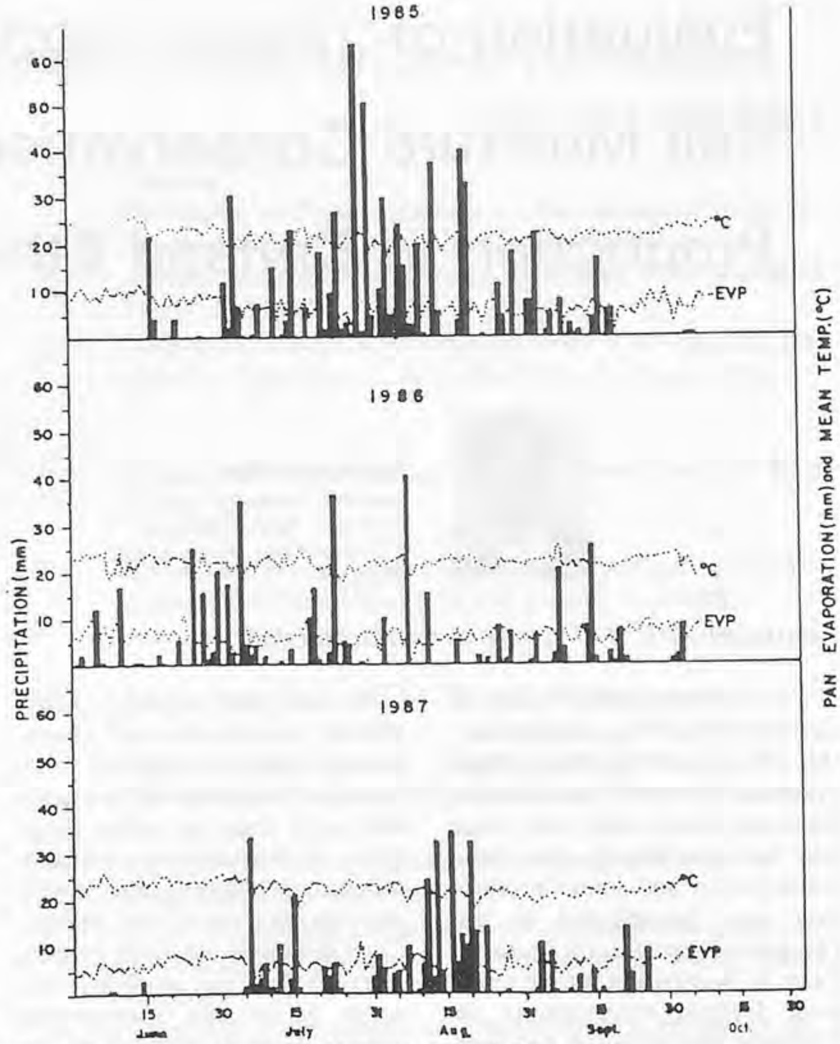

Fig. 1 Seasonal precipitation at Melkassa Research Farm.

Experimental Design and Treatment

Three types of seedbed preparation methods, tied ridges, open ridges (constructed approximately along a contour) and flat or traditional seedbed (a method commonly used by the farmers) were compared. The height of the ridges initially was 20-30 cm. The experimental plots for 1985 and 1986 were laid out on nearly the same site on 1-2% slope. Experimental plots in 1987 were laid out on relatively flatter area a block away from the previous sites. Pre-irrigation was super-imposed on the different seedbeds to see its effects on germination, emergence and stand establishment of the crop. For plots having tied ridges, pre-irrigation was made before it was tied. *Katumane*, an adapted and early maturing maize variety, was used in this experiment.

The soil was disk-plowed to a depth of 20 cm followed by one harrowing. Seedbed preparation was done mechanically and manually except the flat method that was planted after it was harrowed once following disk plow. Ridges were formed by a ridger and tied manually at one meter interval. Maize seeds were planted on June 27, 17 and 23 in 1985, 1986 and 1987, respectively, following the first rain shower. It was planted on 75 cm spaced rows and 25 cm plant spacing in rows to obtain a plant population of 48 100/ha. A plot size of 30 square meters (3 × $10m^2$) was used in a completely randomized design. It was replicated three times. A fertilizer rate of 18/20 kg/ha of N/P_2O_5 was applied at thinning. Hand weeding was carried out as desired. Soil moisture measurements were taken (replicated samples in 1986 and 1987) using gravimetric method at 10 cm interval down to a soil depth of 60 cm approximately during major growth stages of the crop. Finally, grain yield at 12.5% moisture content was taken. In addition, observations were made on seedling emergence, plant height, and days to flowering, maturity and harvesting.

Results and Discussion

Precipitation

The main season (June to October) precipitation distribution at Nazareth Research Farm for 1985, 1986 and 1987 is shown in **Fig. 1**. The amounts were 649, 427 and 390 mm, constituting 83, 67 and 61% of the total annual rainfall for the respective period.

The 1985 main season rainfall was relatively higher compared to the 1986 and 1987 seasons and showed a fairly normal distribution. Analysis of the cumulative annual precipitation indicates that the 1985 data followed more or less the long term annual rainfall pattern except for a slight increase in August and September. Seasonal precipitation index for the short season (March-April) rainfall was slightly lower followed by a relatively higher main season rainfall when compared with the long term (1971-1982) average.

In 1986 the main season (June to October) rainfall was more erratic in quantity and distribution. It was characterized by many dry spells* ranging between 5 and 10 days, particularly during mid- and towards the end of the season. Moreover, 55% of the seasonal precipitation, though patchy, occured during July and August. The cummulative precipitation of the season was in short of the long term average. However, the short season precipitation was relatively higher. June rainfall (81 mm) was much higher than the quantity observed in 1985 and 1987; 30 and 3.3 mm, respectively.

In 1987, the short season precipitation was nearly equal to the long term average. However, the main season rainfall was highly erratic with many and prolonged dry spells, and the total was all time low (**Fig. 1**). The early part of the season was a drought period** with nearly no precipitation in June. Moreover, 85% of the seasonal precipitation occured in July and August leaving a highly unbalanced rainfall distribution. The distribution of the rain at the tail end of the season was more or less similar to the 1986 season but again slightly lower in amount.

Temperature and evaporation are in the range of 19°C and 24°C and 10 and 14 mm/day, respectively. However, both are largely influenced by the seasonal precipitation.

Soil Water Storage

For 1985, soil moisture determination in furrows of improved seedbeds by gravimetric method was not possible due to high precipitation and the resulting waterlogging (ponding), and, therefore, soil moisture data is not presented here for discussion.

Soil moisture content in each seedbed, measured at −0.3 and −15 bar matric potential determined periodically at soil depths of 10-20 and 30-40 cm, critical soil moisture zones, for 1986 and 1987 is presented in **Fig. 2** and **Table 1** below.

During all seasons with extremely varying rainfall, precipitation storage measured as soil moisture by volume in the different seedbeds was found statistically significant at 5% level. However, it is noted that the amount varied in response to the seasonal precipitation pattern, amount and distribution.

In 1986, the available soil water storage was in the range of 16.5% and 34%, and 16.5% and 29% by volume for 10-20 and 30-40 cm of the soil profile studied. The improved seedbeds, open and tied ridges, sustained soil moisture above wilting point up to 100 days after planting covering the two important growth stages; tasseling and partially grain filling. While the traditional seedbed fell below the wilting point at about 70 and 86 days after planting for the respective soil depths.

In 1987, soil moisture content at both soil depths was lower relative to 1986. It was particularly true in the earlier part of the season when precipitation was significantly lower. Otherwise, the

*Daily precipitation of less than 4 mm.

**Lower than the normal precipitation for more than one month or more during the main season.

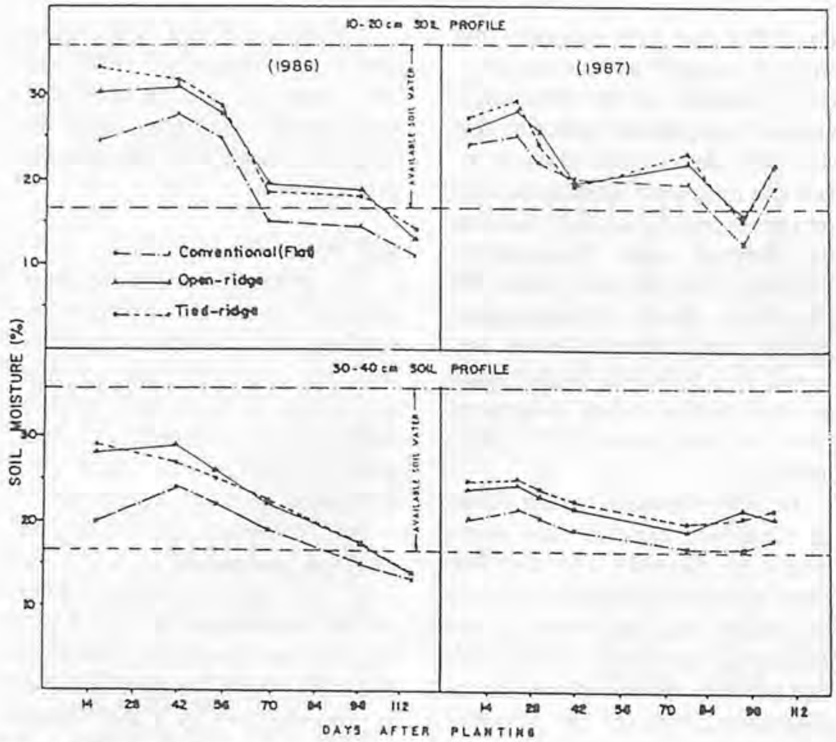

Fig. 2 Effect of seedbeds on soil moisture content.

Table 1 Effect of Different Seedbeds on the Available Soil Water Content (mm) in the Top 60 cm Soil Profile

Year	Treatment	Date of observation			
		July 29	August 26	Sept. 25	Oct. 10
1986	Traditional	63.2 (100)*	12.0 (100)	21.2 (100)	2.6 (100)
	Open ridge	105.4 (167)	38.0 (317)	26.5 (125)	5.0 (192)
	Tied ridge	103.2 (163)	46.3 (386)	32.0 (151)	3.5 (135)
1987	Traditional	44.0 (100)	67.0 (100)	5.9 (100)	—
	Open ridge	53.9 (122)	93.5 (140)	22.7 (387)	10.6
	Tied ridge	56.1 (128)	99.0 (148)	19.9 (340)	13.50

*Values in parenthesis show % increases in available soil water.

moisture content in the different seedbeds followed similar trend as that of the 1986. Even during seasons with poor precipitation improved seedbeds conserved more soil water relative to the traditional seedbed. Therefore, soil moisture observed at the 42 day after planting in the 10-20 cm soil depth (**Fig. 2**) was due to poor gravimetric sampling.

Due to the decline in the amount of precipitation, and naturally the increasing evaporation rate, the moisture content of the seedbeds, particularly shallow depths, declined as the season progressed (**Table 1**). As a result, the difference in soil water storage among the various seedbeds narrowed down considerably towards the end of the season. In general, open and tied ridges sustained sufficient soil moisture content at earlier and mid-crop growth stages (tasseling) and well above the lower limit of the available soil water during the later part of the season. In the traditional (flat) seedbed soil moisture remain consistently inferior throughout the season. In nearly all seasons studied, the level of moisture content declined well below the lower limit of the available soil water even at times of the critical crop growth stages; tasseling and grain filling.

Crop Establishment, Growth and Yield

Table 2 shows the relative influence of pre-irrigation and seedbed preparation methods on the average plant height taken at random right after tasseling.

In 1985 and 1986, pre-irrigated plots showed early seedling emergence, better crop vigour and good stand establishments. While in 1987, seedling emergence and stand establishments on flat seedbeds were very poor due to dry spell following pre-irrigation. Such effect was less pronounced in open and tied ridges. A good explanation for this could be the availability of sufficient soil water in improved seedbeds from pre-irrigation that sustains growth during the dry spell. During other seasons, pre-irrigation has shown slight increases in yield but was not statistically significant. The influence of seedbed preparation methods and pre-irrigation on the grain yield of maize is presented in **Table 3**.

The three-year data show that maize production is significantly (P0.05) affected by seedbed preparation methods. Grain yield ranges between 24 to 46, 24 to 42 and 17 to 40 q/ha in 1985, 1986 and 1987, respectively, with the highest yield obtained from tied ridges. Tied ridges consistently sustained a yield increase by nearly 100% compared with the traditional seedbed. However, the yield difference between open and tied ridges was not statistically significant.

Grain yield has not been stable across seasons and noticeable variations were observed over the three seasons studied and this is believed to have been attributed to variation in seasonal precipitation. This study clearly shows that the effectiveness of the seedbeds depended on the amount and distribution pattern of the seasonal precipitation. In 1985, crop yield was relatively lower compared to

Table 2 Effect of Seedbed on Plant Height (cm)

Seedbeds	1985	1986	1987	Mean
Traditional	143	117	106	122.0
Flat pre-irrigated	176	129	80	128.3
Open ridge	168	107	127	134.0
Open ridge pre-irrigated	179	133	149	153.7
Tied ridge	168	120	100	129.3
Tied ridge pre-irrigated	181	134	156	157.0
Mean	169	123	120	—

Table 3 Effect of Pre-irrigation and Seedbed Preparation Methods on Grain Yield of Maize (q/ha) at 12.5% Moisture Content

Treatment	Year			Total	Mean
	1985	1986	1987		
Flat (conventional)	24.07	23.70	17.26	65.03	21.68a
Flat re-irrigated	23.26	29.49	14.23	66.98	22.32a
Open ridges	40.50	35.07	33.60	109.17	36.39b
Open ridges pre-irrig	43.61	40.29	31.61	115.51	38.50b
Tied ridges	42.45	41.71	36.55	120.71	40.23b
Tied ridges pre-irrig	46.10	42.16	39.68	127.94	42.64b

*Within a column, values followed by the same letter are not significantly different (P0.05) using LSD test.

other seasons largely due to higher precipitation and, consequently, more available soil water for plant growth and development.

In the 1986 and 1987 seasons crop yield trends were similar except in 1987. Pre-irrigation on traditional seedbeds has depressed yield significantly. This effect is believed to have resulted from short dry spells following pre-irrigation which left non-uniform and poor crop stand establishments. During other seasons, pre-irrigation has shown slight increases in yield but was not statistically significant.

Conclusion

From this study, two important results are worth elucidating. The first result is that the improved seedbeds have been effective in conserving sufficient soil moisture to support crop growth even during drought situations. Consequently, maize yield in improved seedbeds has been superior over the traditional, thereby minimizing the risk of total crop failure during drought period as demonstrated in 1987. Secondly, the effect of pre-irrigation on yield is not statistically significant. In drought season, it may even depress yield due to dry spell following pre-irrigation. Generally, the effectiveness of the different seedbeds depends on the amount and distribution of seasonal precipitation.

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Tillage Practices under Irrigated Agriculture in the Semi-arid Region of Nigeria

by
P.R. Maurya
Prof.
Sokoto-ADP
c/o Agroman Ltd.
34 New Gavendish St., London
W1M 7LH, U.K.

Abstract

A number of traditional tillage practices and tillage research findings under irrigated agriculture in the region are discussed in the paper. The evolution of the different kinds of tillage system to suit the farmers' needs and soil-crop environment is also discussed.

Comparisons of deep, medium, shallow and no-tillage on the semi-arid irrigated soils have shown as much variability from study to study as in non-irrigated soils. Probably the major reason for this observed variability is intensity of crop cultivation, type of soil and the micro-climate of the project. The combination of shallow and no-tillage in a yearly cultivation and occasional deep soil tillage (after 3-r years of interval), if required to break the plough sole are the most appropriate for irrigated soils in the semi-arid tropics. Special efforts may be required for sandy and heavy clay soils, where incorporation of crop residue could be benefical.

Introduction

In the semi-arid region, is normally required, among other reasons, to increase the capacity of soil to store rain water by improving its infiltration and reducing runoff; to conserve the soil water by reducing evaporation; and to ensure that the stored water is used by improving rooting depth and controlling the weeds. A wide range of tillage practices (such as zero or no-till, minimum till, conventional and deep tillage), depending on the type of soil and crop grown, are used in this region. The conventional tillage consists of ploughing to a depth of 20-2 cm followed by harrowing to the depth of 8-10 cm, generally after first rain, by the use of mechanical or animal-drawn implements. The zero or no-tillage practice has not been found beneficial over conventional tillage under rainfed cropping in the semi-arid region of West Africa (Huxley, 1979; Dunhum, 1988; Maurya, 1986 and Willcocks, 1984).

Under irrigated agriculture, growing two or three successive crops on the same land in one year results in a more efficient utilization of irrigation water, climatic conditions, land, labour, machinery and other inputs. On the other hand, and under intensive cultivation, the frequent use of machines (tractor traffic) of up to 7 times in a year for land preparation has the tendency to compact the soil and form plough sole which reduces the beneficial effects of tillage on the irrigated soil in the semi-arid region. This warrants an urgent need for identifying the most appropriate tillage practices for the various groups of soils and crops grown under irrigated soil condition for sustainable irrigated farming.

Farmer Tillage Practices under Irrigated Soil Conditions

Most of the West African large-scale irrigation projects are with the small landholder farmers situated in the semi-arid region. Nigeria alone has developed around 100,000 ha under modern large scale irrigation project and at least 500,000-600,000 ha traditional seasonally irrigated Fadama land. This accounts for approximately 20% of the total land under irrigation in the West Africa (Maurya and Kuzniar, 1988). The area covered by the three major large-scale irrigation projects in Nigeria (Kano River, Bakolori and South Chad) extend from approximately longitudes 4°W to 14°E and latitudes 10°30' N (**Fig. 1**). The average annual rainfall varies from 450-750 mm. Most of the rain falls between mid-June and mid-September. Surface soil tex-

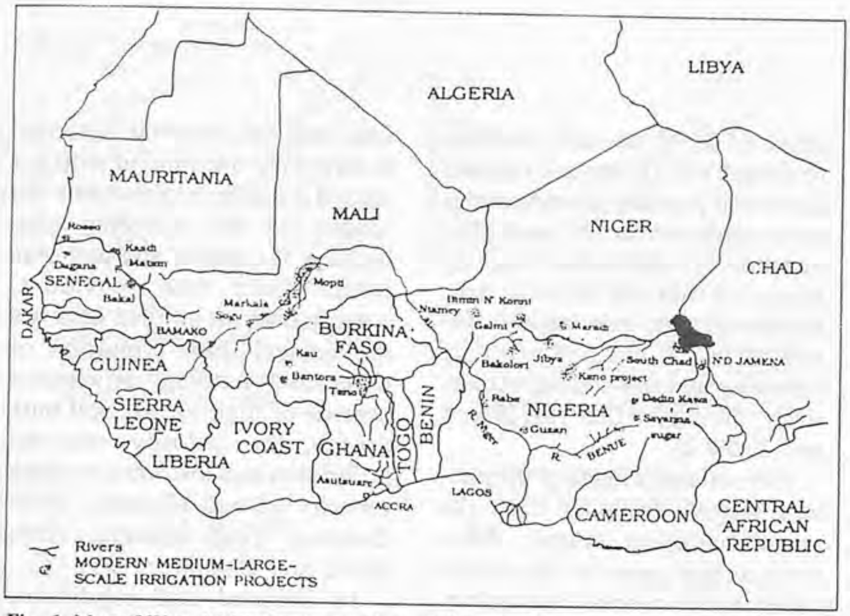

Fig. 1 Map of West Africa showing modern medium- and large-scale irrigation projects.

Table 1 Common Tillage Practices for Land Preparation under Irrigated Soil Conditions in the Semi-arid Region of Nigeria

Cropping season*	Tillage practices	Tractor traffic	Cost/ (N/ha)
a. Irrigated cropping (Wheat, Vegetable, Maize, Rice)	Choice I:** —Disc ploughing once to 20 cm depth —Disc harrowing twice to 10 cm depth —Disc bunding & field layout	4	420
	Choice II: —Disc harrowing twice to 10 cm depth —Disc bunding & field layout	3	280
	Choice III: —Disc harrowing once to 10 cm depth —Manual bunding	1	110
	Choice IV: —No-till —Manual field lay out	0	0
b. Supplemental irrigated crop (Vegetable, Maize)	Choice I: —Disc harrowing once to 10 cm depth —Manual field lay out	1	110
	Choice II: —No-till —Manual field lay out	0	0
c. Rainfed cropping (Rice, Maize, Cowpea, Vegetable, Sorghum, Millet)	Choice I: —Disc harrowing twice to 10 cm depth —Manual field lay out	3	280
	Choice II: —Disc harrowing once to 10 cm depth —Manual field lay out	1	110
	Choice III: —No-till —Manual field lay out	0	0

*Disc ploughing, harrowing and bunding cost 140, 110 and 60 Naira/ha (1 US$ = 8 Naira)
*Irrigated cropping period: Irrigated crops - November to March; Supplemental crops - March to June; and Rainfed crops - June to October.
**Not common on heavy clay soil (Vertisols)
Note: Survey was conducted by P.R. Maurya, 1989-90.

ture in these irrigation projects varied widely; i.e., from sandy to heavy clay soil texture.

Soils that are found in the low lying area of river valleys, lakes and other depressions are called Fadama soils. These soils are generally variable in texture and moist all the year round. Irrigated Fadama soils are normally cultivated using hand hoe or small animal-drawn implements. Minimum and zero tillage practices are common on these soils.

A survey conducted by the author on the Kano River (16,600 ha) and Bakolori (23,300 ha) Irrigation Projects reveals that tractor traffic (passes) for land preparation alone is up to seven times in a year on the same piece of land, depending on the intensity of cropping (**Table 1**). Cultivation on heavy clay soil (Vertisols) presents a special problem. The plough is generally not used as it produces a cloddy seed-bed. Though rotavator produces fine granular soil structure required for a good seed bed, it requires heavy tractors which may induce plough sole. Due to non-availability of heavy machines, farmers are now using disc harrowing from one to two times before planting of crop.

The cost of mechanical land preparation varies with the crop and availability of heavy machines, farmers are now using disc harrowing from one to two times before planting of crop.

The cost of mechanical land preparation varies with the crop and availability of machines on hire. A survey was conducted during 1989-90 by the author to evaluate the cost of mechanical land preparation in large scale irrigation project situated in the semi-arid region of Nigeria. The mean cost of mechanical land preparations were 470, 322, 466, 325 and 270 Naira per ha (1 US$ = 8 Naira) for irrigated wheat, maize, tomatoes, onion and garlic, respectively. This accounts for about 15% of total cost of production of cereal crops and about 7% of total cost of production of vegetable crops.

Effect of Tillage Practices on the Irrigated Soil Properties

Irrgated soils are normally subjected to intensive cultivation to derive the maximum benefits from the land. Due to the intensive cultivation, tillage pans could very easily develop on these soils. The Kano River Irrigation Project is one such project where tillage pans have developed in the Eutric Cambisols (Ahmed and Maurya, 1988). The effects of tractor traffic on soil compaction have been studied by several scientists (Doneen and Henderson, 1953; Oni et al, 1982; Adebaya, 1984). The top soil is usually loosened during conventional tillage but at some depth just below the plough layer, a compacted layer commonly called plough sole develops and is characterized by abnormally high bulk density. This layer restricts the water movement and gaseous exchange. Under such condition, deep tillage (sub-soiling, chiselling) has been reported beneficial for crop production, by improving soil physical and chemical properties (Seve et al, 1985; and Ahmed and Maurya, 1988). The changes in soil properties brought about by deep tillage are often transitory (Duley, 1967; Porro and Cassel, 1986; and Ahmed and Maurya, 1988). In the shallow soils deep tillage may result in mixing the surface fertile soil with the less fertile soil from below, producing little change in soil infiltration rate (Smith, 1951).

The plough sole on an irrigated Eutric Cambisol was shattered by deep tillage: sub-soiling to a depth of 35-40 cm and chiselling to a depth of 2530 cm and changes in the soil physical characteristics were monitored for few years. The increase in infiltration rate by about 3-8 fold and the bulk density in plough sole region was reduced to 1.61 and 1.58 g/cm^3 by chiselling and sub-soiling, respectively, during the first year (**Fig. 2** and **Table 2**).

The residual effects of deep tillage started declining from the second cropping season. After three to four years of crop cultivation under normal conventional tillage, the beneficial effects of deep tillage diminished (Ahmed and Maurya, 1988, 1989). However, frequent deep tillage had adverse effect on crop production due to high infiltration and enhanced water and nutrients losses from root zone and mixing the top and sub-soil while diluting the effect of soil fertility.

No-tillage technique commonly practiced along with residue management considerably improves the soil properties and are useful for crop production in humid tropics, where conventional tillage systems cause accelerated soil erosion (Lal, 1976, Lal et al., 1978; Maurya and Lal 1979, Agboola, 1981). In semi-arid tropical condition, where it is normal to have only one rainfed crop per year, it is difficult to maintain the residue of the preceding crop because of termites and domestic cattle. Under such conditions, crops grown on untilled land are stunted and show symptoms of water and nutrient deficiencies because of high surface soil bulk density, low porosity, retarded infiltration and low water holding capacity of soil (Huxley, 1979; Dunham, 1988; Maurya, 1986; Nicou and Chopart, 1979).

In irrigated soil conditions, soils are generally moist, have higher air humidity and are cropped year round. The continuous use of residue of the preceding crop as mulch on undisturbed soil maintained soil moisture and useful microflora activity. Under maize-wheat annual rotation on an irrigated sandy loam soil, no-tillage increased the soil porosity on surface soil horizon (**Fig. 3**). **Fig. 4** shows that the no-tillage plots had a 50% higher basic infiltration rate (6.6 cm/h) than conventionally tilled (4.4 cm/h) plots (Maurya, 1986).

Water release characteristics and organic matter of soil are considerably improved, while practicing no-tillage with residue (**Figs. 5**

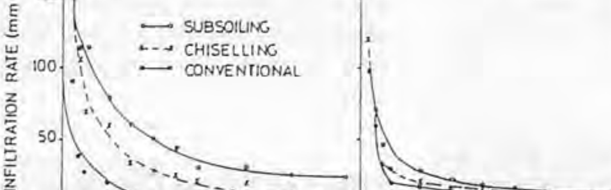

Fig. 2 Effect of deep tillage on infiltration rate of irrigated sandy loam soil (Ahmed and Maurya, 1988).

Table 2 Effect of Deep Tillage on the Bulk Density of Irrigated Sandy Loam (Eutric Cambisols) in Semi-arid Region of Nigeria

Treatment	Soil Depth (cm)			
	0-10	10-20	20-30	30-45
	Soil bulk	density	(g/cm^3)	1984-85 seasons
Subsoiling	1.47	1.58	1.56	1.54
Chiselling	1.45	1.61	1.63	1.63
Conventional tillage	1.50	1.71	1.65	1.57
L.S.D. (5%)				
Tillage			0.045	
Depth			0.044	
Till vs Depth			0.077	
	Soil bulk	density	(g/cm^3)	1985-86 season
Subsoiling	1.49	1.61	1.58	1.58
Chiselling	1.48	1.64	1.63	1.62
Conventional tillage	1.52	1.70	1.63	1.59
L.S.D. (5%)				
Tillage			NS	
Depth			0.035	
Till vs Depth			NS	

NS: Non significant

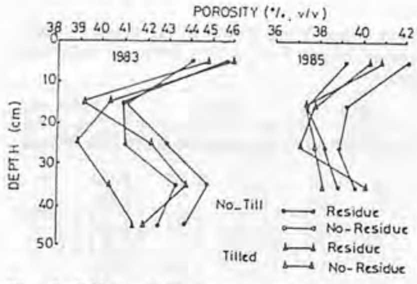

Fig. 3 Effect of tillage practices and crop residue management on total porosity of irrigated Eutric Cambisol in the semi-aid region of Nigeria (Maurya, 1986).

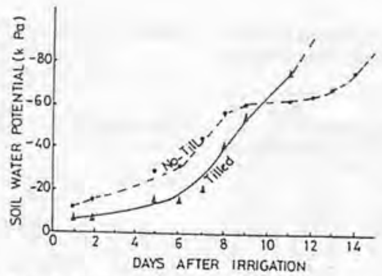

Fig. 5 Soil water potential at 10 cm depth in a 16-day irrigation cycle during the wheat cultivation (14-29 Feb., 1984) on a sandy loam soil as affected by tillage system (Maurya, 1985).

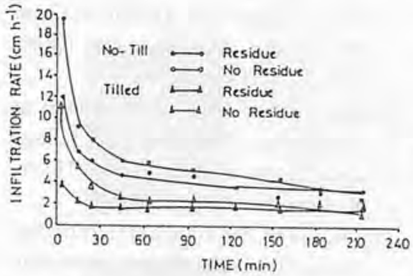

Fig. 4 Effect of no-tillage practices and crop residue management on infiltration rate of irrigated Eutric Cambisol (Maurya, 1986).

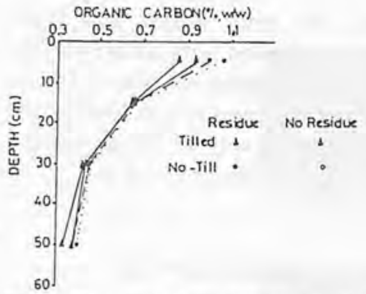

Fig. 6 Organic carbon content as affected by 3 years' practice of no-tillage and residue management techniques on irrigated Eutric Cambisol in Nigeria (Maurya, 1985).

and 6). Similar observations have been reported for humid regions under irrigated soil conditions (Lal et al., 1978). No-tillage had adverse effect on the irrigated sandy soil in the dryer area of semi-arid region and soil physical and chemical properties deteriorated over period of 3-4 years (Maurya, 1990). The minimum or no-tillage practice is the common tillage practice on the Fadama soil, which is normaly moist all round the year and situated in high air humidity areas. Minimum tillage maintains the soil properties as well as the productivity of the Fadama land.

Tillage and Crop Production on Irrigated Soil

Long term conventional tillage under intensive cropping and formation of plough sole make the plant growth and yield performance stabilized at the lowest level. Occasional deep tillage practice (sub-soiling or chiselling to a depth of 30-40 cm) accelerates the crop production for 1-2 years under irrigated soil condition in semi-arid region (Ahmed and Maurya, 1988, 1989 and Miller, 1987). An experiment conducted to compare the various tillage practices on an Eutric Cambisols in northern Nigeria reveals that subsoiling and chiselling increased the grain yield of wheat during the first year of deep tillage and the subsequent residual effect was not significant (**Table 3**).

The no-tillage practice is partially common in irrigated crop cultivation in Fadama and vegetable cultivation in the upland projects. Several long term experiments were conducted on irrigated sandy loam (slightly humid micro-climate) and sandy soil (dry micro-climate) in the semi-arid region to compare the yield performance under no-tillage and conventional tillage systems.

Maize-wheat annual crop rotation on irrigated sandy loam soil, the practice of no-tillage farming with the retention of adequate crop residue (5-6 ton/ha) on the surface, maintained the total annual crop production, In comparison, on irrigted sandy soil having low fertility level, the annual crop production was always lower in the no-tillage than conventional tillage (**Tables 4** and **5**). Mulching (a practice of leaving crop residue on the surface) of irrigated soil did not significantly influence the yield and soil properties when compared with the tradi-

Table 3 Grain Yield of Wheat as Affected by Deep Tillage on Irrigated Sandy Loam Soil in Semi-arid Region of Nigeria

Treatment		Grain yield (t/ha)		
Tillage	Irrigation frequency	1985	1986	1987
Subsoiling	7-day	5.31	3.66	3.50
	14-day	4.68	2.58	3.07
	21-day	4.32	2.10	2.63
	Mean	4.8	2.8	3.0
Chiselling	7-day	5.00	3.52	3.51
	14-day	4.76	3.08	2.29
	21-day	3.97	1.93	2.06
	Mean	4.6	2.8	2.6
Conventional	7-day	4.38	2.96	3.08
	14-day	4.00	2.62	2.73
	21-day	3.81	1.97	2.23
	Mean	4.0	2.5	2.6
L.S.D. (5%)				
	Tillage	0.5	NS	NS
	Irrigation	0.4	0.4	0.4
	Till vs Irri.	NS	NS	NS

NS: Non significant.
Note: From a report of Ahmed and Maurya, 1988.

Table 4 Maize and Wheat Grain Yield (t/ha) as Affected by No-tillage on Irrigated Sandy Loam Soil in Sami-arid Region of Nigeria

Treatment		1982		1983		1984	
		Maize	Wheat	Maize	Wheat	Maize	Wheat
No-till.	Residue	3.3	3.8	4.0	3.3	2.3	4.4
	No-residue	3.4	3.7	2.8	3.6	1.9	4.2
	Mean	3.4	3.8	2.9	3.5	2.1	4.3
Conven. till.	Redidue	4.1	3.0	3.9	3.9	2.2	4.4
	No-residue	4.0	3.1	3.9	3.6	2.2	3.6
	Mean	4.1	3.1	3.9	3.8	2.2	4.0
L.S.D. (5%)	Tillage	0.28	0.18	NS	NS	NS	NS
	Residue	NS	NS	NS	NS	NS	0.20

Note: From Maurya, 1988.

Table 5 Maize and Wheat Grain Yield (t/ha) as Affected by Zero Tillage on Irrigated Sandy Soil in Dry Zone of Semi-arid Region of Nigeria

Treatment		1983		1984		1985	
		Maize	Wheat	Maize	Wheat	Maize	Wheat
Zero-till.	Residue	1.26	1.27	1.14	1.88	1.00	—
	No-residue	1.56	1.29	1.21	1.87	1.08	—
	Mean	1.41	1.28	1.18	1.88	1.04	—
Conven. Till.	Residue	1.90	1.87	2.13	1.94	2.29	—
	No-residue	1:50	1.54	1.81	1.94	1.95	—
	Mean	1.70	1.70	1.92	1.94	2.12	—
L.S.D.(5%)	Tillage	0.41	2.42	0.38	NS	NS	—
	Residue	NS	NS	NS	NS	NS	—

Note: Maurya, 1990.

tionally unmulched conditions. This has also been shown to be the case of tillage practice under rainfed conditions for semi-arid sandy soils (Nicou and Chopart, 1978).

Summary

Irrigated cropping systems have shorter period for the land preparation/tillage operation. Normally, farms will try to avoid tillage operation for the rainfed or/and supplemental irrigated crops. However, irrigated crops are being treated as the main crops of the project. Therefore, farmers prefer to prepare a good seedbed to have maximum benefit from irrigation. Comparisons of deep, medium, shallow and no-tillage on the semi-arid irrigated soils have shown as much variability from study to study as in non-irrigated soils. Probably the major reason for this observed variability is intensity of crop cultivation, type of soil and the micro-climate of the project. The combination of shallow and no-tillage in a yearly cultivation and occasional deep soil tillage (after 3-4 years of interval), if required to break the plough sole are the most appropriate for irrigated soils in the semi-arid tropics. Special efforts may be required for sandy and heavy clay soils, where incorporation of crop residue could be beneficial.

At the present time, limited information is available on the suitability of different tillage systems for each major soil type under irrigated agriculture in the semi-arid region of West Africa. Efforts are required to look in to the farmers' way of tillage operation and to improve on it.

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(Continued on page 22)

Evaluation of Bullock Farming and Power Tiller Farming Systems for Groundnut Crop in the State of Orissa, India

by
R.C. Dash
Lecturer
College of Agric. Eng. and Tech.
Orissa Univ. of Agric. and Tech.
Bhubaneswar 751003, Orissa, India

S.C. Pradhan
Assoc. Prof.
AICRP on Power Tiller
College of Agric. Eng. and Tech.
Orissa Univ. of Agric. and Tech.
Bhubaneswar 751003, Orissa, India

Debaraj Behera
Lecturer
College of Agric. Eng. and Tech.
Orissa Univ. of Agric. and Tech.
Bhubaneswar 751003, Orissa, India

M. Mahapatra
Technical Assistant
AICRP on Power Tiller
College of Agric. Eng. and Tech.
Orissa Univ. of Agric. and Tech.
Bhubaneswar 751003, Orissa, India

Abstract

A trial on the groundnut variety AK-12-24 was conducted in the Central Farm, Orissa University of Agriculture and Technology to evaluate power tiller farming systems and bullock farming systems using improved and indigenous implements. It was observed that power tiller farming systems were superior to bullock farming system considering yield and cost of operation. The farmers in the State of Orissa depend mainly on draft animals for performing various farming operations. These draft animals are hardly engaged more than 1000 h per annum and their feeding and maintenance cost strains the economic conditions of the farmers. Under this condition, an intermediate power source, like power tiller, will help farmers to replace draft animals in the production of this cash crop for the successful implementation of the oilseed production programme of the State of Orissa.

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Introduction

In Orissa 76% of farmers are in the small and marginal categories. They posses only 40% of the cultivable land. It is estimated that the number of operational holdings is 3 328 000 with a cropping intensity of 139% as per the 1984-85 Land Use Statistics. The average size of holding is 1.6 ha only. Due to small and scattered land the farmers depend mainly upon the draft animals inspite of their higher maintenance cost. The initial investment on tractor is very high which is beyond the reach of a common farmer. The farm power available to the farmers of the State is only 0.39 hp/ha which is much less than the all-India average of 0.54 hp/ha. In 2000 AD, India's food grain production is to be increased to 225 million tonnes and the power available in agricultural sector is to be raised to 0.87 hp/ha as envisaged by the National Commission of Agriculture, Government of India. Considering the above aspects, power tillers have been popularized in the state since 1987 and the sale is steadily increasing since then. In Orissa, groundnut is grown in 387 000 hectares out of total cropped area of 8 825 000 ha, i.e., 4.38% of the total cropped area under groundnut cultivation (1987-88). Orissa finds a prominent place in producing groundnut in the all-India basis as 490 000 tonnes produced per year with a production rate of 1.26 t/ha. The net benefit derived from this crop is marginal when followed by the indigenous method. Hence, a comparison has been made between power tiller farming and bullock farming systems with an eye to helping farmers grow this cash crop economically.

Materials and Methods

In Rabi 1989, groundnut variety of AK-12-24 was grown in an area of 0.16 ha in the Central Farm, O.U.A.T., Bhubaneswar to compare power tiller farming and bullock farming systems. The field layout of the experimental plots for the groundnut crop is shown in **Fig. 1**. The experiment was designed on the principle of RBD having five treatments and four replications. The treatments selected are as follows:

T_1 = Rotatilling once by Mitsubishi (12 hp) power tiller.

T_2 = Rotatilling twice by Mitsubishi (12 hp) power tiller.

T_3 = Twice ploughing by M.B. plough using bullock power.

T_4 = Once ploughing by M.B. plough followed by discing using bullock power.

T_5 = Twice ploughing by indigenous plough using bullock power.

For the evaluation, a Mitsubishi (12 hp) power tiller model VWH 120 with rotavator and matching equipment were selected for the power tiller farming system while a medium pair of bullocks of 0.8 to 1.1 hp (0.6 to 0.8 kW) were used for the power source for bullock farming system. The previous crop grown in the field was paddy and the residual average height of the stubble was recorded 10 cm. The experimental field with paddy stubbles was ploughed once by M.B. plough before the trial. The field operations carried out for different treatments are presented in **Table 1**. The manually operated groundnut decorticator and bullock-drawn groundnut digger and manually-operated hand compression sprayer were incorporated under tiller farming system T_1 and T_2 since power tiller operated of such machines were under development stage. The commonly used improved implements were selected under bullock farming systems T_3 and T_4 while local practice followed with indigenous implements were taken in T_5. The row-to-row spacing and plant-to-plant spacing were main-

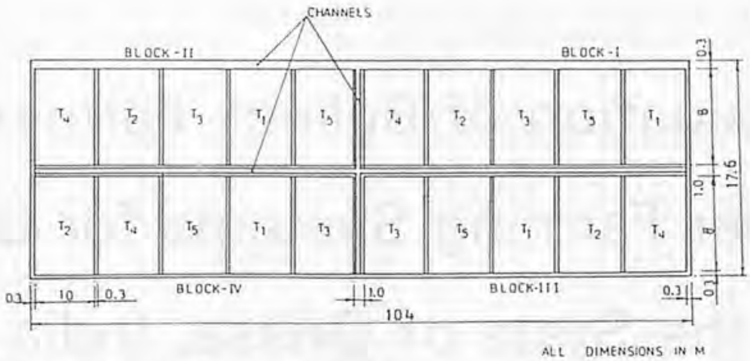

Fig. 1 Field layout for groundnut crop.

Table 1 Operations Carried Out in Different Treatments

Operation	T_1	T_2	T_3	T_4	T_5
Land operation	Rotatilling once	Rotatilling twice	Twice ploughing by M.B. plough	Once ploughing by M.B. plough followed by discing	Twice ploughing by indigenous plough
Seed decorticating	Groundnut decorticator	Groundnut decorticator	Groundnut decorticator	Groundnut decorticator	Manually
Planting	Power tiller operated Jyoti planter	Power tiller operated Jyoti planter	Implement factory 3-row manually operated groundnut planter	Implement factory 3-row manually operated groundnut planter	Behind the plough
Weeding	Power tiller operated weeder	Power tiller operated weeder	Wheel hoe	Wheel hoe	Manual weeding by Khurpi
Harvesting	Bullock drawn groundnut digger	Bullock drawn groundnut digger	Bullock drawn groundnut digger	Bullock drawn groundnut digger	Manually
Stripping	Power tiller operated stripper	Power tiller operated stripper	Manually	Manually	Manually
Transportation	Power tiller trailer	Power tiller trailer	Manually	Manually	Manually

Fig. 2 Seed bed preparation by using power tiller with rotavator.

Fig. 3 Groundnut planting by using implement factory 3 row groundnut planter.

Fig. 4 Power tiller-operated groundnut stripper.

tained for 30 and 10 cm, respectively, for all the treatments except for the bullock farming system that used indigenous implements. Some of implements used in these operations are shown in **Figs. 2** and 4. The level of fertilizer, pesticide and irrigation applications were maintained constant in all the treatments.

The various parameters recorded during the experiment are moisture content, mean soil clod diameter, width and depth of cut, speed of operation, fuel consumption, man and bullock hour, field capacity, dry mass of weeds and crop yield.

Results and Discussion

The performance evaluation of parameters for different treatments are shown in **Table 2**. The effective field capacity for seed bed preparation through power tiller with rotavator was to be nearly four times more than a pair of bullocks saving considerable amount of time. In the case of single rotatilling the mean soil clod diameter was 0.36 cm which is minimum as compared to other treatments under the bullock farming systems. A greater depth of cut was also achieved under power tiller farming systems. it was also observed that the dry mass of weeds under twice rotatilling was minimum, i.e., 62 g/m^2 while a pair of bullocks using indigenous plough was maximum 98 g/m^2. The reason for getting less weeds under power tiller farming systems is the rotary action which not only cuts the weeds into pieces but also mixes them thoroughly with the soil.

The cost of operation per hour for a pair of bullocks and power tillers with implements are shown in **Table 3**. The operating cost for a pair of bullocks has been calculated assuming the initial cost of

Table 2 Performance Evaluation of Parameters for Different Treatments

Particulars	T_1	T_2	T_3	T_4	T_5
Moisture content of soil, % (d.b)	18.50	18.50	18.90	18.50	18.60
Mean soil clod diameter, cm	0.36	0.32	0.48	0.52	0.65
Width of operation, cm	57.20	57.20	16.28	16.28* 36.15**	18.30
Depth of operation, cm	13.50	14.45	12.20	12.20	9.55
Speed of operation, kmph	2.30	2.32	2.20	2.20* 2.32**	2.40
Theoretical field capacity, ha/h	0.13	0.13	0.04	0.04* 0.08**	0.04
Effective field capacity, ha/h	0.10	0.11	0.03	0.03* 0.07**	0.03
Field efficiency, %	77.00	87.12	72.20	72.20* 81.90**	67.40
Drymass of weed, g/m^2	66	62	90	81	98

* M.B. Plough ** Disc harrow.

Table 3 Cost of Operation for a Pair of Bullocks and Power Tillers with Implements

Name of implement	Cost of operation (Rs./h)
A pair of bullock with indigenous plough	9.47
A pair of bullock with M.B. plough	9.49
A pair of bullock with disc harrow	9.78
Mitsubishi power tiller with rotavator	24.76
Mitsubishi power tiller with Jyoti planter	21.31
Mitsubishi power tiller with 10 cm width cage wheel and weeder	20.61
Power tiller operated groundnut stripper	21.52
National power tiller with trailer	23.72

Table 4 Effect of Different Treatments on Yield of Groundnut (t/ha)

Treatments	Replications				
	R_1	R_2	R_3	R_4	Mean
T_1	0.94	0.84	0.92	0.86	0.89
T_2	0.88	0.85	0.72	1.02	0.87
T_3	0.74	0.68	0.63	0.66	0.67
T_4	0.68	0.56	0.71	0.66	0.65
T_5	0.64	0.58	0.57	0.68	0.62

S.EM ± 0.54 C.D at 5% 1.15.

Table 5 Cost of Operation (Rs./ha) and Benefit-cost Ratio for Different Treatments

Name of operation	T_1	T_2	T_3	T_4	T_5
Land preparation and levelling	247.60	485.67	730.00	508.80	653.00
Planting	1 375.00	1 375.00	1 250.00	1 250.00	1 225.00
Seed treatment	50.00	50.00	50.00	50.00	50.00
Fertilizer application	489.42	489.42	489.42	489.42	489.42
Weeding	300.00	280.00	320.00	320.00	395.00
Pesticide application	256.73	256.73	256.73	256.73	256.73
Harvesting	250.00	255.00	252.00	260.00	290.00
Stripping	285.10	253.75	208.00	200.30	190.75
Transportation	44.14	44.14	33.70	28.70	46.48
Total cost	3 297.99	3 489.71	3 589.25	3 363.95	3 596.38
Benefit	5 785.00	5 687.00	4 394.00	4 231.05	4 030.00
Benefit-cost ratio	1.75	1.63	1.22	1.26	1.12

Rs. 4 500, resale value of Rs. 200, working life of nine years and annual use of 1000 h. From annual fixed cost, feeding and maintenance cost the operating cost per hour for a pair of bullocks was found to be Rs. 9.30. The initial cost of the Mitsubishi and National power tiller have been taken to be Rs. 31 440 and Rs. 26 350, resepctively. For calculating the cost of service life of 10 years and annual use of 800 h have also been assumed for these power tillers. The cost of operation has been calculated from the annual fixed cost and variable cost for these power tillers and equipment.

The groundnut crop yield data is shown in **Table 4**. The yield was significantly higher under power tiller farming systems (T_1) and (T_2) as compared with bullock farming systems (T_3), (T_4) and (T_5). The higher yield was attained due to better availability of plant nutrients by thorough mixing of the soil, more levelled and pulverized seed bed, less weed density and optimum plant population. There was no significant difference in yield between the treatments of power tiller farming and bullock farming.

The cost of various operations and benefit-cost ratio for the different treatments are shown in **Table 5**. The total cost incurred under power tiller farming systems (T_1) and (T_2) were much less than the bullock farming systems (T_3), (T_4) and (T_5). The minimum total cost in single rotatilling (T_1) was Rs. 3 297.99 while the maximum cost incurred Rs. 3 596.38 in bullock farming using the indigenous method (T_5). The highest benefit-cost ratio (1.75) was achieved in single rotatilling under the power tiller farming system.

Conclusion

The conclusions are based on the above results and discussions as follows:

1. Optimum seed bed preparation was achieved even in the case of single rotatilling only for groundnut crop under sandy loam type of soil.
2. Dry mass of weeds was 32.6 to 36.7% less in power tiller farming systems than the bullock farming system using indigenous implements.
3. The yield was significantly higher in power tiller farming systems compared to the bullock farming systems. The average crop yield using power tiller farming systems was 40.32 to 43.54% more than that of the bullock farming systems using indigenous implements.
4. The highest benefit-cost ratio of 1.75 was achieved in the case of single rotatilling under power tiller farming system.

Therefore, popularizing the power tillers with the matching equipment like groundnut planter, weeder, sprayer, digger and thresher should benefit the farmers in groundnut production.

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(Continued from page 18)

Tillage Practices under Irrigated Agriculture in the Semi-arid Region of Nigeria

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Appropriate Tillage Package for Wheat Production after Rice in Rice Tract

by
Abdul Razzaq
Sr. Subject Matter Specialist (Eng.)
Adaptive Research Farm
Sheikhupura, Pakistan

Abdul Karim
Asst. Res. Officer
Adaptive Research Farm
Sheikhupura, Pakistan

Bashir Ahmad Sabir
Director of Agriculture
(Adaptive Res.)
Lahore, Pakistan

Abstract

The sole use of cultivator five times, was undertaken. This meant an evaluation of the effect of prominent tillage packages comprising of different combinations of rotavator with cultivator and chisel plow and of disc harrow with cultivator, chisel plow and M.B. plow on wheat production in clay loam soil after rice harvesting in rice tract compared with the conventional practice. The use of disc harrow once followed by chisel plow twice and M.B. plow once followed by disc harrow once were found to be the most appropriate tillage packages. Each of these practices gave the highest tillering and yield with an increase of 14.24% and 19.91%, respectively, and contributed the maximum return viz., Rs. 9.66 per unit expenditure over the conventional practice. The second best tillage package was the use of disc harrow twice followed by cultivator twice as compared to rotavator once followed by chisel plow twice. Non-significant difference was observed in wheat crop tillering and yield between the conventional practice and the use of rotavator once followed by cultivator thrice except that the latter package facilitated mechanical seed drilling free of any obstruction.

Introduction

After wheat and cotton, rice is the 3rd major crop in Pakistan. Fine and medium textured soils, peculiar to rice tract, with poor drainage and water infiltration further impeded by destroying structure with puddling are the particular requirements for rice cultivation. The main crop rotation in rice tract is rice-wheat. Contrary to rice cultivation, land prepared for wheat should be well drained and provides no blockage to water infiltration. After rice harvesting, the fields are full of stubbles and cannot be prepared with the conventional implement to the satisfactory level of wheat sowing. The most common implement owned and used by the farmers with tractor for tillage is the shovel-type cultivator. This cultivator operates at shallow depth of about 15 cm and uproots rice stubbles without crushing or tearing them into pieces which obstruct the subsequent mechanical wheat drilling.

The Department of Agriculture recommends the crushing of stubbles with the use of rotavator before carrying out conventional tillage operation to prepare land for sowing of wheat after rice (Anonymous, 1986-87). In the papers based upon available literature, rotavation of rice stubbles before conducting other land preparation operations for sowing subsequent crops was also emphasized (Razzaq, 1983 and Razzaq et al, 1989). The rotavator, no doubt, completely crushes rice stubbles but it operates to about 7 cm depth and severely damages surface soil structure. Wheat crop needs root zone deeper than 15 cm. Obviously, the growth of wheat crop sown in the poorly prepared rice fields with the sole use of conventional cultivator and even combining it with rotavator remains depressed which considerably lowers its ultimate yield in the rice tract.

Preparation of fallow land with disc harrow and disc plow, pulverising loam soil deeper than 15 cm, has shown positive response towards enhancement of wheat yield (Devrojani, 1983 and Razzaq, 1988). Research on soil — implement — plant relationship is quite a new field. No previous study/reference is available quantifying the effect of tillage practices, manipulating soil (different and deeper than cultivator and rotavator), on sowing of wheat after rice.

The present study was initiated

to develop an appropriate tillage package in consideration with the conventional practice and departmental recommendatioin for wheat production after rice in clay loam soil of the rice tract.

Materials and Methods

The study was undertaken by laying out trials on wheat during 1986-87 to 1989-90 at adaptive research farm at Sheikhupura and at farmers' fields in the following villages of the district: Tehsil Ferozewala: Kalla, Nabipura, Sekhan, Lubanwala, Fateh Rehan, Dalla Wahga and Ahdhian; Tehsil Sheikhupura: Kharianwala and Dheerday.

Every year, trials were laid out in clay loam soil after harvest of rice fine variety, B-385, on 10 similar sites with three replications and in randomised complete block design with the following treatments.

1. Cultivator (5) Conventional practice (check)
2. Rotavator (1) + Cultivator (3)
3. Disc Harrow (2) + Cultivator (2)
4. Rotavator (1) + Chisel Plow (2)
5. Disc Harrow (1) + Chisel Plow (2)
6. M.B. Plow (1) + Disc Harrow (1)

(The arrangement and figures in brackets denote the sequence and times for which implements were run)

On ripening of the rice crop, the last irrigation was given to fields. With this practice, no sooner did the rice crop vacate the fields and the soil was ready for ploughing. The land was prepared using shovel type cultivator of 13 tines, rotavator of 42 blades and 1 778 mm width, offset disc harrow of 16 discs, chisel plow of 3 tines and reversible mold board plow (M.B. Plow) of 2 bottoms mounted with M.F. 375 tractor, 75 H.P.

Planking was done twice. Wheat variety, PAK-81, was sown with calibrated tractor-drawn using recommended and uniform seed rate and other inputs. Chemical weed control was adopted.

Data regarding implement performance and wheat crop tillering and yield were recorded at the appropriate stages. Tillering and yield data were averaged and percent increase over check calculated. Statistical analysis was undertaken on averaging tillers and yield per unit area obtained from each replication every year to examine the significant differences between treatment means at 5% level. Least significant differences (LSD) between treatment means was calculated.

Economic analysis was conducted to examine the viability of the tillage packages under study. The cost-benefit ratio was determined on the basis of expenditure and income relative to the conventional practice. Gross income was derived by adding the income from average grain yield of each treatment for Rs. 95/kg and Rs. 40/kg of wheat straw prevailing during 1989-90. Gross expenditure against each treatment was computed on the basis of rates of 1989-90 assuming that a farmer owns land as shown below:

a. Preparation of land after rice harvesting:
   1. Cultivator
      = Rs. 100/ha/run
   2. Rotavator
      = Rs. 220/ha/run
   3. Disc harrow
      = Rs. 160/ha/run
   4. Chisel plow
      = Rs. 185/ha/run
   5. M.B. plow
      = Rs. 370/ha/run
   6. Planking
      = 2 times, each @ Rs. 50/ha.

b. Seed (treated)
   = 100 kg./ha @ Rs. 4/kg

c. Sowing with tractor drill
   = Rs. 125/ha

d. Ridging for irrigation
   = 2 man-day @ Rs. 35/man-day

e. Weed control with weedicide
   = Rs. 417/ha

f. Fertilizer: (NPK: 113-83-61 kg/ha, each bag of 50 kg weight)
   = i. Urea @ Rs. 145/bag.
   ii. DAP @ Rs. 203/bag.
   iii. Potassium Sulphate @ 85/bag.

g. Irrigation
   = i. Cleaning of water course, 2 man-day @ Rs. 35/man-day.
   ii. Labour charges for 4 irrigations, 2 man-day @ Rs. 35/man-day.
   iii. Water rates @ Rs. 123/ha.

h. Harvesting (manual)
   = 390 kg/ha @ Rs. 95/40 kg wheat

i. Threshing (mechanical)
   = 4 kg/40 kg of yield @ Rs. 95/40 kg wheat.

Results and Discussion

Implement Performance

1. Cultivator (5)

The sole use of cultivator five times as a conventional practice teared the soil to an average depth of 15 cm. The first three cultivations were given alone which uprooted rice stubbles without crushing and tearing them. The last two operations of the cultivator were given along with plank tied behind. This practice broke clods and levelled the soil surface. Inconvenience was experienced in the subsequent drilling operation as the drill had to stop off and on to clear the uprooted stubbles entangled with seed tubes.

2. Rotavator (1) + cultivator (3)

The rotavator completely crushed the rice stubbles and mixed with finely broken down soil up to an average depth of 7 cm. Of the three cultivations after rotavator, one was given alone and the remaining two along with the plank. This practice enhanced the working depth to about 15 cm. and also levelled the soil surface. The seed drilling was conveniently carried out.

3 . Disc harrow (2) + cultivator (2)

The operation of disc harrow twice teared and uprooted the rice stubbles. The soil was partially inverted and pulverised well to an average depth of 23 cm. The use of cultivator twice along with the plank after disc harrow thoroughly mixed the cut soil and levelled its surface for the subsequent drilling operation. The seed drilling was conveniently carried out.

4 . Rotavator (1) + chisel plow (2)

The use of rotavator crushed and mixed the rice stubbles with finely broken down soil to an average depth of 7 cm. After rotavation, twice running of chisel plow bi-directionally opened soil to an average depth of 40 cm. The subsequent twice planking broke the clods that developed as a result of chiselling and levelled the soil surface. The seed drilling was conveniently accomplished.

5 . Disc harrow (1) + chisel plow (2)

Disc harrow teared and uprooted the rice stubbles as well as partially inverted and pulverised the soil well to an average depth of 23 cm. Afterwards, twice chiselling bi-directionally opened the soil to an average depth of 40 cm. The last operation with twice planking broke the clods that developed due to chiselling and levelled soil surface. No inconvenience was experienced in seed drilling.

6 . M.B. Plow (1) + disc harrow (1)

The first operation of M.B. plow once completely inverted rice stubbles along with soil. The working depth was 30 cm. The following disc harrow operation once partially teared the stubbles and pulverised the inverted soil. Planking carried out twice in the end levelled the soil surface. The drilling operation was conveniently completed.

Table 1 Effect of Different Tillage Packages on Tillering of Wheat

Treatment	Productive tillers (No./m^2)				Average tillers (No./m^2)	Increase tillering/check (%)
	1986-87	1987-88	1988-89	1989-90		
Cultivator (5)	289	297	306	316	302a	—
Rotavator (1) + cultivator (3)	307	311	313	317	312a	3.31
Disc harrow (2) + cultivator (2)	323	325	331	333	328b	8.61
Rotavator (1) + chisel plow (2)	326	330	333	335	331b	9.60
Disc harrow (1) + chisel plow (2)	338	341	348	350	345c	14.24
M.B. plow (1) + disc harrow (1)	336	344	349	351	345c	14.24
					LSD = 13	

Tillering

The effect of different tillage packages on wheat crop tillering is shown in **Table 1**.

The above data show that the use of disc harrow once followed by chisel plow twice and M.B. plow once followed by disc harrow once recorded an equal and the highest increase of 14.24% in tillering over the conventional practice, i.e., the sole use of cultivator (5). The use of rotavator (1) plus cultivator (3) enhanced tillering by 3.31% over the conventional practice. An increase of 8.61% and 9.60% in tillering was observed with the use of disc harrow twice followed by cultivator twice and rotavator once followed by chisel plow twice, respectively.

Statistically, a significant difference was found between treatment means at 5% level. The least significant difference was 13. Accordingly, an equal mean of wheat crop tillering under disc harrow (1) plus chisel plow (2) and M.B. plow (1) plus disc harrow (1) was significantly different from the means of other four tillage packages. A non-significant difference was found between the tillering means of disc harrow (2) plus cultivator (2) and rotavator (1) plus chisel plow (2) but these were significantly different from the means of conventional practice and rotavator (1) plus cultivator (3). The tillering means of the conventional practice and the tillage package comprising of rotavator (1) plus cultivator (3) were non-significantly different at 5% level.

Yield

Table 2 shows the effect of different tillage packages on the yield of wheat.

It is evident from the above data that an equal and the highest increase of 19.91% in wheat yield was obtained with the use of disc harrow once followed by chisel plow twice and M.B. plow once

Table 2 Effect of Different Tillage Packages on Yield of Wheat

Treatment	Yield (kg./ha)				Average yield (kg./ha)	Increase over check (%)
	1986-87	1987-88	1988-89	1989-90		
Cultivator (5)	3 240	3 843	4 105	4 265	3 863a	—
Rotavator (1) + cultivator (3)	3 346	4 093	4 177	4 559	4 044a	4.69
Disc harrow (2) + cultivator (2)	3 529	4 360	4 463	4 804	4 289b	11.03
Rotavator (1) + chisel plow (2)	3 652	4 493	4 414	5 069	4 409b	14.13
Disc harrow (1) + chisel plow (2)	3 775	4 527	4 571	5 654	4 632c	19.91
M.B. plow (1) + disc harrow (1)	3 688	4 509	4 678	5 654	4 632c	19.91
					L.S.D. = 219	

followed by disc harrow once over the conventional practice. The use of disc harrow twice followed by cultivator twice and rotavator once followed by chisel plow twice recorded 11.03% and 14.13% increase in wheat yield ,respectively. The operation of rotavator (1) plus cultivator (3) registered 4.69% increase in wheat yield over the conventional practice.

Statistically, a significant difference in treatment means was found at 5% level. The least significant difference was 219. The mean yield of 4 632 kg per ha obtained with the use of disc harrow once followed by disc harrow once was significantly different from the means of other four tillage packages. The means of the yield given by disc harrow (2) plus cultivator (2) and rotavator (1) plus chisel plow (2) were not significantly different amongst themselves. However, these were significantly different from the means of yield of conventional practice and the package comprising of rotavator (1) plus cultivator (3). A non-significant difference existed between the means of yield recorded by the conventional practice and the use of rotavator (1) plus cultivator (3).

Economic Analysis

Table 3 shows the economic analysis of the effect of different tillage packages on wheat production.

The economic analysis shows that the highest return of Rs. 9.66 per unit expenditure relative to conventional practice was obtained with the use of disc harrow once followed by chisel plow twice and M.B. plow once followed by disc harrow once. The next best economical tillage package was disc harrow (2) plus cultivator (2) as it gave a cost-benefit of 1:9.42. the use of rotavator plus cultivator (3) and the tillage package comprising of rotavator (1) plus chisel plow (2) contributed Rs. 7.70 and 6.64 per unit expenditure relative to conventional practice, respectively. The above analysis also indicates that destruction of rice stubbles with the use of disc harrow followed by chisel plow or cultivator was economically more beneficial than rotavation followed by chiselling or cultivation.

Table 3 Economic Analysis

Treatments	Gross expenditure (Rs./ha)	Other expenditure (Rs./ha)	Gross income (Rs./ha)	Other income (Rs./ha)	Cost-benefit ratio
Cultivator (5)	5 203	—	10 333	—	—
Rotavator (1) + cultivator (3)	5 266	63	10 818	485	1:7.70
Disc harrow (2) + cultivator (2)	5 324	121	11 473	1 140	1:9.42
Rotavator (1) + chisel plow (2)	5 423	220	11 794	1 461	1:6.64
Disc harrow (1) + chisel plow (2)	5 416	213	12 391	2 058	1:9.66
M.B. plow (1) + disc harrow (1)	5 416	213	12 391	2 058	1:9.66

Conclusions

1. The destruction of stubbles with the use of disc harrow once followed by chisel plow twice and complete inversion of stubbles with M.B. plow once followed by disc harrow once are the most appropriate tillage packages for wheat production in clay loam soil after rice harvest in the rice tract. Each of these tillage packages recorded significantly the highest tillering and yield with an increase of 14.24% and 19.91%, respectively, and contributed the maximum return of Rs. 9.66 per unit expenditure over the conventional practice, i.e., the sole use of cultivator five times.
2. A non-significant difference in tillering and yield means existed betwen the use of disc harrow twice followed by cultivator twice and rotavator once followed by chisel plow twice which are, of course, significantly different from the respective means of the conventional practice and rotavator once followed by cultivator thrice. However, the return per unit additional expenditure with the use of disc harrow twice followed by cultivator twice was Rs. 9.42. Compared with the tillage package comprising of rotavator once followed by chisel plow twice generates Rs. 6.64 per unit expenditure over the conventional practice. It is, therefore, evident that as the second best tillage package, the adoption of disc harrow twice followed by cultivator twice should be preferred over the use of rotavator once followed by chisel plow twice to prepare land for wheat production after rice in the rice tract.
3. There is also a non-significant difference in tillering and yield means between the conventional practice and the use of rotavator once followed by cultivator thrice except that the later package accommodates subsequent mechanical seed drilling free of any obstruction.
4. Before chiselling or cultivation of land, the use of disc harrow to destroy rice stubbles registered higher wheat crop tillering and yield and was economically more beneficial than the rotavator. Therefore, compared to the rotavator, the use of disc harrow while preparing land for wheat sowing after harvesting of rice should be promoted.

(Continued on page 34)

Livestock Housing in Hot Arid Regions: A Study of Micro-climate Modifiers Using a Model Livestock Building

by
A. Mekonnen
Lecturer
Alemaya Univ. of Agriculture
P.O. Box 138
Diredawa, Ethiopia

V.A. Dodd
Prof.
University College Dublin
Dept. of Agric. and Food Eng.
Earlsfort Terrace, Dublin 2, Ireland

Abstract

The effectiveness of different micro-climate modifiers for hot weather livestock housing were studied in a small climatic chamber of size 4.16 × 2.4 × 1.8 m high with a simulated cow. Fan ventilation and evaporative cooling systems were considered for the study. Temperature and velocity profiles together with air flow patterns were taken as a measure of air distribution in the chamber. Saturation efficiency and static pressure drop across the pads were also taken as criteria for evaluating evaporating cooling pad characteristics.

Wall flow inlets on both sides with air velocity of 3.5m/s appears to be a good arrangement compared to others. For the two pads studied, kool-cel pads of 100 mm thickness appears to have higher saturation efficiency at 1.5 m/s air velocity and 3L/min water flow rate with an acceptable level of relative humidity. Temperature reduction of the order of 10°C can be expected so long as the relative humidity of the supply air does not exceed 60%.

Introduction

The basic justification of a livestock shelter is that it should alter or modify the environment for the benefit of the animals enclosed. Maximum control of the environment includes four thermal factors: temperature, air velocity, relative humidity and solar radiation of which the environmental temperature is the most important and influential. Hence, animal housing in hot regions of the world should be given due consideration. Research shows that animals are more sensitive to heat stress than cold. **Fig. 1** shows the effects of temperature on percentage production of livestock and poultry (Esmay 1986).

Fan Ventilation

The design of closed buildings with forced air movement involves fans, air inlets and outlets. Air may be forced into the building with fans (positive pressure) and allowed to dissipate through outlets, or be forced out of building with fans (negative pressure) and allowed to dissipate through the inlets. The selection of one or the other system is based on performance characteristics/ efficiency of air movement, control capabilities and costs.

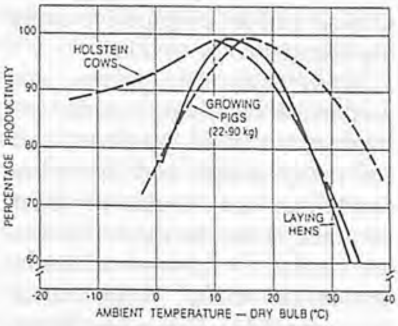

Fig. 1 General effect of environmental temperature on percentage production of livestock and poultry.

Evaporative Cooling

Many of the criteria for evaporative cooler design are based on the experience of industry rather than research data (Durward and Wiersma, 1974). Cooling capacity is dependent upon the volume of air flow and the saturation efficiency. Saturation efficiency, the effectiveness with which water is transferred to the air, is in turn dependent upon such factors as characteristics of the pad, air velocity through the pad and water flow rate for a given locality.

The overall objective of the study reported in this paper is the housing of livestock in hot arid climates. The main environmental problems of livestock housing in these climates are associated with high rather than low temperatures. Evaporative cooling as a means of lowering internal temperatures in a building was considered worthy of study. The provision of uniform temperature is of paramount importance in livestock housing; the achievement of such conditions is dependent on air distribution and air movement which in turn depends on the ventilation system provided.

The paper is devoted to reporting the work associated with the design and construction of a laboratory facility to enable ventilation and an evaporative cooling systems to be studied.

Many researchers in the past used model buildings to study ventilation and allied problems, and for many design and operating conditions the ventilation data obtained from the model studies are similar to those observed in prototype units. Walton and Sprague (1951), Pattie and Milne (1966), Smith and Hazen (1968), Esmay (1970), Dybwad (1974), Randall (1975), Eagan and Hellickson (1978), Timmons (1984) and others used the principle of similitude and dealt with ventilation problems using models. Positive pressure fan ventilation systems however, have not yet been widely reported.

In this paper inlet arrangements for both negative and positive pressure fan ventilation systems were considered.

The Experimental Design

A laboratory scale building was designed based on the ventilating capacity of the air conditioner attached to one side of the chamber for simulation of hot weather air conditions. As measured by a hot-wire anemometer the maximum flow rate from the air conditioner was $0.21 m^3/s$. The chamber dimensions was $4.16 \times 2.4 \times 1.8$ m high providing a floor area of 10 m^2 which is the overall floor area requirement of an average 500 kg dairy cow. A cow was simulated with an air-filled drum at 32.5°C inside air temperature regulated using a thermostat. This in turn maintains the surface temperature at about 31°C which is the surface temperature of the 500 kg dairy cow at 21°C ambient air temperature, in this case the chamber temperature. Based on this simulation the calculated and the measured values of sensible heat loss were similar. **Figs. 2** and **3** show the dimensions and plan view of the psychrometric chamber. The detailed design of the psychrometric chamber and the model cow is given in Mekonnen A., 1991.

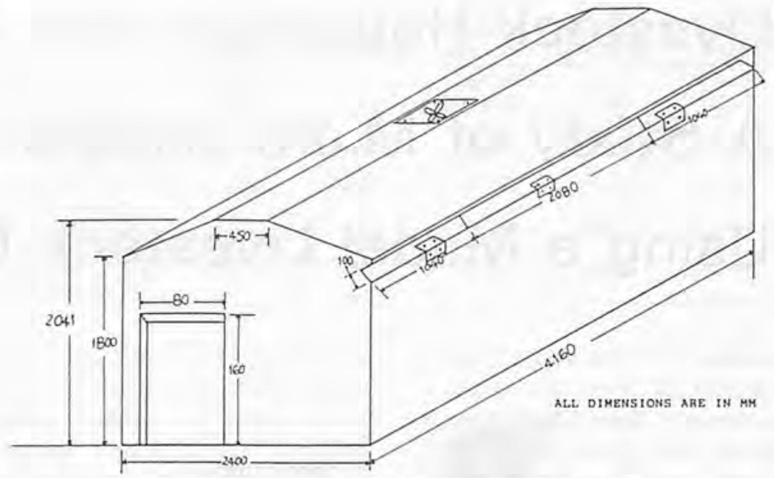

Fig. 2 Dimensions of the psychrometric chamber.

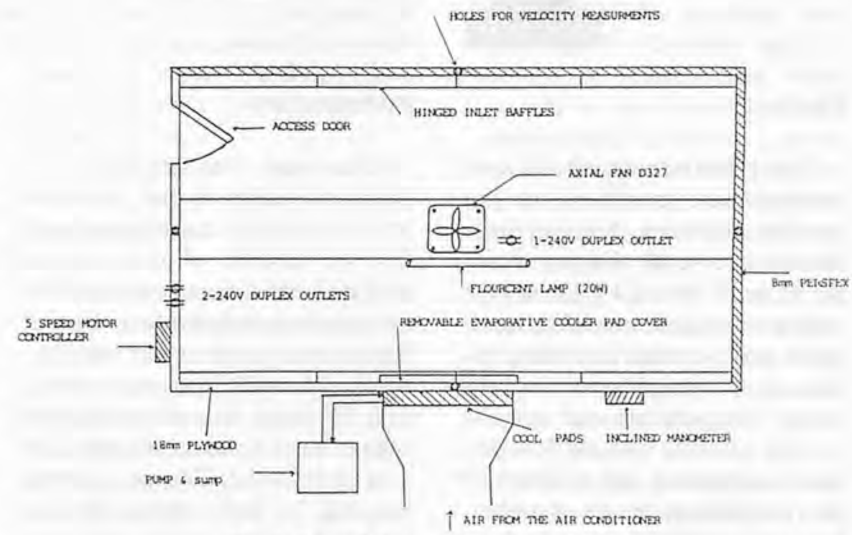

Fig. 3 Plan of the psychrometric chamber.

The air conditioner attached to the chamber can provide different ranges of dry-bulb temperature and relative humidity. The unit permits fitting evaporative pads of any thickness and the system can be separated from the fan ventilation using a removable sliding cover. **Figs. 4** and **5** show the profile view of the chamber and the model cow.

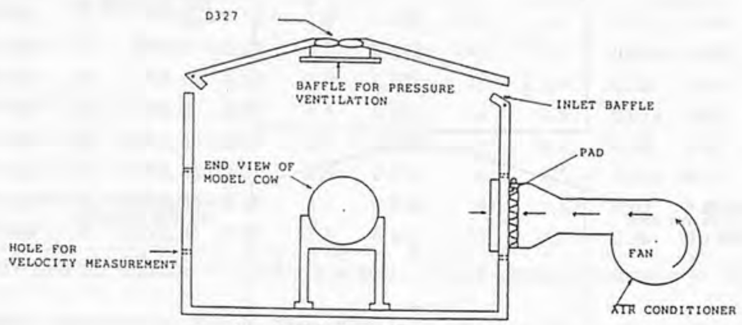

Fig. 4 Profile of the chamber.

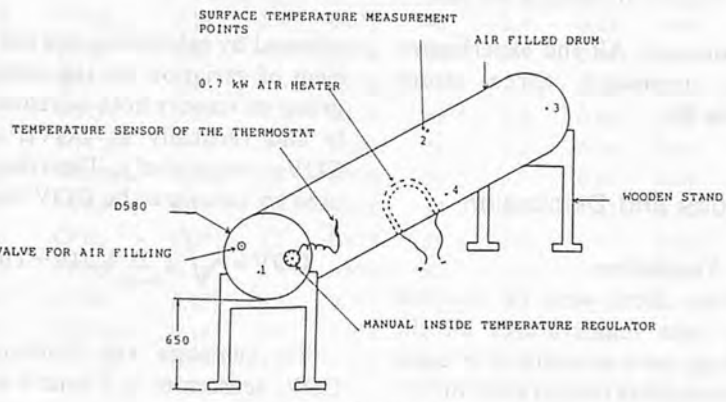

Fig. 5 The simulated cow.

Fan Ventilation

Ten inlet arrangements (six in negative and four in positive pressure) fan ventilation with two flow rates were studied. The flow rates considered were 0.18 and 0.27 m^3/s. The inlet arrangements are shown on **Figs. 6 and 7**.

The description of the inlets considered is as follows:-

1. PWOB, (Pressure fan without baffles)
2. PWB, 0 deg, (Pressure fan with baffles at 0 degree from the horizontal)
3. PWB, 15 deg, (Pressure fan with baffles at 15 deg.)
4. PWB, 45 deg, (Pressure fan with baffles at 45 deg.)
5. WFBS, (Wall flow inlets on both sides)
6. WFOS, (Wall flow inlets on one side)
7. WFCBS, (Wall flow inlets at centre on both sides)
8. CFBS, (Ceiling flow inlets on both sides)
9. CFOS, (Ceiling flow inlet on one side)
10. CFCBS (Ceiling flow inlets at centre on both sides)

Instrumentation and Measurements

Temperature and air velocity distribution were evaluated by measuring them at different locations inside the chamber. LM 335 sensors were used to record the temperature readings with a data logger which was attached to an IBM compatible personal computer. Each sensor calibrated and readings were checked using a digital thermometer. The data logger recorded the readings from the sensors every 5 min. Air velocity inside the chamber was measured manually using a hot-wire anemometer at eight sensor locations (Sensor 2-9).

Location of these sensor are shown on **Fig. 8**.

Functions of Sensors

Sensor 1 Inlet temperature

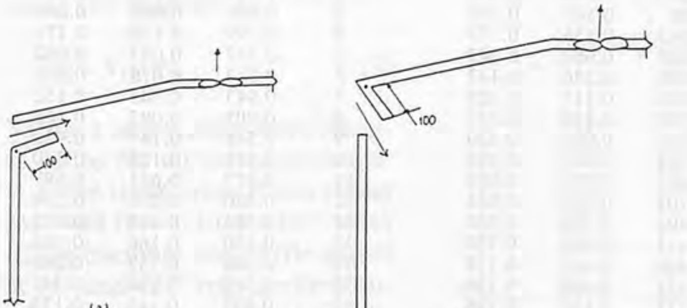

Fig. 6 Slotted hinged inlet arrangements for exhaust fan ventilation system: (a) ceiling flow and (b) wall flow.

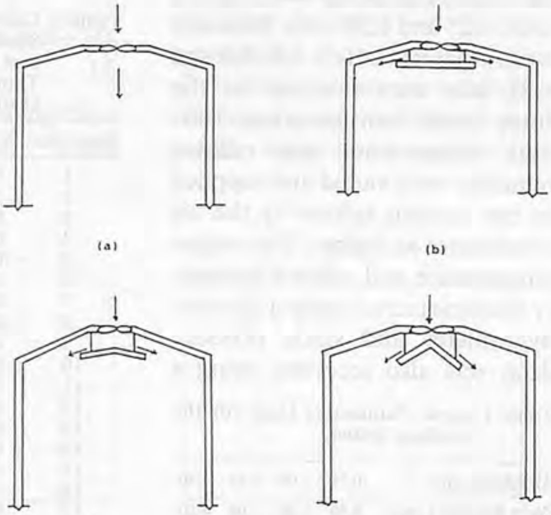

Fig. 7 Baffle arrangements used in the pressure fan ventilation system: a) PWOB, b) PWB, 0 deg, c) PWB, 15 deg, d) PWB, 45 deg.

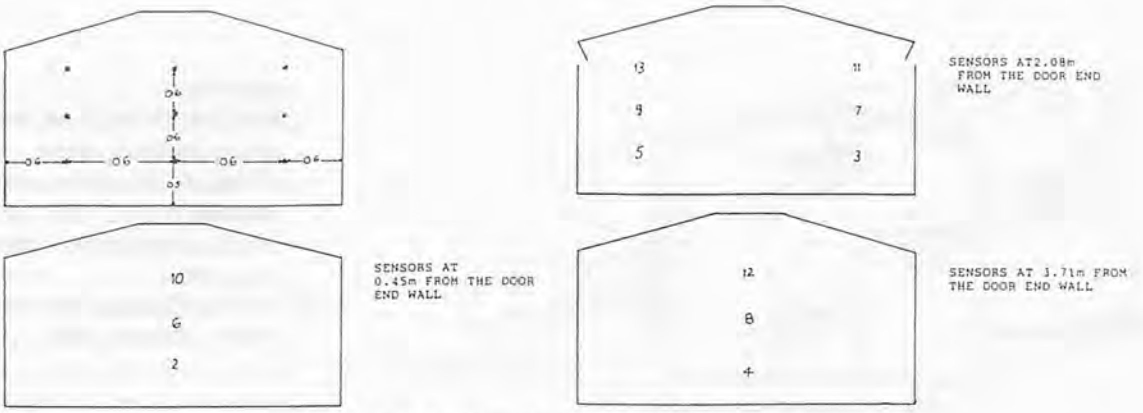

Fig. 8 Position of sensors in the chamber.

Sensor 2-13 Chamber temperature
Sensor 14 Outlet temperature

Air flow patterns of the six inlet designs were documented using P^H smoke pellets. Depending on the ventilation type employed smoke was generated near the inlet which resulted from the burning of P^H pellets and photographs were taken.

Two pad types (kool-cel and aqua-cel) were considered for the study each with three thicknesses of 100, 150 and 200 and 38, 57 and 76 mm, respectively. The kool-cel pads are made of special water proof paper which are flutted for water conveying and strength. On the other hand, the aqua-cel pads are made of plastic fibres with wire mesh on one side to give it strength. The pad face velocity considered were 0.75, 1.00, 1.25 and 1.50 m/s. With this water flow rate of 0.5, 1.6, 3.0 and 4.8L/min were selected for the study under consideration. Dry-bulb temperature and relative humidity were varied and supplied to the cooling system by the air conditioner as desired. The output temperature and relative humidity were measured using a thermo-hygrometer and static pressure drop was also recorded using a manometer. All the experiments were repeated three times (**Table 1**).

Table 1 Input Parameters Used for the Cooling System

Air velocity, m/s	0.75	1.00	1.25	1.50
Water flow rate L/min	0.50	1.60	3.00	4.80
Dry-bulb temp., °C	26.00	29.00	31.50	34.00
Relative humidity, %	36.00	42.00	52.00	62.00

Results and Discussion

Fan Ventilation

Since there were no controls over inlet temperatures all the readings were normalized by using dimensionless temperature differences calculated as follows:

$$T_d = (T_n - T_i)/(T_o - T_i) \quad (1)$$

For analysis, these differences were considerd. To evaluate the distribution of air in the chamber a group of sensors were selected and placed near the model animal. The analysis of temperature distribution in the chamber were assessed by calculating the coefficient of variation for the selected group of sensors both horizontally and vertically as COV_H and COV_V, respectively. The relation used to calculate the COV was:

$$COV = \sqrt{\left[\sum_{(n=1)}^{n} \delta_i^2/(n-1)\right]}/\bar{x} \quad (2)$$

To calculate the horizontal COV, sensors 6, 7, 8 and 9 were selected as they represent the space surrounding the animal and sensor 3, 7 and 11 were taken for calculating the vertical COV. **Tables 2** and 3 show the values of these coefficients.

Examination of the coefficients indicate that wall flow inlets on both sides of the chamber appear to have lower standard deviation values but due to lower values of the mean the COV_H and COV_V

Table 2 Calculated COV_H Values for Selected Groups of Sensors (Sensors 6,7,8 and 9) to Evaluate Temperature Distribution Horizontally

Exp. No.	$\bar{X}_{(6,7,8,9)}$	$S.D_{(n-1)}$	COV_H
1	1.04	0.126	0.121
2	1.04	0.046	0.044
3	0.96	0.145	0.151
4	0.883	0.156	0.177
5	0.805	0.082	0.102
6	0.958	0.136	0.142
7	0.970	0.117	0.121
8	0.988	0.130	0.132
9	0.282	0.065	0.230
10	0.283	0.056	0.198
11	0.605	0.044	0.073
12	0.703	0.015	0.021
13	0.393	0.120	0.305
14	0.413	0.062	0.150
15	0.468	0.055	0.118
16	0.525	0.066	0.126
17	0.725	0.142	0.196
18	0.988	0.121	0.122
19	0.855	0.086	0.101
20	0.913	0.103	0.113

Table 3 Vertical Coefficient of Variations (COV_V) for Selected Groups of Sensors (Sensors 3, 7 and 11)

Exp. No.	$\bar{X}_{(3,7,11)}$	$S.D_{(n-1)}$	COV_V
1	1.070	0.052	0.049
2	1.027	0.046	0.045
3	0.880	0.082	0.093
4	0.797	0.136	0.171
5	0.757	0.047	0.062
6	0.913	0.078	0.085
7	0.943	0.143	0.152
8	0.903	0.095	0.105
9	0.348	0.147	0.422
10	0.373	0.127	0.340
11	0.877	0.611	0.697
12	0.820	0.278	0.339
13	0.583	0.182	0.312
14	0.430	0.166	0.386
15	0.490	0.132	0.269
16	0.510	0.174	0.341
17	0.857	0.148	0.173
18	1.160	0.220	0.190
19	0.883	0.384	0.435
20	0.950	0.312	0.328

Table 4 Dimensionless Velocity Ratios (Vd) for the Pressure Fan Ventilation System

Date	Exp No.	Exp Na	Q, M^3/s	*Vin, m/s	Ain, m^2	RH, %	IN..1	2	3	4	5	6	7	8	9
20-Mar	1	PWOB	0.18	2.4	0.078	45	2.4	0.03	0.04	0.025	0.06	0.025	0.03	0.025	0.04
21-Mar	2	PWOB	0.27	3.5	0.078	45	3.5	0.014	0.086	0.014	0.07	0.015	0.02	0.015	0.034
22-Mar	3	PWB, 0	0.18	2.4	0.078	45	2.4	0.02	0.05	0.02	0.04	0.02	0.06	0.02	0.06
23-Mar	4	PWB, 0	0.27	3.5	0.078	44	3.5	0.014	0.05	0.014	0.04	0.02	0.06	0.02	0.04
26-Mar	5	PWB, 15	0.18	2.4	0.078	40	2.4	0.02	0.05	0.02	0.06	0.02	0.03	0.03	0.04
27-Mar	6	PWB, 15	0.27	3.5	0.078	44	3.5	0.014	0.06	0.014	0.06	0.02	0.04	0.02	0.04
29-Mar	7	PWB, 45	0.18	2.4	0.078	56	2.4	0.03	0.08	0.02	0.1	0.03	0.08	0.03	0.15
30-Mar	8	PWB, 45	0.27	3.5	0.078	53	3.5	0.06	0.11	0.06	0.11	0.04	0.11	0.086	0.14

*Vin = Inlet air velocity, m/s; Ain = Inlet area, m^2; RH = Relative humidity, %; IN..1 = Inlet air velocity at sensor 1, m/s.

Table 5 Dimensionless Velocity Ratios (Vd) for the Exhaust Fan Ventilation System

Exp No.	Exp. Na	Q, M^3/s	Vin, m/s	Ain. M^2	RH, %	IN..1	2	3	4	5	6	7	8	9
9	WFBS	0.18	2.4	0.078	46	2.4	0.03	0.04	0.03	0.04	0.03	0.04	0.03	0.04
10	WFBS	0.27	3.5	0.078	40	3.5	0.06	0.1	0.06	0.1	0.04	0.07	0.04	0.07
11	WFOS	0.18	2.4	0.078	41	2.4	0.08	0.03	0.08	0.06	0.08	0.02	0.08	0.11
12	WFOS	0.27	3.5	0.078	48	3.5	0.06	0.07	0.06	0.1	0.063	0.04	0.07	0.08
13	WFCBS	0.18	2.4	0.078	51	2.4	0.06	0.04	0.08	0.03	0.03	0.04	0.03	0.04
14	WFCBS	0.27	3.5	0.078	59	3.5	0.04	0.06	0.06	0.04	0.02	0.06	0.02	0.07
15	CFBS	0.18	2.4	0.078	53	2.4	0.02	0.02	0.02	0.02	0.03	0.02	0.04	0.025
16	CFBS	0.27	3.5	0.078	55	3.5	0.017	0.015	0.014	0.014	0.023	0.023	0.026	0.023
17	CFOS	0.18	2.4	0.078	52	2.4	0.03	0.03	0.02	0.025	0.02	0.033	0.025	0.037
18	CFOS	0.27	3.5	0.078	51	3.5	0.017	0.017	0.014	0.017	0.014	0.014	0.017	0.02
19	CFCBS	0.18	2.4	0.078	61	2.4	0.02	0.02	0.025	0.02	0.029	0.025	0.025	0.029
20	CFCBS	0.27	3.5	0.078	63	3.5	0.014	0.014	0.014	0.02	0.028	0.06	0.043	0.028

are not significantly lower compared to other inlet arrangements. But lower values of the mean implies reduction in chamber temperature.

Also, baffle angle at 15° and 45° from the horizontal appear to have lower COV_V but the COV_H is not lower compared to other as the inlet is where the fan is located.

Generally, all ceiling flow inlet arrangements have higher values of COV compared to others.

The air velocity distribution in the chamber was assessed by converting the anemometer readings into a dimensionless velocity ratio using the relation:

$$V_d = V_n/V_i \qquad (3)$$

Tables 4 and **5** show these velocity ratios for all the experiments.

From these ratios it was found that wall flow inlets on both sides of the chamber and baffle angles at 15° and 45° from the horizontal have higher ratios which indicate higher velocity readings at that particular location.

The air flow patterns which was drawn by hand from the photographs taken are shown in **Figs. 9** and **10**. From these it was shown that the wall flow and 15° and 45° baffle arrangements have good patterns to ensure good air mix than other arrangements.

The Archimedes Number of the slotted inlets were calculated using the relation:

$$Ar = g\ (T_S - T_O)C_d b\ h(B+H)\ B\ H/(T_S + T_O)Q^2 \qquad (4)$$

For the wall flow and ceiling flows it was calculated to be 7 which means that the jet will remain horizontal rather than dropping unless deflected to the desired space for maximum benefit from the ventilating air.

Evaporative Cooling

All the readings from the experiment for both pad types and all thicknesses were converted to average values for analysis. The standard deviation of identical experiments were very small. For all the experiments the saturation efficiency was calculated and graphs were drawn against pad

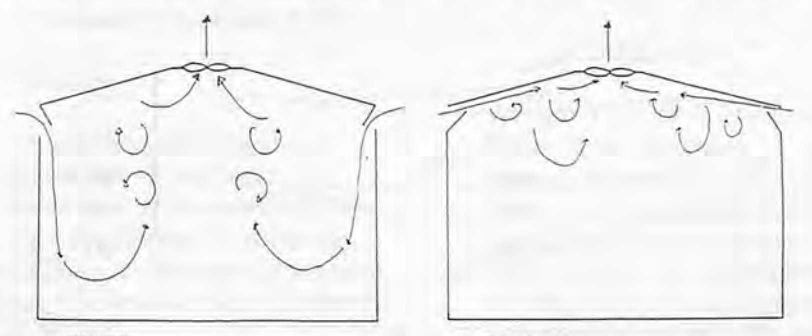

Fig. 9 Air flow patterns of exhaust fan ventilation systems as drawn by hand: inlet temp = 15 deg, inlet velocity = 2.4 m/s for both arrangements.

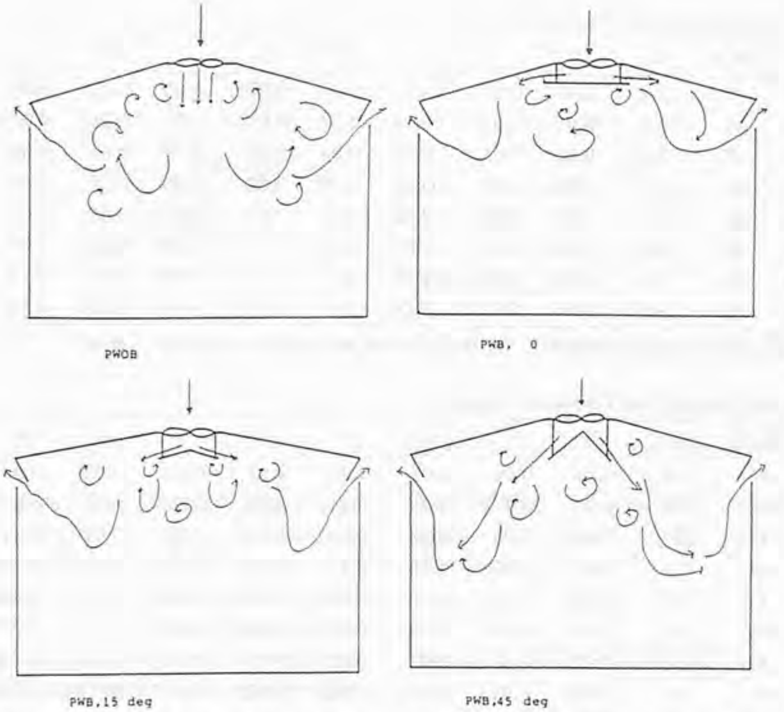

Fig. 10 Air flow patterns of pressure fan ventilation system: inlet temp. = 15.2°C, inlet velocity = 2.4 m/s. for all fan-baffle arrangements.

face velocity, water flow rate and wet-bulb temperature for the dry-bulb temperatures and relative humidities. Graphs were also drawn relating static pressure difference with pad face velocity and water flow rates for both pad types (**Figs. 11-15**).

From the graphs it is clear that air velocity has a positive correlation for lower velocities and a negative correlation as the velocity goes beyond 1.5 m/s, especially for 100 mm kool-cel pad. This may be due to high air-water contact time for lower velocities and breaking down of the layered films as the velocity increases. This turning point depends on pad type and thickness.

The saturation efficiency has a positive correlation with water flow rate but at about 5L/min rate, it is shown that all pads come to the same efficiency value as they cannot cool more than their cooling capacity.

For the ranges of dry-bulb temperatures tested, the system was effective in reducing the temperature by 8°-10°C. But it was also shown that the saturation efficiency increases as the temperature increases but remains constant after a certain value which depends on pad type and thickness (**Fig. 15**).

Different ranges of relative humidity were tested and the system appears to be effective except that the output relative humidity will be higher as the pad thickness increases (150 and 200 mm) for the kool-cel pads and at 78 mm pad thickness of aqua-cel pad.

Generally kool-cel pads have a higher saturation efficiency than aqua-cel pads and look-cel pad of 100 mm thickness at 1.5 m/s air velocity and 3L/min water flow rate gave good results in terms of efficiency and output relative humidity.

The static pressure difference has a positive correlation with pad face velocity and water flow rate and also higher for kool-cel pads than qaua-cel pads.

Model studies indicate that the negative pressure ventilation system with wall flow inlets appear to achieve the most uniform air distribution in the chamber.

Evaporative cooling pad studies also indicate that temperature reduction of about 10°C can be achieved provided the supply air relative humidity does not exceed between 60% and 65%.

The use of a micro-climate modifier combining wall flow of negative pressure ventilation system and evaporative cooling

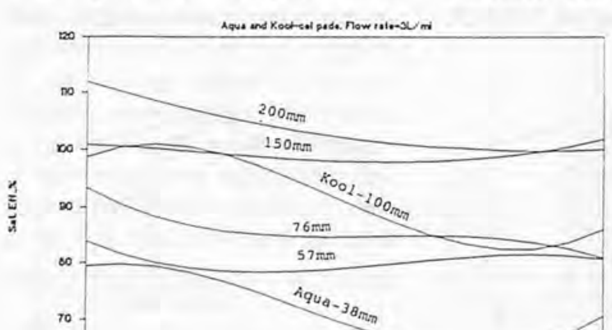

Fig. 11 Saturation efficiency vs air velocity.

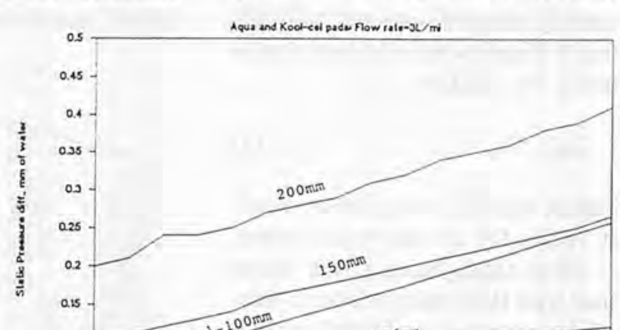

Fig. 12 Static pressure vs air velocity.

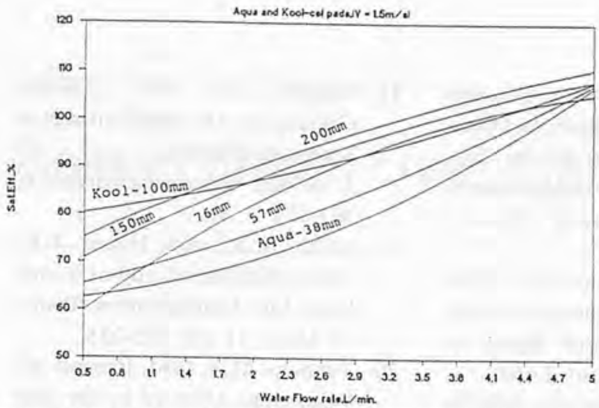

Fig. 13 Saturation efficiency vs water flow rate.

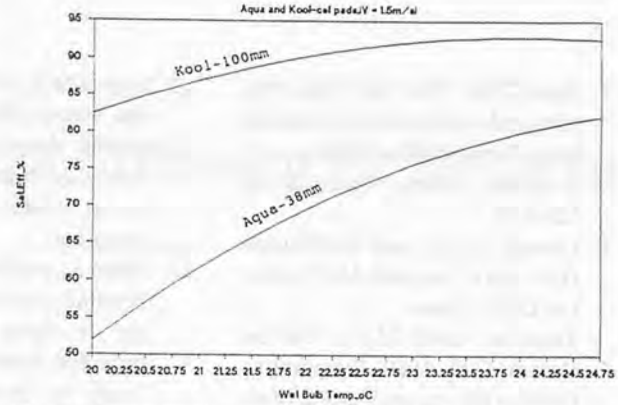

Fig. 15 Saturation efficiency vs wet bulb temperature.

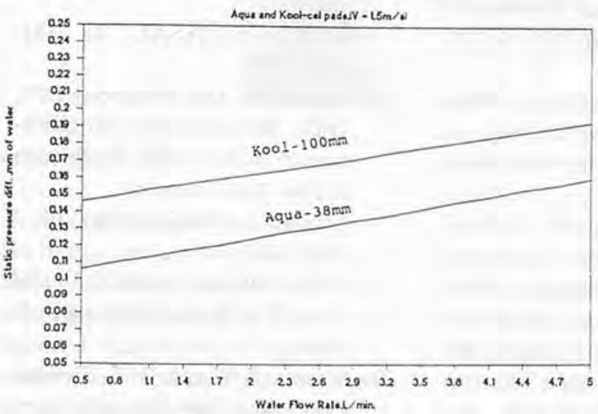

Fig. 14 Static pressure difference vs flow rate.

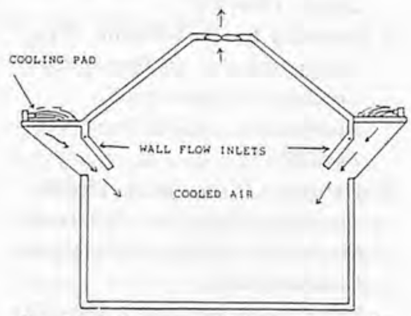

Fig. 16 Exhaust ventilation and evapolative cooling system.

with vertical or horizontal pad arrangement for livestock housing in hot climates on full scale building would be worthy of study. A tentative arrangement of the system is shown on **Fig. 16**.

Conclusion and Recommendations

1) The study should be extended and cover other possible inlet arrangements for hot weather ventilation problems aimed at maximizing air velocity near the animals for direct benefit.
2) These laboratory results should be extended to full-scale livestock houses.
3) The cooling pads should be tested for more ranges of temperature and humidity.
4) The research has to be extended on a full-scale livestock environment for further studies.
5) The characteristics of other types of pads shuld be studied.
6) The use of cooling pad in conjunction with negative pressure fan ventilation system is considered to have promise and to be worthy of study on full-scale buildings.
7) The use of local materials as media for evaporative cooling pads: for example, it is recently reported that clay particles 20 mm size, are successfully used in Brazil for cooling green houses (V.A. Dodd 1991).

Notation

Ar = Archimedes Number
B = Width of the room, m
b = Width of the inlet slot, m
C_d = Coefficient of discharge
COV = Coefficient of variations
g = Acceleration due to gravity, m/sec^2
H = Height of the room, m
h = Height of the inlet slot, m
Q = Flow rate, m^3/s
T_d = Dimensionless temperature difference
T_i = Inlet air temperature, °C
T_n = Temperature at location n, °C
T_o = Temperature of inlet air, °K
T_s = Temperature of the heated surface, °K
V_d = Dimensionless velocity ratio
V_i = Inlet air velocity, m/s
V_n = Velocity at location n, m/s
$\bar{X}$ = Mean value of the temperature readings, °C
δ_i = deviation from the x of the i_{th} point

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(Continued from page 26)

Appropriate Tillage Package for Wheat Production after Rice in Rice Tract

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Animal-drawn Over-the-row Cultivator for Tanzania

by
Eric Rempel
Devcon International Inc.
Box 664, Niverville, MB
Canada
ROA 1EO

J.S. Townsend
Prof.
Agric. Eng., University of Manitoba
Winnipeg, MB
Canada
R2M 0T9

Abstract

A prototype over-the-row cultivator was designed for use with two draft oxen in row crop weeding in Tanzania. The oxen handled more easily than when used with the wide yoke required for an inter-row cultivator. Early test results have indicated better control of the oxen which leads to more timely weeding and less crop damage.

Background

There is considerable literature, emanating from Africa, suggesting that the labor demand of crop weeding seems to impose a major bottleneck on increased crop production (Delgado and McIntire, 1982; Crawford and Lassiter, 1985; Jaeger, 1986; Pingali, Bigot and Binswanger, 1987; Kjoerby, 1983). Furthermore, some of these authors find animal-powered weeding under agronomist-controlled conditions decisively cost effective. In Africa animal-drawn plowing is common, but widespread use of animal-drawn weeders is limited to a few West African countries (Roosenberg, 1987; EFSAIP, 1982; Starkey, 1981; Shetto, 1988; Okai, 1975; Francis, 1988).

KEYWORDS: weeding, draft animal power, row cultivator, crop damage, participatory research.

Peasant farmer resistance to Draft Animal Powered (DAP) weeding in Tanzania is strong. The situation in Iringa, Tanzania, is probably typical. Iringa is a well watered, moderately populated and productive administrative region in the southern highlands of Tanzania. It has had a strong program of DAP promotion since 1982. With funding from the European Economic Community, 14 oxen training centeres were constructed for the purpose of extending the use of oxen for draft. DAP technology was not new to the area and a good number of farmers were using oxen for plowing. Although there was a desire to extend the number of DAP users, the main goal was to extend the range of uses for DAP by those farmers already employing the basic technology.

The Iringa project planners were aware of the farmers' failure to adopt DAP weeding technology and attributed this to the unavailability of inter-row cultivators and the reluctance of farmers to let oxen into their growing crop. To overcome these obstacles, supplies of conventional inter-row cultivators were brought to the centers for resale and a new way of guiding the oxen was introduced.

Traditionally in this area, oxen, after initial training, are guided by voiced commands only. This system works well for plowing where the right hand ox will readily follow the plow furrow. If the oxen do not follow the furrow exactly it does not matter much if some land is not plowed and there is no crop to destroy. However, when these same oxen are used for inter-row weeding the furrow is not there to guide them and the voiced commands do not seem to give adequate control. Farmers are concerned that the oxen will destroy the growing crop. A new guiding system was developed to address this concern. A system of nose rings and reins was introduced. It was thought that this system would allow for more effective communication between the driver and the oxen, hence greater control of the animals would be possible even when the oxen are not well trained. This method continues to be the guidance system of choice for agronomists in Tanzania and is used at all government facilities, including agricultural colleges and ox training centers. However, very few farmers have adopted the system. The reason for the rejection is not clear.

Some 4000 farmers have passed

through the oxen training centers in Iringa. In spite of these numbers, 1988 statistics indicate that while there are 26,000 plows, only 300 cultivators are used in the region. When the inter-row cultivators were brought to the centers, 10 to 20 units were quickly purchased. After this initial enthusiasm, very few were purchased in total (Masunga, 1988). The whole problem of farmers' acceptance or rejection is poorly understood.

The Mbeya Oxenization Project[1] (MOP) is an ongoing effort that is implemented by the Mennonite Economic Development Associates of Winnipeg and funded by the Canadian International Development Agency (CIDA). Mbeya Region is adjacent to Iringa Region. Pre-project studies found the situation in Mbeya and Iringa to be similar, but Mbeya had not had the intensive DAP promotion program.

Research done at the Uyole Agricultural College (UAC) near Mbeya in 1986 confirmed the agronomists' assumption that animal-drawn weed control methods would, in fact, contribute to increased production and would be cost effective. The UAC agronomists found that when all factors of production were monetized, the cost of weeding by hand was Tsh 4 000/ha (US$40/ha) but if oxen were used the cost was about Tsh 500/ha (US$5/ha). In this experiment, the yield was not significantly greater when oxen were used (Shetto, 1988).

The Iringa experience suggested that all or some of the technology offered was inappropriate. To what extent this was true, could only be determined by involving the farmers in the research. To ask the farmers whether cultivator design would affect acceptability was a question too hypothetical in nature to have value. The farmers, who had never seen a cultivator design other than the single available model, could not give any meaningful response to the question. For this reason the MOP staff decided to assess farmers' response to an alternate cultivator design.

In summary, many Tanzanian farmers using draft animals for power have adopted the use of plows, but few of these farmers have adopted the use of cultivators. This is so in spite of indications that the use of these cultivators would be profitable. The reason for this is not understood adequately. Before a program promoting the greater use of DAP can be initiated, greater understanding of this problem must be gained.

Objective

The MOP project team recognizes a number of conceivable constraints to greater use of animal-drawn cultivators. In its several sections, the project addresses these constraints.

The objective of the work described in this article is to test the hypothesis *that Mbeya farmers are not using animal draft weeding technology because the design of available equipment is inappropriate*. In order to effectively test this hypothesis, alternate designs had to be available and farmers had to be involved in the test.

Problems Associated with Inter-row Cultivators

The conventional inter-row cultivators available in Tanzania were examined critically. There are several models, but all follow the basic design illustrated in **Fig. 1** fairly closely.

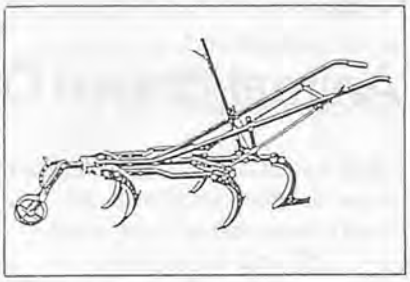

Fig. 1 A conventional inter-row cultivator.

The following points of criticism were found:

1. These cultivators are bolted together and are prone to losing bolts, thus becoming out of service in a short time.
2. They have limited maneuverability. By pulling back on the cultivator and increasing the tension on the chain, the cultivator can be lifted and set over to some extent. By leaning the cultivator it can be guided somewhat in the opposite direction but maneuverability is severely limited.
3. Some models have cast iron parts which are prone to breakage. Farmers reported breaking a part on the first day of operating the cultivator and then had great difficulty obtaining spares.
4. Most of these cultivators have low ground clearance and hence plug easily. They work poorly under weedy and/or muddy conditions.
5. Inter-row cultivators are best suited for hitching behind single animals. Oxen, the draft animal of choice in most parts of Africa, can be used singly but knowledge of the technology is not widespread.
6. In Africa, most inter-row cultivators are pulled by two oxen employing an extra long yoke so that the oxen can straddle two rows. Although this system works, the extra yoke must be constructed, which

[1] Mbeya Oxenization Project, Box 89, Mbeya, Tanzania.

may be a problem, and the oxen never seem to work as well with the long yoke as with the standard yoke.

7. Transportation to the field is a problem. The interrow cultivator cannot be transported to the field on its own. Either a sledge, a cart or some other method is needed to carry the cultivator to the field.
8. If the animals do not follow the rows well or change rows, crop damage will result. It is difficult to lift the cultivator to keep it from destroying the row crop.
9. Guiding the cultivator requires that the operator watch two rows at the same time. This is difficult and the cultivator is usually set narrow in order to damage the crop, thus resulting in significant uncultivated soil next to the row.
10. Working in non-parallel rows is difficult. Although most inter-row cultivators are designed for quick row width changes, it is still not easy.

These factors may have been the reason for rejecting the technology!

A search of *Tools for Agriculture* (Intermediate Development Group, 1985) did not reveal any cultivator that seemed to overcome the above shortcomings. There are a number of Indian manufactures that build light cultivators which can be lifted by the operator if oxen do not follow the crop row. These cultivators are small and have no easy width adjustment (e.g., Cossul's "R.N. Cultivator" and Mohinder's "Triphali" cultivator). Although they are intended for use by a single operator and can be used for interrow work, the design of these cultivators is for seedbed preparation.

Tools for Agriculture does list many light, adjustable width cultivators. For example, the "Western Hoe Occidentale" made by Sismar, Senegal, the "AC-3" cultivator made by CECOCO, Japan, a row crop hoe made by Alvan Blanch, U.K., and a five-tine adjustable width cultivator made by Eicher Goodearth in India. The "Western Hoe Occidentale" was purchased for testing. Other listed cultivators were considered to be sufficiently similar to the "Western Hoe Occidentale," hence testing was unnecessary.

It should be noted that farmers have rarely adopted the use of the interrow, single row cultivator on a large scale. Row crops have never been important in European or Asian agriculture. Only in North America with the commercialization of maize and cotton growing did row crops become important crops to farmers using DAP. Although initially North American farmers used simple inter-row weeders, these immigrant farmers soon developed the more efficient over-the-row cultivator drawn by two horses (Roosenberg, Villa and Esmay, 1987). These same row crops have now become the main crops in many parts of Africa as is the case in the Mbeya area of Tanzania. But over-the-row cultivators are not generally available.

Tools for Agriculture lists one cultivator designed for over-the-row work sold by Agromet Motoimport, Poland. This cultivator has large wheels which would increase the cost and, as pictured in the guide, has little clearance between the front and rear tines. This lack of clearance would not accommodate the weeds and mud of Mbeya.

Several cultivators were imported and tested. The Sine Houe and Ariana cultivators were tested and rejected for lack of handling ease and maneuverability. The "Western Hoe Occidentale" was tested and was found deficient in ground clearance. It would not work in muddy conditions. Other cultivators listed were not tested.

The MOP Cultivator Design

Design Criteria

After a review of the literature and the testing of the most promising cultivator models, the MOP team decided to design its own cultivator. The cultivator should meet the following design criteria:

1. The new design must be capable of over-the-row work.
2. The cultivator may not cost more than US$50, the price of the available inter-row cultivator.
3. The guiding of the cultivator may not be difficult. The machine must be highly maneuverable.
4. The final design must be able to work under muddy conditions. The nature of the rainy season at Mbeya is such that the soil frequently will not be dry when weeding is necessary.
5. The cultivator must be able to handle thick, tall weed growth (up to 70 mm tall).
6. The machine must be simple. Mbeya farmers are not sophisticated in the adjustment of implements and would probably be overwhelmed by an array of adjustments.

The MOP Over-the-row Cultivator

The result of applying these design considerations is the cultivator shown in **Fig. 2** with additional detail in **Figs. 3** and **4**.

The cultivator is pole-drawn, with a 50 mm × 25 mm × 3.2 mm hollow steel section, as a longitudinal member 600 mm long. To this longitudinal member three cross members of the same material are welded. The front cross member is 600 mm long, the center cross member is 560 mm and the rear cross member is 860 mm. The vertical shanks are all 25 mm × 25 mm × 2.5 mm hollow steel section. The vertical shanks are of a length that give a ground clearance of 300 mm. A mild steel piece, 20 × 12 × 115 mm is drilled to hold the share, and is attached to the vertical shank with a shear pin arrangement. The shear pin consists of a readily available 60 mm nail (2.5 inch common nail).

The wheels (220 mm diameter) have a toe-out of about 15 degrees, which gives the cultivator steerability. As the cultivator is leaned in the direction the operator wishes to move it, the wheel on that side contacts the soil more firmly than the wheel on the other side and the cultivator moves in that direction. The two wheel brackets are so arranged that by interchanging sides the wheels become straight and can then be used for transport. Depth control is achieved by sliding the wheel shanks vertically in a clamp, and by altering the angle of the longitudinal member to the draw pole. The handle is designed for two-handed operation, and the height can be adjusted for operator comfort.

A clamping arrangement allows the adjustment of share shanks on the cross members. A variety of light earth engaging shares, built for use on tractor drawn cultivators are being used. In addition, some mild steel, hard surfaced, shares built in the project workshop are being tested. With six vertical shanks but without the wooden pole, the cultivator has a mass of 33 kg.

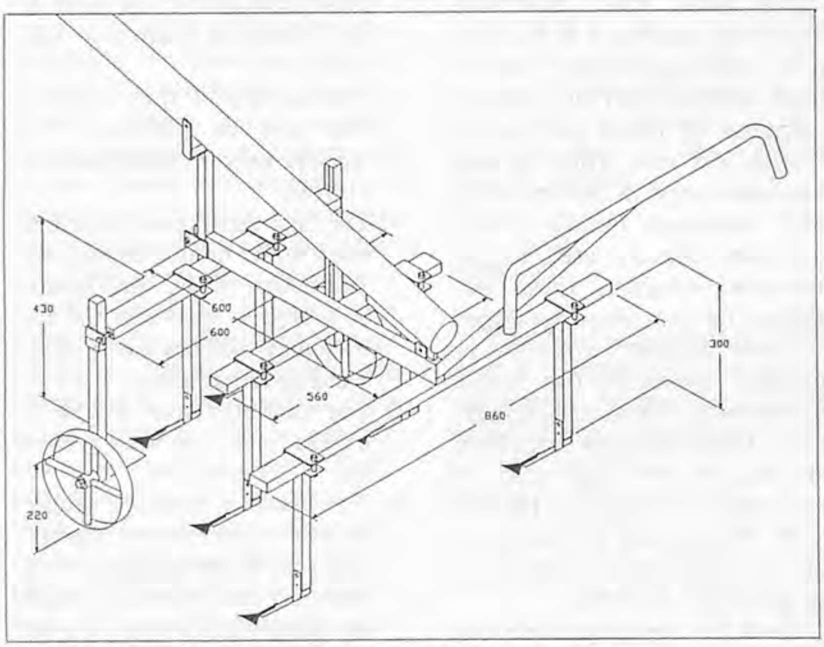

Fig. 2 The Mbeya Oxenization Project over-the-row cultivator.

Advantages of the MOP Over-the-row Cultivator

1. The cultivator is pole-drawn which is unlike most cultivators presently available. With a firm hitch point, the cultivator is more stable and hence more maneuverable than other cultivators.
2. The current ground clearance of 300 mm is adequate for any weed growth.
3. The soils of the region are sandy to clayey loams. These soils can be worked when they are muddy without affecting their structure unduly and are frequently worked in a wet condition. Daily rains are common during the time of most vigorous weed growth such that hand hoeing is common in wet fields. Under these conditions

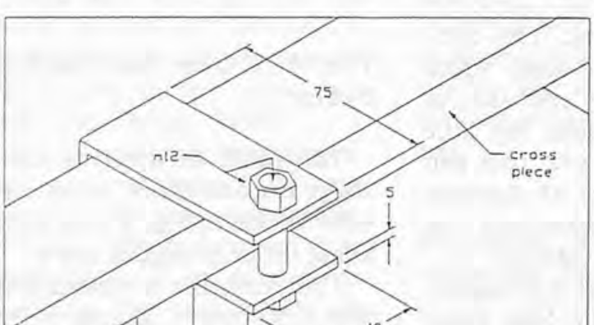

Fig. 3 The vertical shank connection to a cross piece.

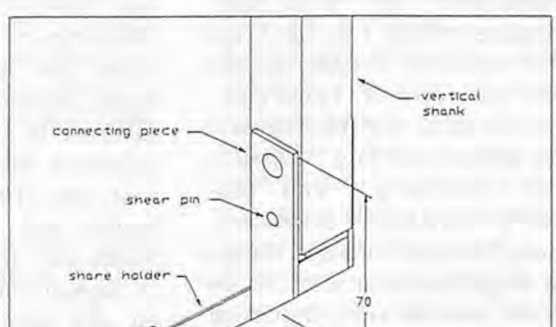

Fig. 4 The vertical shank-share holder connection and shear pin.

50 mm shares work well.

4. The cultivator can be used for pre-planting tillage and as an aid in planting.
5. The wheels allow transportation of the cultivator over short distances.
6. The cultivator is light which adds to its maneuverability.
7. The cultivator is steerable, allowing over-the-row cultivation and resulting in better ground coverage for weed control.
8. It uses a yoke of standard length.

Disadvantages of the MOP Over-the-row Cultivator

1. The wheels are quite small (220 mm diameter), and cannot be used for extensive transport.
2. Because the crop clearance is limited, over-the-row work is not possible after the crop has achieved a certain height of growth.
3. Shear bolt protection of shanks, although adequate, is inconvenient.
4. Construction depends on thick walled hollow rectangular steel section. This section would seldom, if ever, be available in developing countries hence the construction of these cultivators is dependent on direct steel importation.
5. In the interests of economy and maneuverability, the total weight of the cultivator has been kept low. But the penalty for this is that it is now a light cultivator, more vulnerable to breakage.

Testing

In the 1988-89 crop year, 20 farmers from 11 different villages were given a MOP cultivator as well as an Indian made Cossul cultivator. None of the 20 farmers had used a cultivator before but all were familiar with the use of oxen for plowing.

The farmers were visited weekly by project personnel, and encouraged to use the cultivators as they saw fit. The purpose of these visits was to observe how the farmers used the cultivators and to suggest alternate ways of using the cultivators, based both on the ideas of project staff, and also on what was being observed in the fields of other farmers. Care was taken not to prescribe how farmers should use the cultivators. The farmers' suggestions were noted for incorporation into cultivator design alterations.

The 20 farmers who were given the two cultivators were initially skeptical. Fifteen of the farmers are now enthusiastic cultivator users and five neighbors have purchased cultivators. Sixteen of the farmers chose to use the cultivator to open furrow rows for planting.

A major problem with the Cossul cultivator has been breakage. The project team ensured that any breakage was promptly attended to. It is too early to tell which cultivator is preferred.

Observations and Discussion

The weight of the current model, using a thick (120 mm diameter) bamboo or a thinner wooden pole, is such that one can pick up and carry the cultivator when oxen do not follow the row. The cultivator can then be set down once control of the oxen is regained. Farmers have appreciated this feature.

The vertical clearance of the current models has been adequate for all weed growth encountered. Greater clearance would be desirable to allow work in more mature crops. But more clearance also means longer vertical members which increases the weight and the bending moment on the shanks.

Fifty mm wide shares worked well under most conditions. In sandy soils, wider shares could also be used.

The use of the cultivator for seedbed preparation and planting was not anticipated. The use of the cultivator for this purpose developed as a result of farmers' initiative. The shares can be rearranged to give soil coverage equal to the width of the cultivator. Locally made 150 mm wide lister shares are used on the outermost rear shanks. This arrangement creates two furrows 900 mm apart. Thus, when a 900 mm (center to center) yoke is used, it is possible for the furrow ox to walk in a furrow while a planting furrow is opened 900 mm over. This arrangement offers two advantages:

1. The ox team is much easier to guide, especially if the furrow ox has previously been used for plowing and is accustomed to walking in a furrow.
2. All of the soil surface is worked and a planting furrow is opened as well.

The above advantages are more significant than might be first realized. The local farming system is in transition from an almost total hand operation to a more mechanized system. The newly adopted draft animals are not well trained and the inability to accurately guide the animals seems to dissuade farmers from using mechanized weeding in row crops. Primary tillage is always done before the rains begin so that when the heavier planting rains arrive the weeds have usually already germinated. When weeding is completely a hand operation it is immaterial whether weeding is done prior to planting or after crop emergence. With mechanized weeding there is a significant gain in labor economy when weeding is done prior to planting. This fact is not immediately perceived by the farmers. The combination cultivator/furrow opener facilitates the change in farming practices. Early indications are that farmers will adopt this practice before they adopt inter-row weeding.

Spring shanks clean better and do not plug as easily as rigid shanks. The MOP project team tried fitting the cultivator with "S" tines as commonly used with tractor-drawn cultivators. Fitted in this way, the cultivator was too bouncy for effective steering. Furthermore, the cost of the spring shanks doubled the cost of the cultivator.

Oxen, accustomed only to plowing with a chain-drawn plow, have some initial difficulty with the pole but adjust quickly. The MOP design team have found it unwise to take a new team of oxen, however well trained, directly into the field of row crop. It is preferable to have the team spend some time pulling the cultivator on a piece of land with no crop before moving into the row crop.

It seems that oxen adjust to this system of cultivation more easily than to the wide yoke needed to straddle two crop rows which is necessary with the interrow cultivator. After the initial resistance to the pole, oxen accustomed to plowing performed well. Other oxen, accustomed to carting, have had no problem in adjusting to the system.

It seems that farmers understand this to be a light-duty cultivator and, therefore, treat it with respect. The shear pin consisting of a readily available 60 mm nail (2.5 inch common nail) appears to give the cultivator sufficient protection yet is strong enough in normal operation. Early indications are that farmers understand this devise.

It is not clear yet to what extent the operation of this cultivator can become a one-person operation. The North American over-the-row system was a one-man operation made possible because the cultivator was a riding machine that the operator steered with his feet leaving his hands free to rein the horses. With the present design, steering with the feet is impossible. However, some of the cooperating farmers maintain that they will be able to control the oxen with voiced commands leaving their hands free to steer the cultivator. This has not yet been effectively demonstrated. Some people feel that the new cultivator will only be effective once the voice controlled system of guiding the oxen is replaced by a more precise way of guiding. The project team members have tried not to show bias to the over-the-row cultivator but most farmers seem to be showing a preference for the MOP design.

Conclusion

If the assumptions are correct, farmers will find that the MOP cultivator enables them to carry out their weeding at the optimum time more easily. In this way the cultivator will contribute to increased yields. It will allow them to have adequate control of their oxen so crop damage will be minimized. It will reduce the high labor demand of weeding. If this is the case, farmers will respond by purchasing the cultivator and using it extensively.

Recommendations

Closer examination of farmer's reaction to design in the following areas is needed:

1. Handle design — Farmers are accustomed to two-handed walking plows. For this reason initial models were designed for use with two hands. But a cultivator designed for single hand use may be adequate and acceptable. Furthermore, it is not evident that the height adjustment on the handle is necessary. Simplification in these two items would lead to a cheaper tool.
2. Reducing the weight has lead to a problem of strength. Initial indications are that strength is adequate, but on-farm testing must continue. It is not yet evident to what extent farmers understand that this is a light duty cultivator and, therefore, treat it accordingly. Is the shear pin consisting of a readily available 60 mm nail (2.5 inch common nail) the right protection? Other sizes and types of frame members and alternate placement of gussets and other reinforcements should be tried.
3. Project management will need to decide how to tackle the clearance problem. This could be done in several ways and farmers' response will determine which one is chosen.
   a. If weed control is adequate during the early stages of crop growth, later weeding when cultivator clearance is a problem may not be necessary. Education may be sufficient to correct the problem. Tests should still be conducted on alternate vertical clearances.
   b. A small modification (making the longest cross member removable), allows the use of the over-the-row cultivator as an inter-row cultivator, in which case vertical clearance is not necessary.
   c. A ridger would effectively complement the over-the-row cultivator. This would increase the capital cost burden on farmers, but used with cross ties once the crop is well established, ridging reduces water runoff and erosion as well as crop lodg-

ing. These benefits may offset the capital cost.

4. Venues where farmers exchange ox and tool handling techniques, such as plowing competitions, need to be encouraged.
5. Further examination as to which system of ox guidance is most suitable needs to be carried out. Acceptability on the part of farmers is crucial.
6. The 15 degree toe-out on the wheels is arbitrary. Further work is needed as to what the optimum toe-out might be or even if any toe-out is needed.
7. A test marketing survey will be needed before any equipment such as the MOP can be marketed with confidence.

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Mechanical Expression of Oil from Mustard Seeds

by
Y.S. Reddy
M. Tech. Student
Post Harvest Technology Centre
Indian Institute of Technology
Kharagpur 721302, India

N.G. Bohle
Prof.
Post Harvest Technology Centre
Indian Institute of Technology
Kharagpur 721302, India

Abstract

Investigations were conducted on the mechanical extraction of oil from mustard seeds (Brown sarasoon) of commercial variety Varuna in a laboratory press. The processing variables were moisture content, applied pressure and pressing time. Quality parameters of oil such as FFA, colour, specific gravity and iodine value were also studied.

Experiments were designed by the Central Composite Rotatable Design (ÇCRD) employing a process optimization technique termed Response Surface Methodology (RSM) and prediction equation was developed for oil yield. Response surfaces were generated by predicting the values from the prediction equation.

The mustard seeds were manually cleaned and passed through a 0.6-mm sieve. Calculated amount of water was added for desired moisture content and pressed in a laboratory press twice. Maximum oil yield of 28.93 per cent was obtained at 8.7% moisture content (wet basis), 7.848 MPa applied pressure and 70-min pressing time. The mustard oil gave a dirty yellow colour, specific gravity of 0.9079, iodine value of 98 and FFA of 1.01%. These properties were not affected by processing conditions.

Introduction

Mustard seed (Brown sarasoon) is a very popular oil seed in India. It contains 40.8 percent oil by weight. Traditionally oil is extracted or expressed from the seeds for edible purposes while the residual cake is utilised as feed for cattle and poultry. The oil is also used in the manufacture of margarine, shortening and cooking oils.

The local method of oil extraction from mustard seed consists of cleaning of dried seed and extraction of oil by animal or power "ghanis". This method is slow, inefficient and labour-intensive. Recent needs have, however, motivated the production of mustard oil on large scale with the use of a screw and hydraulic press. This requires a systematic investigation of the process conditions by which good quality oil can be efficiently extracted from the seed. The use of an hydraulic press for extraction of oil from oilseeds is appropriate for small and medium scale farmers in developing countries because of its lower initial and operating costs compared with the use of screw press and solvent extraction process. The small and medium scale farmers represent the majority of food producers in these countries and also it fits into the government's plan of rural industrialization.

Efficient extraction of oil from oilseeds using the hydraulic press requires size reduction of the oilseeds, followed by heat treatment and application of pressure. The amount of oil extracted is dependent on particle size, moisture content of the seed, heating temperature, heating time, applied pressure and pressing time. Athmer and Agarwal (1955) explained that the inability to extract oil from whole and half soybeans clearly indicated that cell walls must be broken by flaking operations to allow the oil to be removed from the otherwise impervious cells.

Singh et al (1984) concluded that the moisture content of sunflower seeds was the most significant factor affecting the expression of oil from the seed. A moisture content of 6% (wet basis) was found to be optimum for expression of oil from peanut and sunflower seeds. Heating of oilseeds increased the oil yield due to break-down of oil cells and coagulation of protein. Adjustment of moisture content of the meal to the optimal value for pressing decreases the oil viscosity which, in turn, allowed the oil to flow more readily.

Dedio and Dorell (1977) stated that increasing the pressure beyond 86.78 MPa had relatively small effect on quantity of oil extracted from the flax seeds. Increasing the moisture content of the seeds from 8 to 16 percent resulted in a dramatic drop of total oil recovery from 54.7% to 4.4%. Sukumaran and Singh

(1983) found that with the increase in moisture content, the pressure needed to release the oil from the oil-containing cellular structure of the rapeseed also increased, mainly because of the plasticizing effect of the moisture. This phenomenon could also be due to the cushioning effect caused by the moisture-induced swelling of the mucilage of the outer epidermal cells. Fascina and Ajibola (1989) studied oil expression from canophor nut and concluded that the amount of heat treatment given to samples, moisture content after heating and applied pressure were the most significant factors affecting the yield of oil expressed mechanically. The oil yield increased with increase in moisture content of samples after heating up to between 7.4% and 9.1% (wet basis) and then decreased with further increase in moisture content. They also found that this effect is true in the case of melon seeds. The highest oil yield of 41% was obtained, at an expression pressure of 25 MPa, when conditioned to initial moisture content of 9% to 12% (wet basis) which were heated to achieve a moisture content reduction of about 5%. This yield corresponds to an expression efficiency of 80% compared to melon oil content of 51%. Further reduction in moisture content did not increase the oil yield from the samples.

No study is known to have identified the effects of processing factors on oil yield from mustard seeds. Some properties of oils that can be used to determine quality are specific gravity, colour, iodine value and FFA. The specific gravity of oil is of diagnostic value in the consideration of the quality or purity of the oil and is used in assessing the weight of oil in bulk shipments or stored in large tanks.

The study was carried out, therefore, to investigate the effects of moisture content, applied pressure and pressing time on the yield and quality attributes of oil expressed from mustard seeds.

Table 1 Levels, Coded Values and Intervals of Variation of Factors Included in CCRD

Factors	Codes	Levels					Interval of Variation
		−1.682	−1	0	+1	+1.682	
Moisture content, % (wb)	X_1	8.15	8.70	9.50	10.30	10.85	0.8
Applied pressure, MPa	X_2	2.586	3.924	5.886	7.848	9.186	1.962
Pressing time, min	X_3	43.18	50	60	70	76.82	10

Table 2 Level Combinations for a 3-variable Central Composite Rotatable Design (CCRD) to Optimize Oil Yield from Mustard Seed

Treatment No.	Coded values of the factors			Oil yield (%)	
	X_1	X_2	X_3	Observed (Y')	Predicted (Y'')
1	−1	−1	−1	23.51	22.78
2	+1	−1	−1	19.88	19.21
3	−1	+1	−1	27.12	26.72
4	+1	+1	−1	21.24	20.89
5	−1	−1	+1	24.86	24.57
6	+1	−1	+1	20.78	20.56
7	−1	+1	+1	28.93	28.96
8	+1	+1	+1	22.60	22.69
9	−1.682	0	0	28.02	28.54
10	+1.682	0	0	19.89	20.27
11	0	−1.682	0	17.63	18.46
12	0	+1.682	0	23.50	23.57
13	0	0	−1.682	22.15	23.13
14	0	0	+1.682	26.22	26.15
15	0	0	0	23.96	24.25
16	0	0	0	24.41	24.25
17	0	0	0	24.41	24.25
18	0	0	0	23.96	24.25
19	0	0	0	24.10	24.25
20	0	0	0	24.86	24.25

Each treatment was replicated twice for a total of 40 treatments

Materials and Methods

Experimental Design

In order to determine the effects of individual factors on oil yield from mustard seeds, the experiments were designed for fitting second order model using Central Composite Rotatable Design (CCRD) (Montgomery, 1976). The design chosen was a 2^3 factorial design and CCRD is made rotatable by the value of α i.e., $2^{3/4}$. The factors included in the design were moisture content (8.15-10.85% wet basis), applied pressure (2.586-9.186 MPa) and pressing time (43.18-76.82 min.). The range of each factor was selected based on preliminary experiments. A 3 factor, 5 level CCRD of Box et al (1978) was used for fitting second order response surfaces. The coded levels of −1.682, −1, 0, +1, +1.682 used in a 3 factor CCRD (**Table 2**) were obtained from Box et al (1978) and the value of coded levels and intervals of variation of the variables used in the CCRD are shown in **Table 1**.

Natural values (levels) of the factors corresponding to the coded values shown in the **Table 1** are obtained from the formula as follows:

$$X_j = \frac{X_j - X_{jo}}{j}$$

where,

x_j = Coded value of the factor
X_j = Natural value of the factor
X_{jo} = Natural value of the base level of the factor, i.e., average of initial and final values of the factor
j = Interval of variation of the factor

Laboratory Press

The expression of oil from mustard seeds was carried out

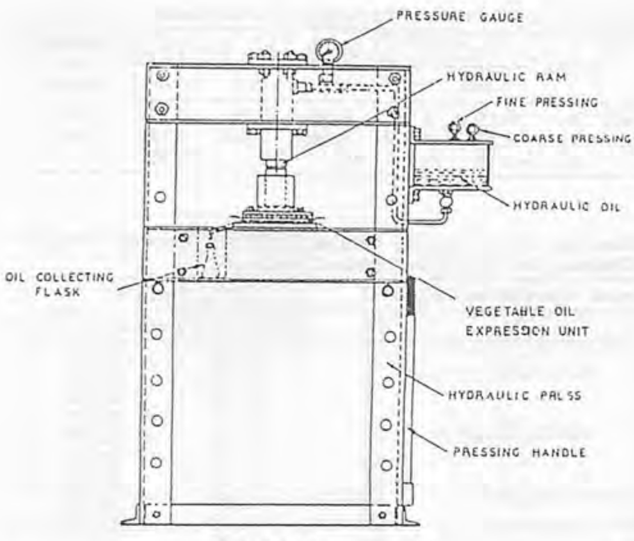

Fig. 1 Laboratory hydraulic press.

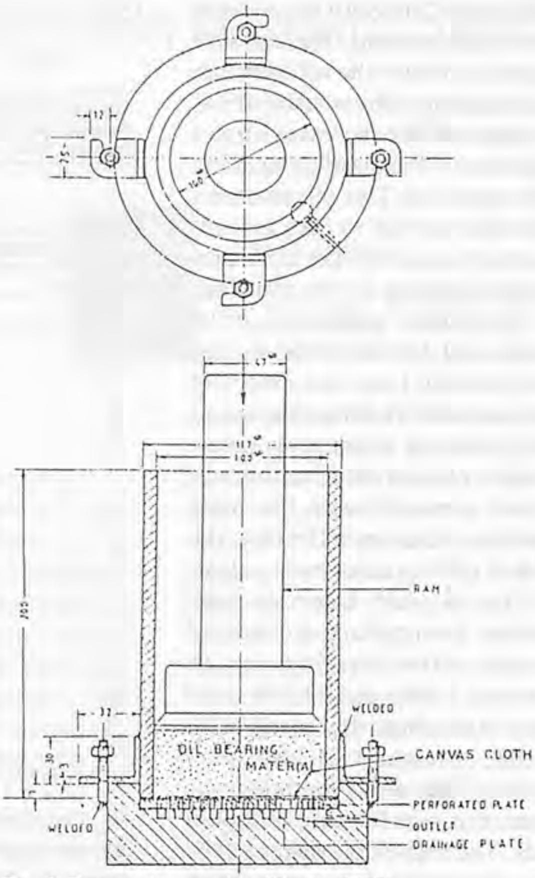

Fig. 2 Press unit assembly (Sivala, 1989).

using a laboratory press shown in **Fig. 1**. It is a 20-tonne hydraulic press with a press unit assembly. The press unit consists of bottom drainage plate with outlet, perforated plate, canvass cloth as strainer, pressing ram and hollow cylinder.

The bottom drainage plate made of mild steel provides 5 mm wide and 5 mm deep channels at an interval of 5 mm over an area of 100 mm dia of the plate. A slope of 0.01% was provided for free flow of oil towards the outlet. A nozzle was attached to the outlet for unidirectional flow of oil for collection. A perforated plate with 3 mm diameter drilled holes, exactly fits in the bottom drainage plate and the two plates act as one single unit in operation. A circular canvass cloth having a diameter exactly matching with the perforated plate as well as with the external diameter of the hollow cylinder placed on the top of the perforated plate. The pressing ram made of mild steel with 47 mm diameter at top and 100 mm diameter at bottom. The length of the ram was 220 mm. The pressing ram distributes the pressure over the sample. A hollow cylinder of 100 mm internal diameter and 117 mm external diameter and a height of 200 mm was used for pressing the seeds.

Test Procedure

The mustard seeds used in the study were obtained from the Agricultural Engineering Department Farm, I.I.T, Kharagpur. The dried seeds were cleaned and milled to the desired particle size (0.6 mm sieve). Samples of ground mustard seed were then adjusted to the various moisture contents considered in the study. A calculated amount of water was sprayed on the samples to increase the moisture contents to the desired levels and the samples were pressed immediately.

The sample of 100 g was weighed and poured into the hollow cylinder. The bottom of the hollow cylinder rested over the canvass cloth laid on the perforated plate. The samples were leveled off before application of the load. The initial height of the sample was recorded (26.6 mm). The assembled setup was placed concentrically on the platform of the hydraulic press **(Fig. 1)**. The load was gradually applield up to the desired level and maintained constant for the requisite pressing time. The pressure intensity was calculated by noting the magnitude of load from the dial and dividing it by the area of the ram (78.5 cm^2). At the end of the desired pressing time, the pressure was released and the cake was removed by turning the hollow cylinder counter-clockwise. The pressed samples were broken and again poured into the cleaned press unit for second pressing. The pressing time for the two pressings was identical. The sum of the time taken for two pressings was taken as the pressing time in the experimental design. At the end of the second pressing, oil collected was measured with the measuring cylinder and expressed as a percentage of bone dry material.

Analytical Methods

The moisture content of the samples was determined by oven drying 100 g of sample at 130°C for 6 h as recommended by Young et al. for oil seeds with high oil contents. The particle size analysis was performed for milled samples according to ASAE standard S319 which involved the use of a set of standard sieves. The AOAC direct gravimetric method of soxhlet extraction was used in the determination of the oil content of the ground seed and meal. A Lovibond Tintometer was used in the determination of oil colour. A 10 ml specific gravity bottle was used for determining the specific gravity of oil samples. The FFA of oil was determined by titration using methonolic sodium hydroxide solution. The iodine value was determined by wijjs method.

Statistical Analysis

The statistical analysis (correlation coefficient) was made through a computer program written for RSM analysis and three dimensional response graphs were drawn by hand.

Results and Discussion

The initial regression equation obtained after the analysis of data (**Table 2**) for oil yield is as follows:

$$Y' = 24.2521 - 2.4592X_1 + 1.51745X_2 + 0.89887X_3 + 0.05467X_1^2 - 1.14416X_2^2 + 0.13601X_3^2 - 0.56375X_1X_2 - 0.11125X_1X_3 + 0.11375X_2X_3 \quad (r = 0.986) \quad ...(1)$$

Where Y' is the predicted oil yield in per cent and X_1, X_2 and X_3 take only the following coded values of the variables.

$$X_1 = \frac{\text{Moisture content (M)} - 9.5}{0.8} \quad ...(2)$$

$$X_2 = \frac{\text{Applied pressure (MPa)} - 5.886}{1.962} \quad ...(3)$$

$$X_3 = \frac{\text{Pressing time (T)} - 60}{10} \quad ...(4)$$

Eq.1 can be expressed in terms of the natural values of variables by substituting the values of X_1, X_2 and X_3 from Eq.2 through Eq.4.

$$Y' = 19.85214 - 1.74831M + 7.33665P + 0.024707T + 0.08542M^2 - 0.29723P^2 + 0.00136T^2 - 0.35917MP - 0.01391MT + 0.005798PT \quad ...(5)$$

From **Table 2** it can be seen that maximum oil yield of 28.93% was obtained at 8.7% moisture content (wet basis), 7.848 MP applied pressure and 70 min pressing time. The minimum oil yield of 17.63% was obtained at 9.5% moisture content (wet basis), 2.586 MPa applied pressure and 60 min pressing time.

The response surfaces of oil yield presented in **Figs. 3** and **4** were generated by predicting the values from Eq.5 for different range of variables studied.

The effect of applied pressure and pressing time at 8.7% moisture content is shown in **Fig. 3**. Increasing the applied pressure from 3.924 MPa to 7.848 MPa and pressing time from 50 min to 70 min, increased the oil yield at a higher rate of up to 5.886 MPa. Beyond this pressure, the rate of oil yield declined. The

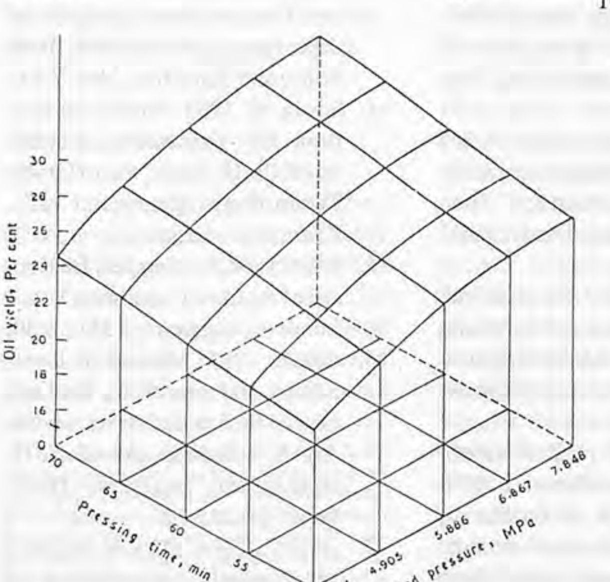

Fig. 3 Response surface of oil yield at 8.7% moisture content (w.b.).

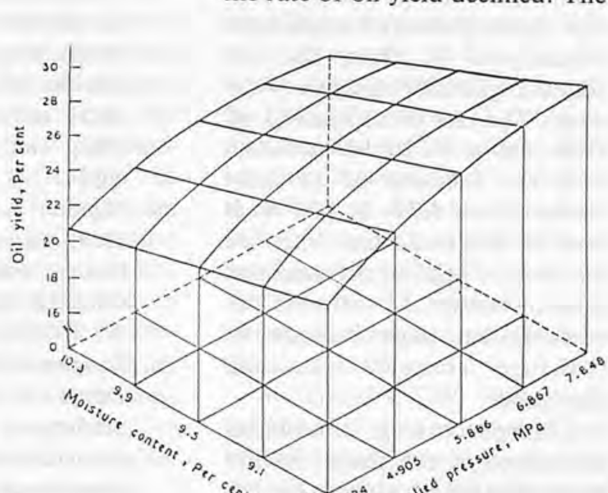

Fig. 4 Response surface of oil yield at 70 min pressing time.

Table 3 Some Properties of Mustard Oil

Properties	Literature Values	Measured (average)	Measured (standard deviation)	Measured (range)
Specific gravity	0.913	0.908	0.001	0.907-0.909
Colour	DR	DR	—	—
Free fatty acids, (%)	2.00	1.01	0.11	0.90-1.12
Iodine value	99	98	2	96-100

lowest and highest oil yields of 22.78% and 28.93% were observed at 3.924 MPa applied pressure for 50 min pressing time and 7.848 MPa applied pressure, 70 min pressing time, respectively, the initial oil content being 40.08%. The optimum treatment combination for maximum oil yield of 28.93% was thus 8.7% moisture content (wet basis), 7.848 MPa applied pressure and 70 minute pressing time. The rate of oil yield increase was more or less uniform with the increase of pressing time from 50 min to 70 min.

Fig. 4 shows the response of oil yield at 70-minute pressing time. Increasing the moisture content from 8.7 to 10.3 percent and applied pressure from 3.924 MPa to 7.848 MPa decreased the oil yield from 24.573% to 22.694%. This decrease in oil yield accompanied by an increase of moisture content might be due to the plasticizing effect of the moisture. With the increase of moisture content, higher pressure is required to release the oil from the oil-containing cellular structure of the seeds. The rate of decrease in oil yield was more or less uniform with the increase of moisture content from 8.7% to 10.3%. It can be deduced that with the increase of applied pressure and pressing time, the oil yield increased, but with increase of moisture content oil yield decreased.

The processing conditions considered in the study did not have significant effects on the colour, specific gravity, FFA and iodine value of oil. **Table 3** shows the average values of properties which were close to values quoted in the literature.

Conclusion

The oil yield was significantly affected by moisture content of milled mustard seeds, applied pressure and pressing time. For the range of variables considered in the study, the maximum oil yield of 28.93% was obtained from the milled mustard seeds (0.6 mm sieve) conditioned to a moisture content of 8.7%, pressed for 70 min at 7.848 MPa applied pressure.

The processing conditions at the levels used did not adversely affect the colour, specific gravity, FFA and iodine value of mustard oil.

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Evaluation of Swaziland's Tractor Hiring Services

by
Edgar T. Dante
Res. Assoc.
Agric. and Food Eng. Dept.
Asian Institute of Technology
G.P.O. Box 2754, Bangkok 10501
Thailand

Abstract

Swaziland's tractor hiring service (THS) has effectively introduced the use of tractors to the farmers throughout the country. Tractors replaced ox cultivation but their use has not resulted in a significant increase in crop production. As it operates under a centralized government authority, the service suffered huge financial losses and experienced numerous operational and organizational difficulties. Recommendations to improve the performance of THS include making the service self-governing, supporting the growth of private THS, improving quality of tractor works and extending appropriate staff development and motivation schemes.

Introduction

In many agrarian countries, making agriculture considerably productive and efficient has often been seen as the most effective means of attaining real economic development. This implies a gradual shift from the traditional methods of farming to a more efficient mechanized farming system. But mechanization normally requires high capital expense that an average farmer cannot afford. Thus, to introduce mechanization, government support is usually necessary.

Tractor hiring service (THS) is a typical government program aimed at mechanizing agriculture operations without imposing high capital acquisition costs on the farmers. The aims of THS are varied among countries. Some of these objectives are to increase crop production, to open new lands for cultivation and resettlement, to demonstrate the use and benefit of new technology and to encourage the modernization of traditional agricultural system (Pingali et al, 1987).

This paper summarizes the findings of the evaluation study conducted in conjunction with the "Management for Rural Development" training course at the Mananga Agricultural Management Centre (MAMC) in Swaziland in 1988. The objectives of the sutdy were to understand the operational and organizational problems of the THS and to suggest means to improve its efficiency and effectiveness. It is hoped that recommendations presented in this paper may be useful and relevant in other developing countries as well.

The study was conducted through visits and interviews of tractor operators, tractor pool supervisors, mechanization officer and technical advisor. Visits to selected farmers and farm managers were also done. Supplementary data were obtained from review of THS documents which were made available through the Ministry of Agriculture and the MAMC Library. Most of the recommendations and conclusions have been derived through class discussions and brain storming sessions involving 35 rural development officers from various countries in Africa.

Background and THS Organizational Structure

Swaziland is a subtropical country located in southern Africa with an area of 17 363 km^2 extending 176 km north to south and 135 km east to west. It borders with South Africa and Mozambique. In 1986, there were 0.6 million Swazis. About 82% of the total land area is classified as agricultural land. Sugarcane accounted for 75% of the total value of agricultural production. Other principal crops include cotton, corn, pineapple, orange, potato and rice (Kurian, 1987).

Swaziland's THS was established in 1974 as an integral part of the Rural Development Area (RDA) program of the Ministry of Agriculture (MA). It received seed money from the British govern-

Acknowledgement: Contributors from the participants of the first "Management for Rural Development" (MRD1) course at the Mananga Agricultural Management Centre, Swaziland are highly acknowledged. Special thanks to Dr. A. Dorward, the course director, for arranging all visits and interviews and the Netherlands government through the MAMC for providing financial support.

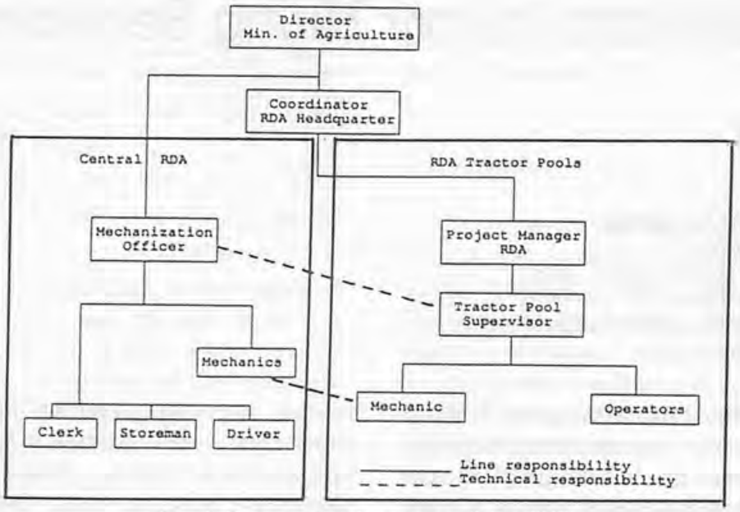

Fig. 1 Organizational structure of the THS.

ment which also supplied a great deal of its institutional framework and provided training to the first group of THS staff. As a non-profit extension service to the farmers, the THS was presumed to become self-sufficient after six years of operation (the assumed economic life of a tractor) and thus eventually be handed over to a suitable farmer's association. Until 1988, however, the project has remained under the MA because it was thought that no such suitable farmer's association or private entities existed that could operate the service satisfactorily (Ministry of Agriculture, 1980).

The organization of the THS is illustrated in **Fig. 1**. The Director of Agriculture serves as the overall managing director of the RDA program with the RDA coordinator and THS mechanization officer (MO) under him. Though the organizational structure shows that the MO is directly responsible to the Director of Agriculture, he, in fact, works very closely with the RDA coordinator. Each tractor pool is staffed with one pool supervisor, one semi-skilled mechanic, and tractor operators. The pool supervisor is directly responsible to the RDA project manager but has a technical responsibility to the MO at the central RDA.

The basis of the organization is the establishment of small tractor pools in each RDA. The number of tractor pools grew from six in 1974 to nine in 1988. Each pool had, on the average, four standard tractors of different sizes. At the national level, there is a central facility which provided major repair and maintenance of the tractor pools as well as supervised all mechanization activities of the service.

Has the THS Achieved It's Objectives?

The main objectives of the THS were to stimulate interest in mechanization and to create a demand for it, to augment the production of corn and to encourage the development of private sector tractor hiring. The prospects for success of these objectives are discussed below.

The THS has, in fact, created awareness of and demand for the tractor service. The queues of impatient people anxious to avail of the tractor and the increase in the number of tractors are proofs of this. Also, as reported, the four tractors assigned to each tractor pool can only satisfy 75% of the total demand in any RDA (Ministry of Agriculture, 1977).

Unexpectedly, the introduction of the THS has not resulted in increased corn production in the country. The Ministry of Agriculture suspects that this apparent failure of the THS to increase maize production is caused by the majority of the customers who use the tractor simply as a replacement of the traditional ox cultivation and not as an aid to increase cropping intensity or expand the area of cultivation (Ministry of Agriculture, 1980). In fact, the production of maize since the start of the THS in 1974 to 1983 has gradually declined along with the decrease in area harvested **(Fig. 2)**.

The THS has also failed to stimulate the growth of private tractor hiring service which was the underlying aim of the THS.

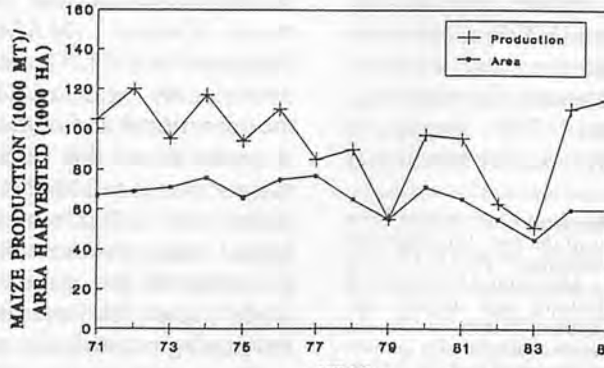

Fig. 2 Maize production and ara harvested, 1971-85.

Most of the private tractor hire businesses seemed to have ceased to exist for the simple reason that tehy cannot compete with the government's subsidized tractor hiring rates and were unable to meet the repair and maintenance cost of the tractor.

Finally, the project, after 14 years of operation, has not become self-sufficient but rather still dependent on government subsidy.

Management and Operational Problems

There have been a number of problems both in management and operation aspects which greatly affected the performance and thus the overall level of success of the THS. These problems are: inappropriate organizational setup, lack of financial autonomy, lack of incentives for the staff, poor quality of tractor works, concurrent and time-bound operations.

Inappropriate Organizational Set-up

The management of the THS were mainly due to the conflict between the role of the RDA project manager and the MO towards the THS staff. To note, MO has only technical responsibility towards the THS staff. Thus, he has no authority of employing THS staff, though he can recommend to the RDA project manager. The MO has also no right to take disciplinary action on the THS staff. This creates problems to the MO because some of the THS were inappropriately selected. For example, one tractor pool supervisor, an animal science graduate, confessed that she does not know well about the tractor and has not had any formal training concerning her job. One tractor operator also expressed confusion as to whom he should report to because it seems there are two bosses in the organization.

Lack of Financial Autonomy

The THS project does not operate as a self-accounting unit nor does it operate with its own bank accounts. All hire revenue are deposited regularly the Ministry of Finance while the THS operating expenditures are taken from an annual budget allocated by the government. With this system, all purchases made by the project follow the long and bureaucratic government accounting procedures which result in serious delays and sometimes difficulty in acquiring important tractor spare parts.

Lack of Incentives for the Staff

Since the service was handed over to the government, all THS staff were henceforth treated as established civil servants and subject to civil service rules and regulations. Since salaries are not tied to the number of hours worked there is no incentive to work longer hours, even in the peak season. This resulted in the drastic decline of tractor utilization since 1980. In the first five years of the service, a tractor can work up to 800-1000 h per year compared to 300-400 h per year in later years.

Concurrent and Time-Bound Operations

Many problems emerged because of the concurrent and time-bound nature of tractor operations, needs to be done within a particular region at the same time and usually within a short period of time. First, available tractor units wre sometimes insufficient to cater to the demand during the peak season. Thus, difficulty ensured in terms of which the farmers are to be served. Second, with the tractors overworked during peak season, breakdowns and lack of spare parts became a serious problem. The problem became more complicated by the fact that purchase of spare parts still follow the long and bureaucratic accounting procedures of the MA. Finally, when the machines should be working around the clock, the service was often held back by incentive problems with operators who will work only within the regulation eight-hour day.

Poor Quality of Tractor Works

As a practical matter, there have been substantial difficulties in meeting a satisfactory quality of tractor works because some of the regulations, evaluation criteria, and incentives did not emphasize this factor. For example, one merit system rewards a tractor operator who can attain a desired level of tractor utilization, i.e., number of hectares per year. To achieve this, some tractor drivers only considered plowing a greater area of land and did not pay attention to the quality of their work. In addition, tractor operators were also required to economize on fuel consumption. To achieve this, they took various steps that harmed the quality of their work. The most common is by shallow plowing at high speed.

Can Swaziland's THS Do Better?

The THS has, in fact, played a significant role in the modernization of Swaziland agriculture. Its 14 years of operation has already created dependence of the farmers on mechanization in their farm power needs. But there are many defects in the operation and management of the service which resulted in a considerable financial loss. While it is vital to retain the service to farmers, it is equally important to implement changes so as to minimize financial losses and improve tractor utilization. Changes are recommended in the following areas: management and organizational structure, staff development and motivation, developing private tractor hire service and improving the quality of tractor work.

Management and Organizational Structure

The THS should be made a self-governing organization. Decisions on the operation to be performed, prices to be charged, and so on, are better made by the MO than by a centralized government authority. Being self-governing, the THS should have an independent organizational structure headed by the MO which will then have both functional and technical responsibilities towards the tractor supervisors, mechanics and operators. He will become fully responsible for selecting THS staff.

Financial Autonomy

Working capital must be granted by the government at the start of the reorganization, after which the service should be allowed to operate at self-accounting. THS revenue will be deposited in a THS account and the purchase of spare parts should come from this THS account.

Staff Development and Motivation

A built-in training program must be developed within the THS organization to cater to the needs of all the THS staff. In addition, opportunities for technical and managerial training within or outside the country must be made available equally to the THS staff. To provide incentives to the THS staff, higher salary scale and overtime pay should be given.

Developing Private THS

More explicit attention could be paid in encouraging the growth of private tractor hire. To make this possible, the government service should not compete with private hire businesses. Rather, it should provide complementary and support services to them. One approach is the division of tractor works. For example, opening new land for cultivation and settlement which requires heavy and specialized equipment could conceivably be provided by the government while the plowing and transport could be left for the private hire businesses. During the peak season, when the private hire service cannot cope with the emand, the government's tractor fleet can be used as a supplement. To support the development of the private tractor hire, the following practical approaches may be considered:

1. Regular training program in business management and technical aspects,
2. Credit/leasing system for machinery purchases,
3. At national tractor pool level, maintenance, technical and management consultancy/support should be provided to private operators, and
4. Formation of an operators' association.

Improving Quality of Tracrtor Work

THS workers should particularly be concerned about the relationship of the THS with the farming community it serves and to pay special attention to timeliness and quality of work. A policy emphasizing these significant factors must be put on top priority. There are many possible means to implement such policy. First, farmers should take part in the performance evaluation of the tractor operators. They may be allowed to recommend the dismissal of highly undesirable operators. Second, pool supervisors should constantly monitor and supervise the tractor operators while working at the field.

Conclusions

Swaziland's THS has played a leading role in the successful transformation of the country's farming system from traditional ox cultivation to modern mechanized farming. It has demonstrated the benefits of using tractor in terms of convenience and timeliness in farming. However, many of the expectations of the THS have not been realized. Crop production has not increased significantly and the THS has remained dependent on government subsidy. Being integrated with a centralized government authority, THS operations became inefficient as all purchases followed long and bureaucratic accounting procedures. Performance of the THS could be greatly improved by making it self-governing and self-accounting.

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Yam Tuber Response to Different Levels of Soil Compaction

by
Lawrence O. Fawole
Senior Lecturer (Agric. Mechanization)
Agronomy Dept.
University of Ibadan
Ibadan, Nigeria

Emilolorun A. Aiyelari
Lecturer (Agric. Mechanization)
Agronomy Dept.
University of Ibadan
Ibadan, Nigeria

Abstract

The influence of soil compaction on growth characteristics was observed by growing yams in soils of five levels of bulk densities ranging from 1.24 to 1.96 g/cm^3. This was to ascertain the predictability of the depth of growth from a knowledge of soil characteristics and yam species. The experimental results show that within the limits of the experiment, there was no significant correlation between length/depth and soil bulk density although the average girth of tubers produced increased with increasing bulk densities.

Introduction

Yams are positively geotropic in soils of good tilth devoid of obstructions like stones, roots and hard pans. The depth of the tuber is unpredictable but the shape remains cylindrical until the growth point encounters an obstruction. Evasive action results in the amorphous shape, branching, broadening and bending, often seen in yams **(Fig. 1)**.

Although there is a dearth of information on the behaviour of tuberous crops to varying soil bulk densities or soil compactions, much has been done on the effect of soil compaction on shoots and root development in grasses and some legumes. Kayombo and Lal (1984) in their work on cassava (*Manihot utilisima*) observed that a 2-pass compaction treatment of a tractor mounted 2-ton roller (bulk density not determined) had no consistent effect on the tuber yield, but the 4-pass compaction (bulk density not determined) treatment, however, resulted in decreased fresh tuber yield. Although they concluded that cassava can withstand more soil compaction than grain crops, the same result or assertion may or may not hold for yam in view of its growing pattern which differs considerably from that of cassava.

When yams grow too deep into the soil, they become very difficult to harvest even by the most efficient harvesting technique. It is projected that if a highly compacted layer of soil is used to replace the hard pan, roots or stems all causing obstructions to its downward growth, the depth of growth and tuber shape may become predictable but assorted shapes of tubers should be expected. This present work was, therefore, set up to see how yam tubers will respond to different levels of obstructions — degrees of compaction and also to see whether the depth and width of growth can be predicted to some extent. These two parameters are very important, particularly in designing an appropriate harvesting technique.

Fig. 1 Amorphous shapes of the tail ends of tubers probably due to the obstruction during growth.

Materials and Methods

The experiment was conducted outside the green house of the Department of Agronomy, University of Ibadan using top soil collected from the Rockfeller plot of the University Teaching and Research Farm. The yam setts planted were the early maturing variety called *Abi*. Five levels of bulk densities were planned as follows: 1.2; 1.4; 1.6; 1.8 and 2.0 g/cm^3. This was to be in accordance with Kar and Varade (1972) who found that between 1.9 and 2.0 g/cm^3, roots of most plants were entirely prevented from penetration and that roots at these levels only spread over the surface of the compacted soil. In addition, Aiyelari (1990) in his work on conventionally tilled yams found that the soil bulk density determined at harvest ranged between 1.3 and 1.5 g/cm^3. Compacted soil samples were packed in special polythene bags which were 26.3 cm in diameter and 32.0 cm high, thus having a volume of 17.3 × 10^3 cm^3. With this volulme, the weight of soil corresponding to a particular bulk density could be determined from the simple definition of density. This weight of soil was then compacted into the polythene bags as described below.

A hollow cylinder made from galvanised iron sheet gauge 14 and open at both ends was obtained. The bottom of the cylinder was placed on a flat wooden board and the weighed amount of moistened soil transferred to the cylinder and was compacted with rods and tamped to obtain the desired bulk density. This was then turned into the poly bags. The bulk densities achieved were 1.24 g/cm^3 with penetrometer resistance 7.5 N/cm^2; 1.42 g/cm^3 (15 N/cm^2); 1.62 g/cm^3 (17.5 N/cm^2); 1.76 g/cm^3 (25 N/cm^2) and 1.96 g/cm^3 (30 N/cm^2), respectively. Each bulk density was then carefully replicated 24 times to accommodate the scope of the experiment. The bulk density as the major treatment in the experiment was designated 1, 2, 3, 4 and 5. There were also three planting depths at each bulk density designated a, b and c for 5, 7, and 9 cm, respectively. The experimental design is a randomized block with 3 depths of planting, 5 levels of bulk density and 8 replicates. The soil now in polybags was then scooped out to the various depths and the setts, each weighing 200 g planted and covered with the loose soil scooped out. The setts are small whole tubers. Mulching was done in mid-January while watering was done twice a week. Fertilizer NPK (15, 15, 15) was applied as a basal dressing four weeks later when sprouting of tubers had begun. Harvesting parameters such as depth of growth, geometry and size of tubers were determined at physiologic maturity. The length and girth of tubers were measured using a tape-measure while the weights were determined by a field weighing balance with graduation of 0-20 kg.

Table 1 Yam Measurements I at Physiologic Maturity

Bulk Density g/cm^3	Tuber Length (cm) Planting Depth			Tuber Girth (cm) Planting Depth			Tuber Weight (g) Planting Depth		
	a	b	c	a	b	c	a	b	c
1.24	13.8	13.4	12.0	14.2	12.1	13.0	373	430	385
1.42	18.0	14.8	18.7	20.5	21.5	22.2	466	403	482
1.62	18.0	16.3	17.9	21.0	16.6	19.4	425	320	374
1.76	16.5	11.4	18.9	18.2	17.8	18.3	307	364	433
1.96	13.5	20.4	22.4	19.3	23.4	22.3	296	533	551

Planting Depth a = 5cm; b = 7cm and c = 9cm.
Figures are averages of eight reps.

Table 2 Yam Measurements II at Physiologic Maturity

Bulk Density (g/cm^3)	Tuber Length (cm)	Tuber Girth (cm)	Tuber Weight (g)
1.24	13.0	13.0	385
1.42	17.3	21.3	451
1.62	17.3	21.3	451
1.76	15.5	18.0	368
1.96	18.4	21.3	457

Results and Discussion

The summary of the measurements of the length, girth and weight of tubers recorded at harvest (maturity) are contained in **Tables 1** and **2**. It was expected that the tubers would find it easiest to penetrate the soil with the least compaction (1.24 g/cm^3) and thus having longer tubers and least girth. Contrary to this expectation, the tuber lengths at 1.24 g/cm^3 bulk density ranged from 7 to 19 cm with a mean value of 13.8 cm whereas the highest bulk density soil had lengths ranging from 8 to 28 cm and a mean of 13.5 cm. In fact, the longest tuber measurement (30 cm) was obtained at 1.62 g/cm^3, the same group from which the heaviest tuber was also obtained. Irrespective of the planting depth, the mean tuber weight was highest (557 g) at the 1.96 g/cm^3 bulk density and lowest (368 g) at 1.76 g/cm^3. **(Table 2)**. The implication of this is that perhaps soil bulk density has no effect on tuber weight. The only positive correlations were obtained with tuber girth and shape. As expected, the tuber girth was highest (35 cm) at the highest bulk density soil although the mean girths were the same at both 1.42 and 1.96 g/cm^3 irrespective of planting depth. The tuber shape though cannot be quantified. **Figs. 2, 3** and **4** show a general trend of response to bulk density. At the highest bulk density, it was evident that some tubers found it difficult to penetrate the soil vertically downwards and so resulted in having L-shapes with flattened proximal bottoms **(Fig. 3)**.

Plate 4 indicates that the lowest bulk density (1.24 g/cm^3) was probably more promising for predicting tuber shape and position. Note that at bulk densities 3, 4 and 5, the growing tuber continued downward mainly as fingerlike sections. The cross-sectional area of the tuber had to reduce for the same growing force or effort. In bulk-density 2 the whole tuber coned or tappered downward for the same reason but at bulk density 3 (1.62 g/cm^3) the finger tended to be lateral and flat (L-shaped tuber).

It would seem that the physio-

Fig. 2 Tubers produced at bulk density 5. Note the growth and tail ends.

Fig. 3 Tubers produced at bulk density 3. Note the L-shaped tail ends.

Fig. 4 Array of tubers produced at the different bulk densities.

logic reaction which triggers the fingerlike projections is initiated at bulk densities higher than 1.4 g/cm^3 but transitional at around 1.4-1.6 g/cm^3. At bulk density 1, however, tuber cylindricity tended to be maintained while girth increased. Perhaps if a conventionally tilled yam encounters a hard pan of bulk-density 1.2 g/cm^3 during the latter part of its tuberisation, elongation would be checked while fattening is promoted.

Statistical analysis showed that the planting depth and bulk density which formed the block and treatment, respectively, in the experimental design (that is randomized block design) have no significant effect on both the length and weight of tubers produced even at 5% level of significance. On the other hand, the analysis of variance showed that the treatments, that is bulk densities, have significant effect on the girth of tubers produced. The F-test indicated that treatment effect is highly significant at 5% level of significance. The analysis showed that the higher the bulk density, the larger the girth.

Conclusions and Recommendations

Results have shown that within the scope of the experiment, both the depth of planting and the soil bulk density have no significant effect on tuber weight and length. This could be explained by presuming that the soil has taken in rain water prior to tuberisation, such that the soil (hard pan artificially created) is now softened thereby having a reduced bulk density (lower than at planting). It is, therefore, easy for the young tubers to grow down instead of flattening out.

Tuber girth is significantly affected by the soil bulk density. The higher the bulk density, the higher the tuber girth. While the planting depth has no significant effect on tuber shape, positive correlations are obtained between soil bulk density and tuber shape. Tuber shapes tend to be amorphous at high bulk densities.

At higher levels of soil bulk densities (if possible) other than the ones used in this experiment, it is possible to obtain contrastive results, particularly on tuber length and yield and thus the predictability of the depth of growth.

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Joint Use of Open Channel and Underground Pipeline for Irrigation Water Conveyance

by

R.C. Yadav
Sr. Scientist (Eng.)
Central Soil and Water Conservation
Research and Training Institute
Research Centre
Agra, India

L.S. Bhushan
Principal Scientist (Soils) and Officer in Charge
Central Soil and Water Conservation
Research and Training Institute
Research Centre
Agra, India

Abstract

A new concept for the most efficient water conveyance developed elsewhere by the first author is briefly described. The most efficient water conveyance was designed for the Research Farm, Chhalesar, Agra, where open channel and underground pipeline are already in use. The breakeven point height for use of channel vis-à-vis underground pipeline is 115 cm. The costs and savings that can accrue due to different water conveyance modes are presented. In a total existing network of 1156 m long a saving of Rs.18,860 as against all open channel and Rs.23,200 against all pipeline is possible with joint use. This overall saving is 18.5% and 21.8% of total cost of all channel and all underground pipeline, respectively. Water conveyance for similar reclaimed ravine lands is recommended.

Introduction

In India nearly four million ha land is affected by gully and extensive net work of gullies known as ravines. The gully erosion is also a severe problem in many other countries of the world but are known by different names. The gullies occur along rivers generally within 2 km along banks. **Table 1** lists the ravines in the states of India. The ravines occur in discending order of magnitude in the state of Uttar Pradesh, Madhya Pradesh, Rajasthan and Gujarat along rivers, namely Yamuna, Chambal and Mahi. The Chambal River flows in Rajasthan, Madhya Pradesh and Uttar Pradesh.

The problem of gully erosion may be small on a national scale but in itself is a great problem for the areas where it exists. The villages and families affected by gully erosion have been receiving the attention of the Government and non-Government organizations (NGO). Many soil conservation curative schemes are enforced. Small and shallow gullies (**Fig. 1**) are developed for agriculture and deep gullies are kept under forest vegetation.

Land terracing and levelling will be undertaken in large areas in years to come at the cost of heavy investment. The land terracing and levelling are carried out with tractor-drawn blade scrapers (**Fig. 2**). **Fig. 3** shows the resulting land forms of the terraced lands. The creation of irrigation facilities for these sites will bring quick returns from the investments (**Fig. 4**) and many other reforms for erosion control.

Table 1 Total Area Under Ravines in India

State	Ravine area (million ha)
Uttar Pradesh	1.230
Madhya Pradesh	0.683
Rajasthan	0.452
Gujarat	0.400
Maharashtra	0.020
Punjab	0.120
Bihar	0.600
Tamil Nadu	0.060
West Bengal	0.104
Orissa	0.113
Himalayan Foothills	0.193
Total	3.975

Developed gullied lands have typical feature of differential topography, water source in the valley (in case rivers as water source) and deep wells (over 60 m or so). Water conveyance is a problem under these situations. Under gravity irrigation, water is conveyed through unlined and lined channels (**Fig. 5**). The channels have to follow long routes and at some places high embankment is required. This involves more construction work than the direct route.

An alternate method of water conveyance uses underground

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Fig. 1 Shallow and small gully that can be developed for agriculture

Fig. 2 Tractor power use in land development work.

Fig. 3 Gullied land after terracing and levelling into agricultural field.

Fig. 4 View of successful crop on levelled field.

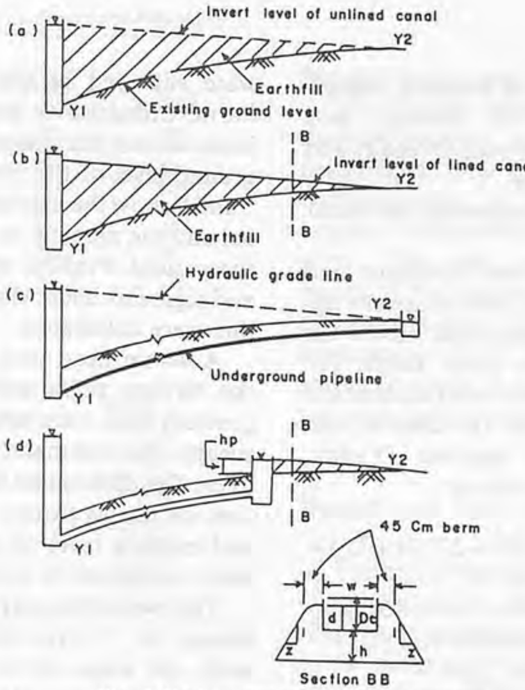

Fig. 5 Various water conveyance systems.

pipeline. The cost of pipe and ancillary material is high. It is usual to provide a reservoir so that pipeline or channel will have a steady source of supply. Thus, pumping cost for underground pipeline and open channel is the same and the cost of pumping does not appear in the comparative cost.

The objective of this paper is to briefly describe the new concept for the most efficient water conveyance (Yadav, 1985) and application to designing a conveyance system at the Research Farm, Chhalesar in Agra. Ultimately, it is hoped that the new concept will find application and use in many other reclaimed gullied land areas in India as well as in other countries.

Theory

Fig. 6 shows that the total unit cost of conveyance is highest when the conveyance is near the water source for the open channel and decreases towards the point of distribution. The unit cost is constant for all along the route for underground pipeline. The total unit cost of water conveyance per unit length in both cases of open channel and underground pipeline will be equal at the breakeven point height (h). This occurs at a particular embankment height. It is cheaper to convey water from the source to point P through underground pipeline and from point P to the point of distribution through open channel. This combined water conveyance is most efficient.

Design models for ascertaining the breakeven height h for a given man-machine-material cost structure at the site of project has been established by Yadav (1983b) for unlined channel and underground pipeline, also by Yadav (1985), for the line channel and underground pipeline. Following is a comparative cost items of the models for the breakeven point.

The total unit cost of conveyance through open channel =

Total unit cost of water conveyance through pipeline.

i.e., cost of channel + cost of embankment + cost of evaporation + cost of land + cost of repairs and maintenance. =

Cost of pipe + cost of excava-

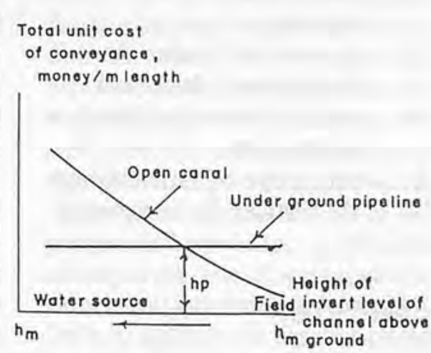

Fig. 6 Break-even cost curve of water conveyance.

tion + cost of bedding material + cost of laying and backfilling + cost of repairs and maintenance

(All the cost factors are per meter length)

With the cost functions and rearrangement, the universally applicable mathematical model for the breakeven point height for lined rectangular most economical cross-section of the channel and underground pipeline (Yadav, 1985) are as follows:

$$Kh_p^n + 5\{W + 2Z(h + D_c) + 0.9\} \times C_{uh} \times 10^{-5} = [C_p + (1.5D^2 + 1.95D + 3.3)C_{eu} + (0.72D^2 + 1.14D + 0.17)C_{gu} + (0.81D + 3.13)C_{1fu}] - [0.1WT_fC_{wu} + C_c] \quad \ldots\ldots\ldots\ldots (1)$$

where

C_c = cost of channel per metre length, money/m

C_{eu} = cost of earth work, money/m^3

C_{gu} = cost of bedding material per cu m. money/m^3

C_{1fu} = cost of laying and back filling per cubic metre, of underground pipeline, money/m^3

C_p = cost of pipe with collar per metre length, money/m

C_{uh} = cost of land/ha, m'ey/ha

C_{wu} = cost of water per cu.m. of volume, money/m^3

D = diameter of pipe, m

D_c = overall depth of open channel, m

h_p = breakeven point height, m

K = coefficient

n = exponent

T_f = duration of water flow in the channel, days/year

W = width of water surface in a channel, m

Z = side slope of embankment (1. vertical, 2. horizontal)

Case Study

The profile of the routes where irrigation channels are running were surveyed at the Research Farm, Chhalesar to ascertain the invert level of the channels and the ground level of the terrain. **Figs. 7** and **8** show the network of channel and the pipeline as existing at the ground. Profiles were plotted and segments under channel/pipeline were delineated.

A 40-cm head was allowed at the farthest point and hydraulic gradient lines were established to irrigate the command area of all lines. The differences in the elevation of the hydraulic grade line and existing level of the ground were calculated at each point.

The two wells nearly had a discharge of 7 litres/second. The wells are about 60 m deep and centrifugal pump (10 m × 7.5 m size) were driven by 15 hp diesel engines. The existing channel lines are rectangular channel constructed with brick masonary and laid on earthen embankment. The pipelines are 125 mm 2.5 kg/cm^2 PVC pipes, burried in the ground. The hydraulic characteristics of the open channel and pipe lines are given in **Table 2**. The channel sections are the most economical (b = 2d) rectangular cross section.

The cost of work and material for an irrigation project were ascertained from the existing rates and values are given in **Table 3**. The earth work volume for embankment heights 25 cm, 50 cm, 100 cm, 150 cm and 200-cm above the ground were estimated for the cross section shown in **Fig. 9**. The equivalent cost were calculated with the earthwork rate (**Table 3**). The best fit constant values were evaluated for the relation.

$C_b = kh^n$

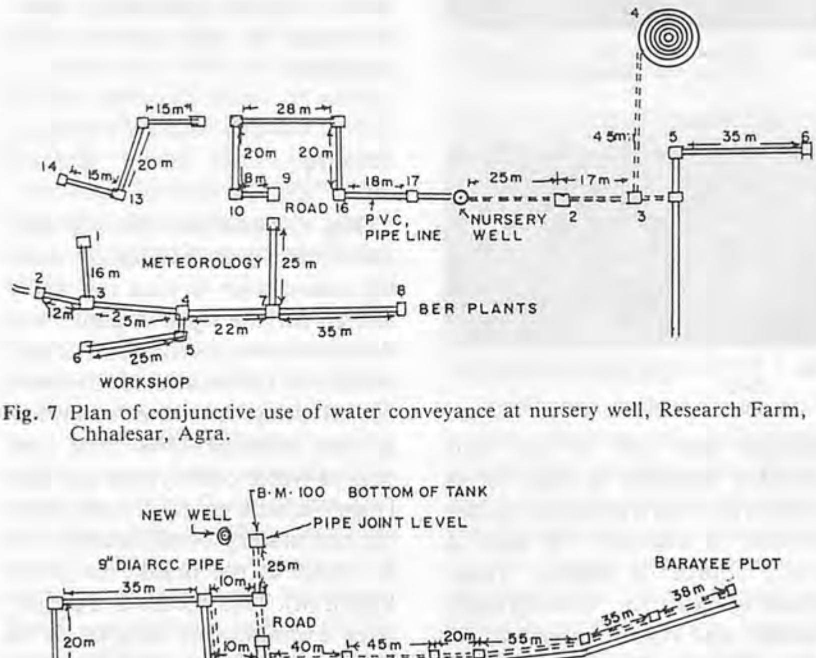

Fig. 7 Plan of conjunctive use of water conveyance at nursery well, Research Farm, Chhalesar, Agra.

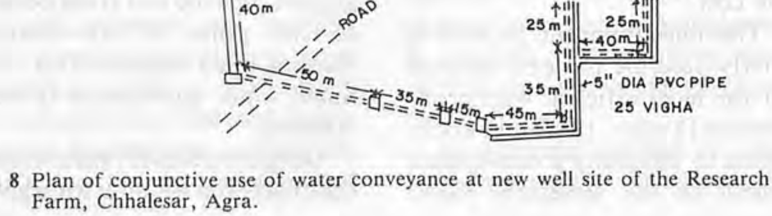

Fig. 8 Plan of conjunctive use of water conveyance at new well site of the Research Farm, Chhalesar, Agra.

Table 2 Hydraulic Characteristics of Open-lined Canal and Underground Pipeline

Discharge	Head loss	Open channel			Pipe size
		Flow depth	Overall depth	Width	
l/s	m/100m	cm	cm	cm	cm
5	0.05	6	20	12	15
7	0.05	7	22	14	18
10	0.05	9	24	18	20
20	0.05	14	29	28	40
50	0.05	24	39	48	40
100	0.05	36	51	72	50

n = 0.016

Table 3 Construction Cost of Channel and Pipeline, Agra

Item	Notation	Cost
Unit cost of excavation	Rs/m^3	5.20
Unit cost of laying and Back-filling	Rs/m^3	4.20
Unit cost of bedding materials	Rs/m^3	28.00
Unit cost of irrigation water	Rs/m^3	2.00
Cost of land/ha	Rs/ha	25000.00
Cost of channel for discharge 5 lit/s	Rs/m	20.00
Cost of channel for discharge 7 lit/s	Rs/m	23.00
Cost of pipe with collars for l/s	Rs/m	54.78
Cost of pipe with collars for l/s	Rs/m	73.00

Table 4 Cost of Embankment Construction, $c_b = kh^n$

Discharge l/s	Coefficient k	Exponent n	Coefficient of determination
5	29.77	1.28	0.847
7	29.02	1.29	0.852

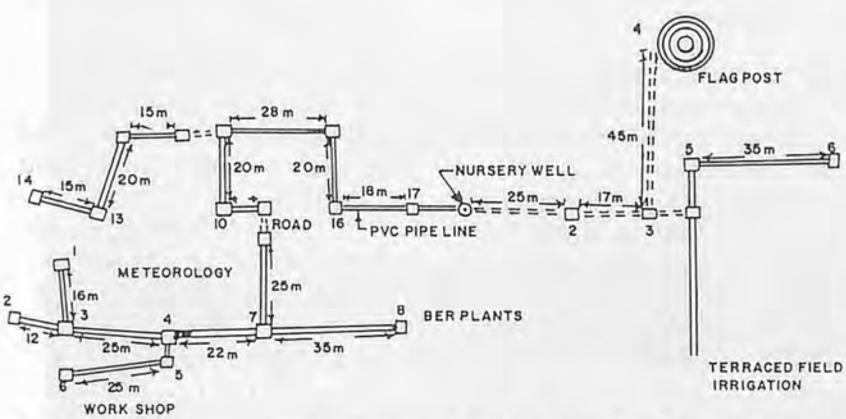

Fig. 9 Economical water conveyance net work for nursery well at Research Farm, Chhalesar, Agra.

where

C_b = cost of embankment

n = exponent

h = height of embankment, m

The vaues of k and n are given in **Table 4**.

Computation

With the cost and parameters of the irrigation system operating at the farm, the breakeven point height was calculated with the Equation 1. To account for head-loss in the number of existing culvert, the head loss of 0.08 m/100 m was taken and the breakeven point height was determined for 125 mm pipeline and channel for discharge of 7 l/s. Detailed calculations are given in the Appendix A. Appendices B and C show the sample calculation for the total unit cost of water conveyance for open channel and for pipeline, respectively.

The average elevation of each channel/pipeline segment were determined. The total unit cost corresponding to the average height of embankment were determined. The unit cost times the length of the segment formed the total cost of water conveyance and summation of all the cost constituted the total cost of water conveyance for the network.

Result and Discussion

The breakeven point height for Chhalesar is 115 cm. This means that for channel segments, where it is necessary to construct embankment for heights more than 115 cm, the underground pipeline should be used.

Table 5 shows the existing network of channel and pipelines and the one proposed as designed by the theory developed by Yadav (1985). It is by chance that the existing network of channel and pipeline are the same as designed for the nursery well. For a new well site, the existing channel is 105 m and pipeline is 556 m. For the idealy designed network, the pipeline of 100 m and channel of 561 m should be used.

The cost of irrigation water conveyance for both the well network as all channel, all pipeline and the proposed conjunctive use are also given in **Table 5**. Using water conveyance by all channel for the nursery well is more economical than all underground pipelines. The cost of all channels and all pipelines in the case of new well show that either of the system could be used. Joint use of water conveyance reduces the cost of the project in both cases. A 18-20% saving in the cost of water conveyance as against the channel and 19-26% as against the pipeline could be made for the topographic condition under this study. The over-

Table 5 Irrigation Network, Cost of Water Conveyance Mode and Saving from the Most Efficient Water Conveyance at Chhalesar (Agra)

Well particulars	Total length of conveyance m	Existing		Proposed joint use		Cost of project			Saving with joint use as against	
		Channel m	Pipeline m	Channel m	Pipeline m	All channel	All pipe	Joint use	All channel	All pipe
Nuresery	495	408	87	408	87	41,695	45,540	33,755	7,940 (19%)	11,785 (26%)
New well	661	105	556	561	100	60,317	60,812	−49,397	−10,920 (18%)	11.415 (19%)
						Total cost: 102, 012-106, 352 Overall saving			18,860 18.5%	23,200 21.8%

all savings due to joint use was 18.5% against all channels and 21.8% as against all pipelines.

The conveyance section where channels and pipeline should be installed for joint use are shown in **Figs. 5** and **6**.

The network of nursery well is almost similar to the existing one. However, some modification in the hydraulic gradient, i.e., related bed slope and depth of channel needs to be improved upon. In the case of new well network, the conveyance segment from point 7 to point 10 should be underground pipeline and the rest should be open channel. This underground pipeline from point 6 to point 22 should be an open channel. The segment from point 3 to point 17 should also be a channel.

Studies (Yadav, 1983a and Yadav, 1985) have been shown that the contribution of the cost of land in the total cost is 1%, that of evaporation cost 14%, and of embankment and repair cost, 85% for discharge less than 10 l/s in the case of open channel. For underground pipeline, the cost of concrete pipe was 12%.

The channel and pipe network in the study area are already in use. Therefore, joint use will perform well and will further reduce the cost of the project. The pipes are conveying water from wells and are working well. This can be designed to any sites of undulating and variable topographic condition, a topography that will develop when the ravines are reclaimed.

Conclusions

1. Breakeven points height for the Chhalesar area is 115 cm.
2. Underground pipelines should be used where the need arises for constructing an embankment more than 115 cm.
3. Joint use of open channel and underground pipeline results in 20-25% savings in the cost for ravine land at the Chhalesar farm.
4. The system can be quickly designed and ideal conveyance determined for any locations of ravine land development to be undertaken.

APPENDIX A Calculation of breakeven point height (hyp):

Substitution of values of constant, cost factors and parameters of channel and underground pipeline from **Table 1**, **Table 2** and **Table 3** in Equation 1 results the following:

$$29.77h^{1.28} + 5\ (0.12 + 2 \times 1\ (hp + 0.2) + 0.9)\ 25{,}000 \times 10^5$$
$$= 54 + (1.5 \times 0.15^2 + 1.95 \times 0.15 + 3.3)\ 4.2 + (0.72 \times 0.15^2 + 1.14 \times 0.15 + 0.17)\ 28 - (0.1 \times 0.12 \times 100 \times 2) + 22)$$

solution of this results in

$$29.77h^{1.28} + 2.5hp = 38.05$$

by successive calculation best fit value of hp of 1.15 m was obtained.

APPENDIX B Total unit cost of water conveyance through open channel.

The mathematical model for total unit cost of water conveyance through open channel (Yadav, 1985) is as follows:

$$C_{ci} = 2(C + kh^n) + (W + 2(h + D_c) + 0.9)C_{hu} \times 10^{-4} + 0.2W.T_fC_{wu}$$

Substituting values of parameter as in appendix A results as under:

$$C_{ci} = 2(22 + 29.77h^{1.58}) + 0.12 + 2 \times 1(h + 0.2) + 0.9)2.5 + 0.20 \times 0.12 \times 100 \times 2$$
$$= 59.5h^{1.28} + (0.12 + 2(h + 0.2) + 0.9)2.5 + 48.8$$

For different value of embankment height (h,m) cost of water conveyance can be calculated.

APPENDIX C The corresponding equation for total unit cost through underground pipeline (Yadav, 1985):

$$C_{cp} = 2\ C_p + (1.5D^2 + 1.95D + 3.3)C_{3u} + (0.72D^2 + 1.14D + 0.17)C_{gu} + (0.81D + 3.31)C_{1fu}$$

Substitution of values of parameter as in appendixes A and B results in:

$$C_{cp} = 2\ 54 + (1.5 \times 0.15^2 + 1.95 \times 0.15 + 3.13) \times 5.2 + (0.72 \times 0.15^2 + 1.14 \times 0.15 + 0.17)\ 28 + (0.81 \times 0.15 + 3.13)\ 4.2$$
$$= Rs.92/m.$$

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Effect of Different Tillage Methods on Sunflowers and Some Soil Properties and Energy Consumption of These Tillage Methods

by

Poyraz Ulger
Prof.
Dept. of Farm Machinery
Tekirdag Agric. Faculty
Thrace Univ.
Turkey

Birol Kayisoglu
Dept. of Farm Machinery
Tekirdag Agric. Faculty
Thrace Univ.
Turkey

Selcuk Arin
Assoc. Prof.
Dept. of Farm Machinery
Tekirdag Agric Faculty
Thrace Univ.
Turkey

Abstract

Turkey is one of the major growers of sunflower producing 20% of the world's supply. Sixty-five percent of the production comes from the Thrace Region. Sunflower is very important for Turkey's agricultural mechanization program. One of the problems is tillage. Besides that straw on the field are burned after wheat harvest in order to make tillage easy for sunflower.

Sunflower production differs by regions in Turkey but common is a wheat-sunflower rotation. This research was undertaken to determine the energy consumption and effects on soil properties of different tilling methods in the yield of sunflower crop.

Materials and Methods

The technical properties of tillage implements used in the research are described in **Table 1** and the implements are sketched in **Fig. 1**.

Table 1 Technical Properties of Implements

Item	Width (mm)	Tilling Depth (mm)	Weight (kg)	Specifications
Single moldboard plow	560	400	200	Mounted, 1-Bottom General purpose
Two moldboard plows	700	290	225	Mounted, 2-Bottom General purpose
Chisel plow	1 750	390	380	Mounted, 7-Bottom
Subsoiler	1 000	540	132	Mounted, 1-Bottom
Rototiller	1 100	110	300	Mounted, 540 rpm 8-Flange, 28 Knives

Split-plot trial design was established for the tilling methods as shown in **Fig. 2**. Other mechanization applications for sunflower production were similar for all the methods. The soil was clayey-loam.

Soil temperature measurements were made with an electronic digital apparatus at depths of 0-10 cm on straw and without straw.

Soil samples were taken from depths of 0-15 cm and dried at 105°C for 24 h in an oven. The volume weight was calculated by using the formula;

Volume weight (g/cm^3)
= [Dried soil weight (g)]/[Field weight of soil samples (cm^3)]

Samples were taken from depths of 0-30 cm of soil with a soil auger. The moisture content of the soil samples was calculated according to the base of dry soil weight with an equation as follows;

$$Sm = \frac{(Ww - Wd)}{Wd}$$

where;
Sm = soil moisture, %
Ww = wet weight, g
Wd = dry weight, g

After operation of the tillage implements, the crop residue was determined from three randomly selected places among the plots with straw by using a rope with

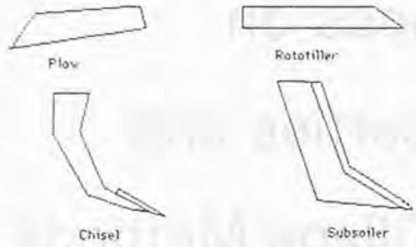

Fig. 1 Operating units of the implements.

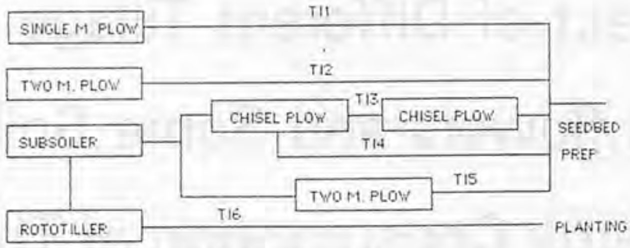

Fig. 2 Flow chart of the tilling methods.

marks at hundred points. The points that contacted with residue were counted and calculated as percent of residue.

Effectiveness of Field Capacity

The effectiveness of field capacity was calculated using the formula below:

$$Ef = \frac{\text{Cultivated area (ha)}}{\text{Total working time a day (h)}}$$

The total volume of soil disturbed by each implement during operation was calculated by multiplying the field capacity with the depth of cut and 10 000 (10 000 m^2 = 1 ha).

$$V = 10000\ EfD$$

where;
V = Soil volume disturbed, m^3/h
D = Dept of cut, m

Yield

The sample plants were harvested by hand for each plot. The formula for determining the yield was:

Yield = [Total weight of harvested plant (kg)]/[Plots area (da)]

Energy Consumption

The energy consumption of the tillage implements and methods were estimated by using the formulas:

$$Em = \frac{Eb}{Ef} \times \left(\frac{Wtr}{Atr} + \frac{W}{Ai}\right)$$

$$Efu = Uft \times Ev$$

$$Eh = 2.3 \times Ul \times n$$

$$Et = Em + Efu + Eh$$

where;
Em = The energy of machine, MJ/ha
Eb = Energy for building of machine, 100.7 MJ/kg
Ef = Effective field capacity, ha/h
Wtr = Weight of tractor, kg
Wi = Weight of machine, kg
Atr = The time of using for tractor, h
Ai = The time of using for machine, h
Efu = Energy of fuel for machine, MJ/ha
Uft = Energy consumption for unit area, l/ha
Ev = Energy value of fuel, 47.2 MJ/l
Eh = Energy of human, MJ/ha
Ul = Unit human labor, ha/h
n = Number of human
Et = Total energy for a implement, MJ/ha

Results and Discussion

The soil temperature, when the tillage methods were used, are given in **Fig. 3**.

In 1989, the maximum soil temperature was 17.65°C for the plots without straw in T12 method and the minimum was 16.56°C for the plots with straw in T13 method. While the difference between methods was significant (F = 3.39*), the difference between plots was not significant (F = 0.98). In 1990, the maximum soil temperature was 18.90°C for the plots without straw in T12 method and the minimum was 18.02°C for the plots with straw in T12 method. Both differences between plots (F = 0.50) and methods (F = 30) were not significant.

The soil volume weights are given in **Fig. 4**. In 1989, the maximum soil weight was 1.41 g/cm^3 for the plots without straw in T15 method and minimum was 0.95g/cm^3 for the plots with straw in T11 method. While the difference between plots was not significant (F = 0.24), the difference between methods was significant (F = 12.71**). In 1990, maximum soil volume weight was 1.38 g/cm^3 for the plots with straw in T15 method and the minimum was 0.98 g/cm^3 for the plots with straw in T11 method. The difference between methods was significant (F = 18.28**) while the difference between plots was not significant (F = 1.77).

Average soil moisture values are given in **Fig. 5**. In 1989, the maximum soil moisture was 24.56% for the plots with straw in T13 method and minimum was 20.55% for the plots without straw in T14 method. While the difference between plots was not significant, the difference between methods was significant (F = 7.02**). In 1990, the maximum soil moisture was 23.00% for the plots with straw in T13 method and minimum was 19.20% for the plots without straw in T15 method. The difference between methods was significant (F = 3.87*) while the difference be-

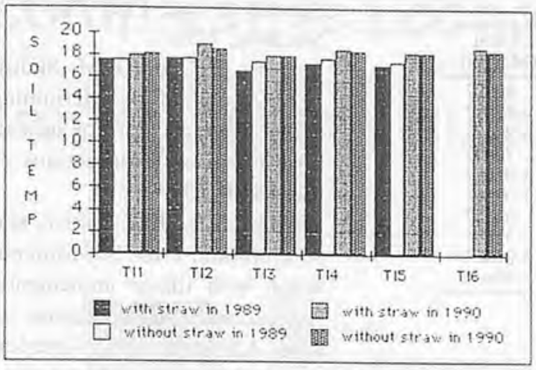

Fig. 3 Soil temperature in depths 0-10 cm (°C).

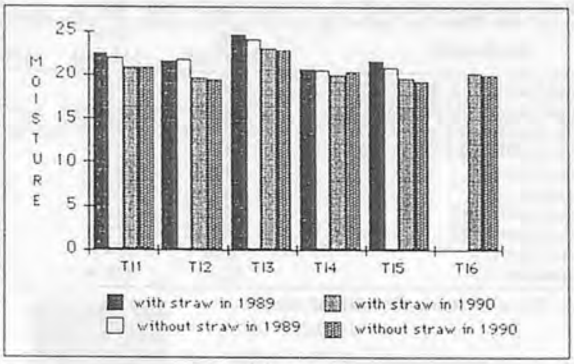

Fig. 5 Average soil moisture in depths 0-30 cm.

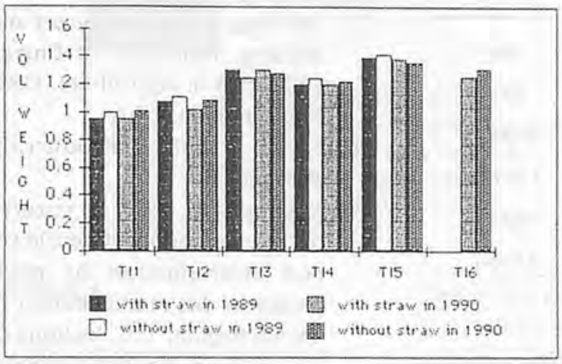

Fig. 4 Soil volume weight in depth 0-15 cm.

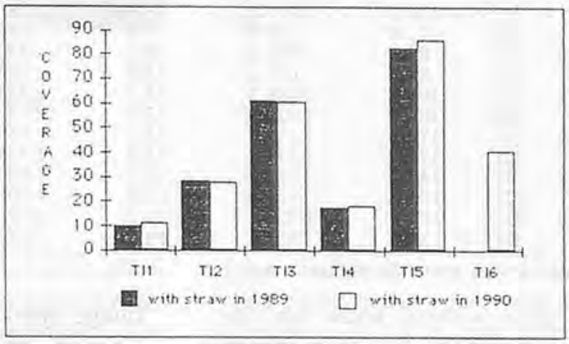

Fig. 6 Crop residue coverage.

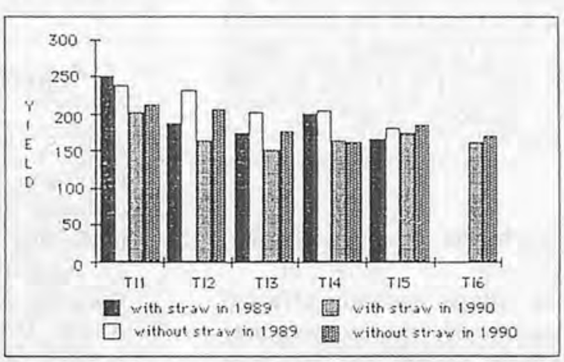

Fig. 7 Yield of sunflower (kg/da).

tween plots was not significant (F = 0.03).

The crop residue coverages for the plots with straw are given in **Fig. 6**. In 1989, the maximum coverage was 83.8% in T15 method and the minimum was 10.3% in T11 method. The difference between methods was significant (F = 693.23**). In 1990, the maximum was 86.1% in T15 method and the minimum was 11.2% in T11 method. The difference between methods was significant (F = 265.72**).

The effective field capacity and performance of the machines are given in **Table 2**.

The field of sunflower for each method is given in **Fig.** 7. In 1989, the maximum yield was 2 501 kg/ha for the plots with straw in T11 method and the minimum was 1 656 kg/ha for the plots with straw in T15 method. Both differences between plots and methods were significant with the value of F = 129.94 and F = 9.00, respectively. In 1990, the maximum yield was 2 128 kg/ha for the plots without straw in T11 and the minimum was 1 508 kg/ha for the plots with straw in T13 method. The differences between plots and methods were significant (F = 89.96) and (F = 25.28).

The energy consumption of the tillage implements and methods are given in **Tables 3** and **4**. Maximum energy consumption was 1 089.2 MJ/ha for the plots with straw for the subsoiler and the minimum was 524.5 MJ/ha for

Table 2 Effective Field Capacity and Performance of Implements

Item	Speed (km/h)	Eff. (ha/h)	Soil vol. disturbed (m^3/h)
Single moldboard plow (1)	5.50	0.260	1 040
Single moldboard plow (2)	5.80	0.270	1 080
Two moldboard plow (1)	5.30	0.360	1 044
Two moldboard plow (2)	5.80	0.390	1 131
Subsoiler (1)	3.60	0.310	—
Subsoiler (2)	3.80	0.320	—
Chisel plow (1)	4.90	0.708	2 660
Chisel plow (1)	5.10	0.751	2 850
Rototiller (1)	4.20	0.530	583
Rototiller (2)	4.50	0.550	605

Note: (1) with straw (2) without straw.

Table 3 Energy Consumption of Implements (MJ/ha)

Implements	Em (MJ/ha)	Efu (MJ/ha)	Eh (MJ/ha)	Total (MJ/ha)
Single moldboard plow (1)	118.1	755.2	8.4	881.7
Single moldboard plow (2)	112.0	719.8	7.9	839.7
Two moldboard plow (1)	88.1	736.3	6.1	830.5
Two moldboard plow (2)	81.7	637.2	5.6	724.5
Subsoiler (1)	91.0	991.2	7.0	1 089.2
Subsoiler (2)	89.3	934.6	6.9	1 030.8
Chisel plow (1)	55.2	542.8	3.2	601.2
Chisel plow (2)	50.9	516.8	2.9	570.6
Rototiller (1)	66.8	934.6	4.2	1 006.3
Rototiller (1)	62.4	920.4	3.9	986.7

Note: (1) with straw (2) without straw.

Table 4 Energy Consumption of Tillage Methods (MJ/ha)

Method	No.	Em (MJ/ha)	Efu (MJ/ha)	Eh (MJ/ha)	Total (MJ/ha)	Average
T11	(1)	118.1	755.2	8.4	881.7	
	(2)	111.9	719.8	7.9	839.7	860.7
T12	(1)	88.1	736.3	6.1	830.5	
	(2)	81.7	637.2	5.6	724.5	777.5
T13	(1)	195.8	2 006.0	13.1	2 214.9	
	(2)	189.8	1 923.4	12.7	2 112.2	2 164.1
T14	(1)	179.1	1 571.8	13.1	1 919.7	
	(2)	171.0	1 571.8	12.5	1 755.3	1 837.15
T15	(1)	146.2	1 534.0	10.2	1 690.4	
	(2)	140.2	1 451.4	9.8	1 601.4	1 645.9
T16	(1)	157.8	1 925.8	11.2	2 091.8	
	(2)	151.7	1 855.0	10.8	2 017.5	2 056.1

Note: (1) with straw (2) without straw.

the plots without straw for the chisel plow. The maximum energy consumption for the methods was 2 214.9 MJ/ha for the plots with straw in T13 method and minimum was 724.5 MJ/ha for the plots without straw in T12 method.

Conclusions

1. The tillage methods affected significantly the temperature, volume, weight and moisture content of the soil. In addition, the methods affected the yield of sunflower. The yield for the plots without straw tilled by plow was higher than those of the plants with straw.
2. The yield of sunflower increased with an increasing tillage operation.
3. Energy consumption was nominal in the use of plow.

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Comparative Economics of Energy Sources among Indian Rural Households

by
Lali Yadav
Extention Specialist (H. Sc.)
College of Home Science
Haryana Agric. Univ.
Hisar 125004
India

Anju Nagpal
Home Science Extn. Edu.
College of Home Science
Haryana Agric. Univ.
Hisar 125004
India

Sudesh Gandhi
Asst. Scientist, Family Resource Management
College of Home Sciences
Haryana Agric. Univ.
Hisar 125004
India

Abstract

The comparative economics of different fuel items, namely; agro-waste, dung cakes, biogas, fire-wood and kerosene oil on the basis of socio-economic status, land-holdings and season was determined under rural household conditions. The study was undertaken in the two purposively selected villages of Hisar District of Haryana State in India. It was found that biogas was reported to be the most economic fuel source according to different socio-economic status, landholdings and season of the year. Agro-waste ranked second in the series which was followed by firewood. The comparative economics of dung cakes earned the fourth position while kerosene oil was last in the series.

Introduction

Under the present stage of the development all the developed and developing countries are passing through the stage of energy crisis. This is very much true in countries like India where high population increase, developmental activities and limited resources of energy have built up an acute pressure on all the developmental activities. Under these circumstances, it was thought proper to undertake a project that would compare the economics of different fuel items used by the households in rural areas. Patil and Dhangade (1984) studied the economics of biogas plants and observed that medium sized biogas plants (250 ft^3) were relatively more profitable. Unni (1986) claimed that the requirement of wood in India was 2650 m^3 at that time which will become 3000 m^3 by 1990. It was assumed that by the end of the century, 250 million more people will be unable to get firewood for their cooking requirement.

Materials and Methods

The study was conducted at Haryana Agricultural University, Hisar, India, in 1990. The different fuel items considered for the purpose of study were agro-waste, dung cakes, biogas, firewood and kerosene oil. The comparative economics of these energy sources was made with the different categories of respondents according to their socio-economic status, landholdings and season of the year. The comparison utilized the benefit-cost ratio formula:

$$\frac{\text{Benefit cost ratio}}{\text{(b/c ratio)}} = \frac{\text{Total Benefits}}{\text{Total Cost}}$$

The main components of cost were: i) time used by the respondents from procurement to utilization; ii) market price of input used; and iii) actual labour cost put in by the respondents per day. While the benefit component was energy obtained, the energy value of the amount of fuel items was converted into man-days equivalent and priced at the prevailing rates in the locality.

Benefit-cost ratio more than unity indicated that energy sources are economically viable.

Results and Discussion

The comparative economics of different sources across socio-economic status, landholdings are season categories is presented in the following text.

Agro-waste and Socio-economic Status

The benefit-cost ratio of agro-waste was high in high socio-economic status category (2.38) as compared to medium (1.43) and low (1.22) socio-economic status categories of the respondents (**Table 1**).

This might be due to the fact that high socio-economic status respondents spent less time in procurement of agro-waste because of either more transportation facilities available to them or their own sources of agro-waste, i.e., land which leads to less labour and time cost.

Agro-waste and Landholdings

Table 1. shows that for landholding categories of the respondents, large-sized farmers reported high benefit-cost ratio of agro-waste (1.45) followed by respondents with medium-sized farms (1.32), small (1.18) and landless (1.03).

The probable reasons might be that the women in large-sized farmers devote less time and have higher facilities to procure it. Consequently, the use of less time leads to less labour cost. Moreover, the respondents with high socio-economic status from large-sized and medium-sized landholdings might get better benefit-cost ratio because they tend to grow more crops as compared to the low category.

Agro-waste and Season

Almost similar benefit-cost ratios of agro-waste was observed in winter (1.47) and rainy season (1.46). A high benefit-cost ratio was found in the summer season (1.70). Probably more fuel is consumed during rainy and winter season as compared to summer due to humidity and low atmospheric temperature.

Table 1 Comparative Economics of Agro-waste Among Socio-economic Categories, Landholding and Season Categories

Category	Frequency	Time used (h)	Value of input used (Rs)	Labour (kWH)	Total cost	Energy obtained (kWH)	Value (Rs)	Benefit cost ratio	Overall benefit cost ratio
a) Socio-economic status									
Low	46	172.00	1.32	38.22	542.72	575.55	661.88	1.22	
		(516.00)		(22.50)					
Medium	49	138.00	1.47	30.66	433.56	615.36	707.66	1.43	1.45
		(414.00)		(18.08)					
High	25	22.00	0.40	4.89	69.28	191.67	164.83	2.38	
		(66.00)		(2.80)					
b) Landholding									
Landless	34	102.00	0.92	22.66	329.68	385.12	338.90	1.03	
		(306.00)		(13.30)					
Small	19	66.00	0.66	14.44	206.42	243.13	243.13	1.18	
		(198.00)		(8.50)					1.21
Medium	33	115.00	0.99	25.55	369.06	416.59	476.59	1.32	
		(345.00)		(15.00)					
Large	35	45.00	0.66	10.00	140.56	234.42	206.29	1.47	
		(135.00)	(5.90)	(5.90)					
c) Season									
Summer	121	335.00	3.83	74.44	1083.27	1603.28	1840.59	1.79	
		(1005.00)		(43.90)					
Winter	121	340.00	3.40	75.55	1098.95	1423.28	1610.54	1.47	1.54
		(1020.00)		(44.50)					
Rainy	121	332.00	3.23	73.77	1054.46	1382.91	1544.30	1.46	
		(996.00)		(43.50)					

Figures in parentheses are value in terms of rupees.

Table 2 Comparative Economics of Dung Cakes Among Socio-economic Categories, Landholding and Season Categories

Category	Frequency	Time used (h)	Value of input used (Rs)	Labour (kWH)	Total cost	Energy obtained (kWH)	Value (Rs)	Benefit cost ratio	Overall benefit cost ratio
a) Socio-economic status									
Low	40	220.00	99.00	52.20	834.81	825.00	948.75	1.14	
		(660.00)		(30.70)					
Medium	40	120.00	25.50	26.66	401.23	425.00	488.75	1.22	1.18
		(360.00)		(15.60)					
High	19	24.00	10.75	5.33	85.89	179.16	125.41	1.46	
		(72.00)		(3.11)					
b) Landholding									
Landless	34	165.00	34.00	36.60	550.63	645.80	651.66	1.18	
		(495.00)		(21.50)					
Small	15	55.00	13.50	12.22	193.22	266.66	234.66	1.21	
		(165.00)		(7.20)					1.72
Medium	28	69.00	22.25	9.30	238.55	370.83	326.33	1.37	
		(207.00)		(5.40)					
Large	26	55.00	18.75	12.22	195.97	312.50	275.00	1.46	
		(165.00)		(7.20)					
c) Season									
Summer	103	375.00	185.89	83.25	1403.91	1350.00	1595.62	1.14	
		(1125.00)		(58.20)					
Winter	103	400.00	175.00	88.89	1437.22	1458.00	1610.59	1.12	0.01
		(1200.00)		(62.20)					
Rainy	72	349.00	90.00	77.55	1182.75	750.00	862.50	0.73	
		(1047.00)		(45.70)					

Figures in parentheses are value in terms of rupees.

Dung Cakes and Socio-economic Status

The dung cake benefit-cost ratio figured in higher, medium and low socio-economic status categories of the respondents was 1.46, 1.22 and 1.14, respectively. The possible reasons for the results might be that the high socio-economic respondents had better resources of herd size and land. Consequently, dung might be available to them easily leading to low consumption of time in procurement of dung (**Table 2**).

Dung Cakes and Landholding

Large farmers were reported to have high benefit-cost ratio (1.46) as compared to medium (1.37), small (1.21) and landless farmers (1.18). The respondents with large landholdings probably have large herd size and, thus, dung was easily available to the respondents leading to better benefit-cost ratio. In comparison, small and landless women farmers had to collect or purchase the dung cakes from others which leads to more time utilization and monetary value in procurement of dung cakes.

Dung Cakes and Season

According to the findings in the study, the benefit-cost ratio of dung cakes was higher in the summer season (1.14) as compared to winter season (1.12). Dung cakes were not economically viable in rainy season (0.73).

In the summer season, dung cakes burn with high efficiency because these are dried easily whereas during the rainy season, due to with moisture content dung cakes do not burn efficiently. As a result, less energy is needed in the summer season which leads to low benefit-cost ratio.

Biogas and Socio-economic Status

Table 3 shows that biogas was much more economical for high (5.84) and medium (5.54) socio-economic categories of the respondents as compared to low category (4.80). Higher dung availability with greater number of animals might be the probable factor for the above findings. The respon-

Table 3 Comparative Economics of of Biogas Among Socio-economic Status, Landholding and Season Categories

Category	Frequency	Time used (h)	Value of input used (Rs)	Labour (kWH)	Total cost	Energy obtained (kWH)	Value (Rs)	Benefit cost ratio	Overall benefit cost ratio
a) Socio-economic status									
Low	6	35.30 (105.90)	45.00	4.66 (2.70)	134.28	537.50	618.12	4.60	
Medium	13	66.30 (198.90)	105.00	14.73 (8.60)	260.09	1254.00	1442.10	5.54	5.33
High	11	64.30 (192.90)	108.00	14.28 (8.40)	253.90	1290.00	1483.50	5.84	
b) Landholding									
Landless	3	16.30 (48.90)	15.00	3.67 (2.16)	76.06	358.33	315.33	4.14	
Small	6	35.00 (105.00)	33.50	7.70 (4.50)	143.09	800.27	920.32	6.43	6.42
Medium	7	39.30 (117.50)	40.20	8.73 (5.10)	163.20	960.33	1104.38	6.76	
Large	14	77.30 (23.19)	79.60	17.12 (10.10)	322.43	1899.16	2184.04	6.77	
c) Season									
Summer	30	165.90 (497.70)	129.00	36.87 (21.70)	648.45	3081.66	3547.91	5.47	
Winter	30	175.00 (525.00)	129.00	38.88 (22.90)	676.94	3081.66	3547.91	5.24	5.28
Rainy	30	180.00 (540.00)	129.00	40.00 (23.60)	692.60	3081.66	3547.91	5.12	

Figures in parentheses are value in terms of rupees.

Table 4 Comparative Economics of Firewood Among Socio-economic Status, Landholding and Season Categories

Category	Frequency	Time used (h)	Value of input used (Rs)	Labour (kWH)	Total cost	Energy obtained (kWH)	Value (Rs)	Benefit cost ratio	Overall benefit cost ratio
a) Socio-economic status									
Low	39	90.00 (270.00)	68.25	20.00 (11.80)	350.05	428.75	493.06	1.41	
Medium	54	102.00 (306.00)	95.55	22.66 (13.30)	411.92	600.25	690.28	1.66	1.60
High	34	68.00 (204.00)	66.95	15.11 (8.90)	279.86	420.58	493.06	1.76	
b) Landholding									
Landless	31	124.00 (372.00)	60.45	16.25 (9.51)	448.60	379.75	334.18	0.74	
Small	24	72.00 (216.00)	46.80	16.00 (9.40)	269.24	334.83	294.65	1.09	1.44
Medium	34	68.00 (40.10)	53.30	15.11 (8.90)	265.21	334.83	294.65	1.11	
Large	38	90.00 (270.00)	32.50	20.00 (11.80)	344.96	408.33	469.58	1.36	
c) Season									
Summer	127	300.00 (900.00)	150.80	66.66 (39.30)	1090.10	1131.08	1300.74	1.19	
Winter	127	313.00 (939.00)	188.50	69.55 (41.00)	1168.54	1184.17	1361.79	1.16	1.15
Rainy	100	280.00 (840.00)	162.50	44.44 (26.20)	1077.72	1020.00	1173.95	1.09	

Figures in parentheses are value in terms of rupees.

dents with low socio-economic status who had low benefit-cost ratio by the use of biogas plant might be due to less availability of dung, consequently, leading to low production of gas to meet the family requirements.

Biogas and Landholding

The results in **Table 3** pertaining to landholding and benefit-cost ratio of biogas infer that large-sized (6.77) and medium-sized farmers (6.76) had almost similar benefit-cost ratio followed by small-sized farmers (6.43). The landless famers had lowest benefit-cost ratio (4.15). This might be due to the fact that the farmers with large and medium landholdings tend to have large number and type of animals as compared to landless and small farmers.

Biogas and Season

The data in **Table 3** show that the benefit-cost ratio of biogas was different among the three seasons. It was high in summer season (5.47) followed by winter (5.24) and rainy season (5.12). In the summer season the rise in temperature might be high or more gas is producted compared to the other two seasons.

Firewood and Socio-economic Status

Table 4 shows that firewood was more economical for the respondents with high socio-economic status (1.76) followed by medium (1.66) and low-status (1.41). The most probable reasons might be that the high-socio-economic status respondents had to spend less time in cutting, collection, transportation and storage of fuel items. The women respondents of medium- and low-socio-economic status might be having scarce resources and spending much time in cutting, collection, transporting and storage of firewood. Obviously, more time is consumed resulting in more labour cost of the firewood.

Table 5 Comparative Economics of Kerosene Oil Among Socio-economic Categories, Landholding and Season Categories

Category	Frequency	Time used (h)	Value of input used (Rs)	Labour (kWH)	Total cost	Energy obtained (kWH)	Value (Rs)	Benefit cost ratio	Overall benefit cost ratio
a) Socio-economic status									
Low	6	6.00 (18.00)	18.00	1.33	36.78	71.66	42.28	1.14	
Medium	13	18.00 (54.00)	45.00	4.00	101.36	179.16	125.42	1.24	1.28
High	11	12.30 (36.90)	39.00	1.61	77.51	155.27	108.69	1.40	
b) Landholding									
Landless	3	6.00 (18.00)	11.25	1.33 (0.70)	24.05	44.72	26.42	1.10	
Small	6	7.00 (21.00)	19.50	1.55 (0.90)	42.05	89.58	52.85	1.25	1.27
Medium	7	8.30 (24.90)	30.00	1.08 (0.60)	55.98	119.47	70.47	1.26	
Large	4	14.00 (42.00)	36.00	3.11 (1.80)	90.70	173.19	121.23	1.34	
c) Season									
Summer	30	47.00 (141.00)	60.00	10.44 (6.10)	207.91	238.89	210.22	1.01	
Winter	30	45.00 (135.00)	69.75	11.11 (6.50)	226.20	277.70	244.38	1.08	1.06
Rainy	30	52.00 (156.00)	75.00	11.55 (6.81)	237.87	286.66	252.26	1.12	

Figures in Parentheses are value in terms of rupees.

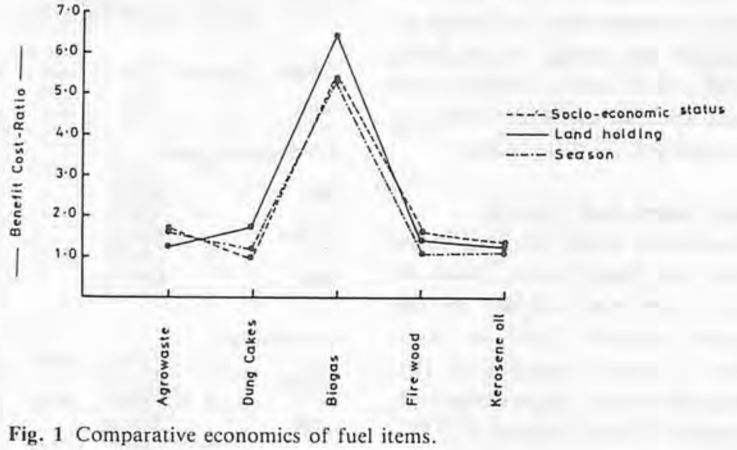

Fig. 1 Comparative economics of fuel items.

Firewood and Landholding

The benefit-cost ratio of firewood was observed more among respondents with large landholdings (1.36) followed by medium (1.11), small (1.09) and landless respondents (0.74). This might be because respondents with large, medium or even small land holdings have the basic resources like land and trees which provide more firewood for their use. The respondents with no landholding either collect or purchase firewood which might consume more time, money and labour cost. As the cost of firewood is increasing and its availability is becoming scarce, the benefit-cost ratio is decreasing among landless, small and even the medium farmers **(Table 4)**.

Firewood and Season

Table 4 shows that the benefit-cost ratio was high in the summer season (1.19) as compared to winter (1.16) and rainy season (1.09). This might be because of low temperature in winter and more moisture in the firewood during rainy season.

Kerosene Oil and Socio-economic Status

Respondents with better socio-economic status had higher benefit-cost ratio (1.40) for kerosene oil followed by medium (1.24) and low (1.15) categories might be due to greater time consumption in procuring and transporting firewood (**Table 5**).

Kerosene Oil and Landholding

Table 5 shows also that the benefit-cost ratio of kerosene oil was high among large farmers (1.34) followed by medium (1.26), small (1.25) and landless farmers (1.10). More time and money consumed by the landless, small and medium farmers than the respondents with large landholdig might have been the probable reasons for the above findings.

Kerosene Oil and Season

During the rainy season the benefit-cost ratio was higher (1.12) as compared to winter (1.08) and summer (1.01). This might be due to the fact that kerosene as a fuel consumed less time and labour during the rainy season as compared to other sources (**Table 5**).

Conclusion

The comparative economics of different fuel items was high among respondents with high socio-economic status, better landholdings and during the summer season, except in the case of kerosene oil where benefit-cost ratio is higher during rainy season. The overall benefit-cost ratio of biogas was maximum (5.70) followed by agro-waste (1.57), firewood (1.39), kerosene oil (1.23) and dung cakes (0.97). Interestingly, among landholding categories the benefit-cost ratio was high in biogas followed by dung cakes, firewood, kerosene oil and agro-waste.

Therefore, it is suggested that the use of non-conventional energy resources like biogas and improved mud stoves should be promoted keeping in view the different attributes of these technologies matching with the social system.

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New Co-operating Editor

Tien-song Peng

Date of Birth: March 27, 1930

Qualification:

1954 B.S. (Agric. Eng.) National Taiwan Univ.

Experience:

1962-65 Instractor, Dept. of Agr. Engineering, National Taiwan University

1965-72 Associate Professor, Dept. of Agr. Engineering, National Taiwan University

1972-84 Full Professor, Dept. of Agr. Engineering, National Taiwan University

1976-86 Co-operating Editor, Agricultural Mechanization in Asia, Africa and Latin America

Present Position:

1992 to Date—Senior Researchist and Deputy Director, Taiwan Agricultural Mechanization Research and Development Center ■■

A Computer Model to Select Optimum Sizes of Farm Machinery and Power for Mechanization Planning

by
Alim Isik
Dept of Agric. Mechanization
Faculty of Agriculture
Univ. of Cukurova
Adana, Turkey

Alaettin Sabanci
Prof., Dept. of Agric. Mechanization
Faculty of Agriculture
Univ. of Cukurova
Adana, Turkey

Abstract

A Computer (PC) model, named EMPS, has been developed to select optimum sizes of farm machinery and tractor power based on farm size, cropping patterns, soil properties, and climatic conditions. The model was designed in order to minimize total costs of farm machines and tractors. The basic management data for the optimum selection of farm machinery and power were analysed for the Çukurova Region of Turkey, and computations were carried out with a computer by a software program written in BASIC. In conclusion, it is shown that optimum machinery sizes and optimum levels of tractor power have been varied with size of the farm land and with cropping pattern. Because of variation of machine size and power level in multi-crop systems, such type of systems should be prefered in production planning, as accurate and wise pre-scheduling should be made before purchasing any machinery and tractors for a farm.

Introduction

The profitability in production of a farm depends to a great extent on the long and short-term decisions about mechanization planning. Selection of the power level of the tractors and sizes of other machines most suitable to the farm peculiarities and to the production plans is the most important portion of the long-term decision policies. The short-term programs, on the other hand, comprise those regarding instanteneous and daily decisions about application of the available machinery in accordance with the proper utilization techniques (Elderen, 1977; Evcim, 1982).

Provision of mechanization equipment for a farm can be materialized either by purchasing as new or as used or by renting. The most suitable of these is governed by such factors as the production area, crop pattern, growing technique, and economic strength of the particular farm (Işık and Sabancı, 1987). Especially, the selection decision about the purchasing having long-term effects makes the future of the farm dependent upon the correctness and suitability to the farm of these decisions. Therefore, instead of buying tractors and other machinery arbitrarily, firstly estimating the most suitable tractor power and machine size by using the relevant data pertinent to the farm with the help of definite models, and later purchasing of the tractors and machines determined in such manner would increase the profitability of the farm.

With microcomputers becoming a more important toll in the agricultural industry, several programs have been developed to assist farm managers and scientists in decision making about how to manage their machines or production operations and how to select their machineery requirements effectively (Burrows and Siemens, 1974; Hughes and Holtman, 1976; Singh and Holtman, 1979; Bolukoǧlu, 1982; Rots et al., 1983; Ozkan et al., 1985; Freemeyer and Hunt, 1985; Hetz and Esmay, 1986; Ozkan and Edwards, 1986; Ozkan et al., 1989; Darga, 1989). Chen (1986) and Colvin et al. (1989) developed models to predict machine capacity and fuel use on various crops and field operations.

In this study, especially in the irrigated agricultural farms where machinery investments are considerably high, a model for selecting the optimum sizes of the machinery set and the power level of the tractor suitable to this set, which the farm should own, depending on the farm size, crop pattern, and soil and climatic peculiarities of the region is developed and explained. For this purpose, the management data in the overall conditions to Turkey have been gathered and analysed, and

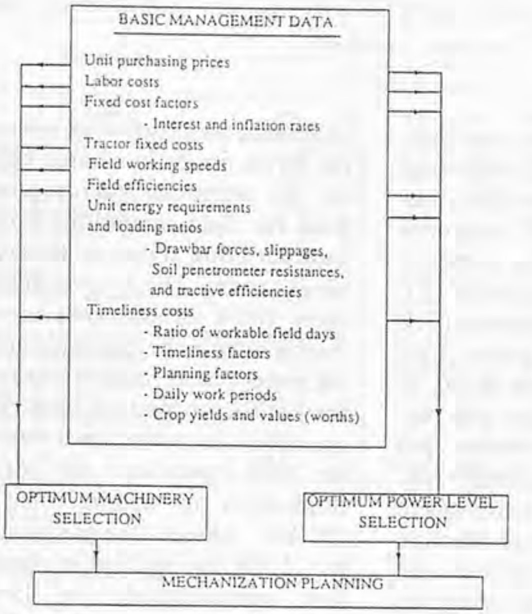

Fig. 1 Basic management data for the optimum selection of the farm machinery and power, and their relationships with mechanization planning.

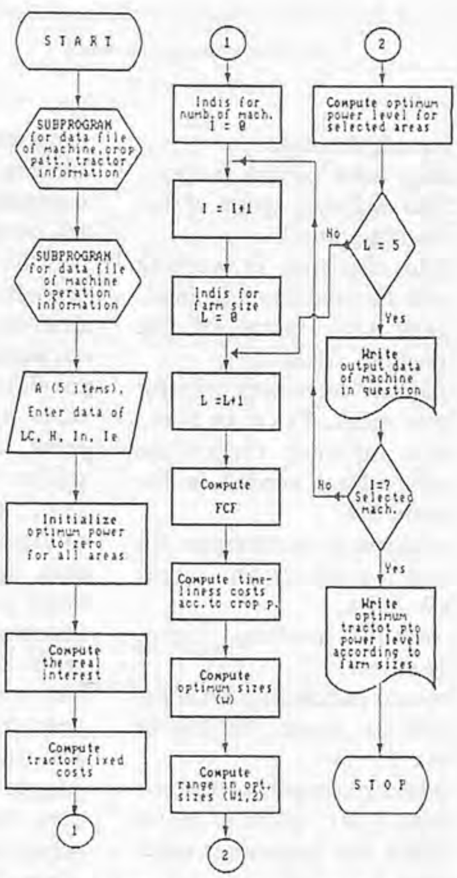

Fig. 2 Flow chart of the program which computes the optimum and close-to optimum machinery sizes and the optimum power levels depending on the farm area and on the crop pattern.

the computations have been carried out on computer with the help of a program written in BASIC language.

The applicability of the developed model and the resultant program to the prospective large agricultural farms to be operational in the near future in the Southeastern Anatolian Project (GAP, the biggest agricultural project in Turkey) areas is another important aspect of the study.

Input Data and Model Description

The basic management data needed as input to select optimum farm machinery and power for the mechanization planning are summarized in **Fig. 1** (Işık, 1988). As seen from this figure, any mechanization planning is affected by a lot of technical and economical management data.

The management data used in the model were determined in the Çukurova Region conditions in Turkey by using special methods developed and explained in Işık (1988).

The Farm Machinery and Power Selection (FMPS) model is based on the general method known as: "the least cost method" or "minimization of the total costs" which essentially aims at the selection of the tractor power level and machinery sizes making annual costs a minimum as it materializes the completion of the required work in a definite period (Edwards et al., 1983; Hunt, 1985; ASAE, 1987; Işık, 1988). In this method, if the first derivative of the function defining the total cost composed of all the relevant costs included timeliness costs also depending on the machine or the tractor size is taken with respect to the machine capacity or to the pto power of the tractor, then the root of the resultant expression gives directly the optimum size causing the smallest annual total cost. And, an optimum mechanization system consists of those tractors and machines which are individually of optimum sizes. These optimum quantities can be determined with the help of the following equations for a machine or a tractor to be used in a multi-purpose process:

$$W^* = [\sum_{i=1}^{n} [10.A_i.(LC+TFC+(K_i.Y_i.V_i.A_i/(X_i.U_i.h_i)))/(S_i.e_i)]/(FCF\ .\ p)]^{1/2} \quad \ldots\ldots\ldots\ldots (1)$$

$$P_{km} = [\sum_{j=1}^{m} \sum_{i=1}^{n} [A_i.E_i(LC+K_i.Y_i.V_i.A_i/(X_i.U_i.h_i))/(R_i.FCF.T_p)]]^{1/2} \quad \ldots\ldots\ldots\ldots (2)$$

Where,

W^* :optimum machine width, m,
A :production area, ha,
LC :labor costs, TL/h or $/h,
TFC:fixed costs related to the tractor operating the machine, TL/h or $/h,
K :timeliness factor, day^{-1},
Y :potential crop yield, unit/ha,
V :crop value, TL/unit or $/unit
X :planning factor,
U :time usage or the ratio of workable days in the planned

period, decimal,

h :daily work period, h/day,

S :field working speed of the machine, km/h,

e :field efficiency in working with the machine, decimal,

FCF:fixed cost factor of the machine, decimal,

p :machine purchasing price for unit width, TL/m or \$/m,

P_{km} :total optimum tractor pto power level needed in the farm, kW,

E :total energy requirement for unit production area, kW-h/ha,

R :tractor loading ratio, decimal,

T_p :tractor purchasing price per unit pto power, TL/kW or \$/kW,

i :subscript denoting the operating type of all the crops for which the machine is used, (i = 1,2,......,n)

j :subscript denoting the crop type of all the crops (j = 1,2.....,m).

The limit values close to the single optimum width value given by equation 1 can be determined with the help of the following equation.

$$W_{1,2} = W^* + d/(2.FCF.p) \pm [d.(W^* + (d/(4.FCF.p)))/(FCF.p)]^{1/2} \quad (3)$$

where,

$W^*_{1,2}$ = is the double answer defining the machine widths with which the annual machine costs are approximately minimum, and

d is the arbitrary money amount that the farm can pay above the minimum cost of the machine size desired to reach. This d value was taken about 2% of the purchasing prices of the machines, in this study.

The flow-chart of the developed computer program is given in **Fig. 2**. As seen in this figure, the program has two subprograms. One of these subprograms, FMPS.DAT, contain data related to names of machines, unit purchasing prices (p, Tp), field working speeds (S) and field efficiences (e), salvage values (SV), economical life (EL), arbitrary money amounts (d), loading ratios (R), drawbar force requirements (Fc), slippages (sl), cone index (Cn), timeliness cost variables (K, Y, V, X, U, h), types of crops, crop patterns, and average tractor pto power. The other one, FMPS NR. DAT, contains crop and pattern numbers, ratios of production area in the selected patern and types of machines and operation numbers according to crop patterns. Some data such as farm size (A), tractor usage duration in a year, (H) labor cost (LC), interest (In) and inflation (Ie) rates are entered from the monitor as input data. These data can be changed according to demands and general conditions. So, the model has a universal applicability.

The validation test of the developed model has been done by comparing values of the actual values with the model solutions of farm machinery sizes and tractor power levels in the selected two farms in the Çukurova Region of Turkey.

Example Runs and Discussions

To illustrate results of this model, only two crop patterns, mono-crop and multi-crop patterns, which contain cotton, wheat, main crop corn, and second crop soybean, were selected and their solutions are given in **Tables 1** and **2**, respectively. These solutions have been found for 5 different farm sizes (50, 100, 200, 500 and 1000 ha), 0,5 \$/h labor cost, 750 hours/year tractor usage duration, 0,70 nominal interest ratio and 0,60 general inflation ratio in conditions of Turkey.

As shown in **Tables 1** and **2**, increasing the production areas of the farms results in a linear effect on the optimum tractor power level for field operations except transportation in both of the cropping patterns. The one which allocates 100% of the area to the cotton only is the pattern requiring grater power requirement than the multi-crop pattern does. For example, the power level needed for field operations for cotton production in 200-ha field is 221 kW, whereas the same value is 121 kW for multi-crop pattern (less approximately by 45%). According to these findings then, it can be reasoned that the farms should plan their productions in conformity with the differences among the power requirements for their prospective multi-crop patterns. The unit pto power requirement values for the farm sizes selected are computed to be 1.08-1.18 kW/ha for cotton production, 0,57-0,72 kW/ha for the multi-crop pattern. The regression equations for these patterns are:

$y = 5,332 + 1,078 \times$; $R^2 = 1,00$ for cotton,

$y = 8,424 + 0,560 \times$; $R^2 = 1,00$ for multi-crop pattern

where,

x = farm size, ha

y = optimum pto power level, kW.

Hence, by these results, it can be asserted that the optimum power requirement varies depending on the crop patterns and on the machinery usage ratios in these patterns, and it decreases with increasing farm area.

When an evaluation is made from the standpoint of the agricultural machines, it is observed that the types of these machines are directly related to the crop types, but their optimum sizes are effected by the farm area and the annual usage period as well other than the crop types, also.

The number of machine types required for the multiple-crop pat-

Table 1 Optimum Farm Machinery Sizes and Power Levels According to Farm Size and Crop Pattern* (100% Cotton Farm A)

Implement	Optimum width (m)					Range in optimum width (m)				
	Fram size (ha)					Farm size (ha)				
Name	50	100	200	500	1000	50	100	200	500	1000
Subsoiler	2.3	3.3	4.6	7.3	10.4	1.7- 3.2	2.5- 4.3	3.7- 5.8	6.1- 8.7	8.9- 12.0
Chisel	1.5	2.1	2.9	4.6	6.5	1.0- 2.1	1.5- 2.8	2.3- 3.8	3.8- 5.6	5.5- 7.7
Mouldboard plough	2.5	3.6	5.0	8.0	11.3	1.9- 3.3	2.8- 4.5	4.2- 6.1	6.8- 9.3	9.9- 12.8
Heavy discharrow	2.9	4.1	5.8	9.2	13.0	2.3- 3.7	3.4- 5.1	4.9- 6.9	8.0- 10.6	11.6- 14.7
Field cultivator	3.3	4.7	6.7	10.6	15.0	2.7- 4.2	3.9- 5.7	5.7- 7.9	9.3- 12.0	13.5- 16.7
Discharrow	2.1	3.0	4.2	6.6	9.4	1.6- 2.8	2.3- 3.8	3.4- 5.2	5.6- 7.8	8.2- 10.8
Scrubber	8.1	11.4	16.2	25.6	36.2	6.8- 9.6	9.9- 13.2	14.3- 18.2	23.2- 28.1	33.3- 39.2
Centrifugal fertilizer	10.9	15.5	21.9	34.6	48.9	9.5-12.6	13.7- 17.5	19.8- 24.2	31.9- 37.5	45.7- 52.4
Universal planter (mech.)(*)	14.9	29.6	58.9	146.8	293.3	13.4-16.7	27.3- 32.0	55.7- 62.2	141.7-152.0	286.0-300.7
Channel plow (one per 40 m)	67.4	95.4	134.9	213.3	301.6	63.4-71.7	90.6-100.4	129.2-140.8	206.1-220.7	293.0-310.4
Rotary ridge maker	6.8	9.6	13.6	21.5	30.4	5.5- 8.4	8.1- 11.5	11.7- 15.8	19.1- 24.3	27.5- 33.7
Leveller	8.4	11.8	16.7	26.5	37.4	7.3- 9.6	10.5- 13.3	15.2- 18.5	24.5- 28.6	35.0- 40.0
Rows cultivator	6.4	9.0	12.8	20.2	28.6	5.4- 7.5	7.9- 10.4	11.4- 14.3	18.4- 22.1	26.4- 30.9
Rotary hoe (ground drived)	4.5	6.4	9.1	14.3	20.3	3.7- 5.5	5.4- 7.6	7.9- 10.4	12.9- 16.0	18.5- 22.3
Cultivator with fertilizer	5.2	7.4	10.5	16.6	23.5	4.4- 6.2	6.4- 8.6	9.3- 11.9	15.0- 18.3	21.6- 25.5
Field sprayer	14.1	20.0	28.3	44.7	63.3	12.8-15.6	18.4- 21.7	26.4- 30.3	42.4- 47.2	60.4- 66.2
Rotary cutter	2.0	2.9	4.0	6.4	9.1	1.6- 2.6	2.3- 3.5	3.4- 4.8	5.5- 7.4	8.0- 10.2
Optimum total Pto power level (kW)	59	113	221	544	1083	-	-	-	-	-

(*): Planter width that complets operation in a day.

Table 2 Optimum Farm Machinery Sizes and Power Levels According to Farm Size and Crop Pattern*

Implement	Optimum width (m)					Range in optimum width (m)				
	Fram size (ha)					Farm size (ha)				
Name	50	100	200	500	1000	50	100	200	500	1000
Subsoiler	3.3	4.6	6.5	10.4	14.6	2.5- 4.3	3.7- 5.8	5.4- 7.9	8.9- 12.0	12.9- 16.6
Chisel	2.1	2.9	4.1	6.5	9.2	1.5- 2.8	2.3- 3.8	3.3- 5.1	5.5- 7.7	8.0- 10.6
Mouldboard plough	3.6	5.0	7.1	11.3	15.9	2.8- 4.5	4.2- 6.1	6.1- 8.4	9.9- 12.8	14.3- 17.7
Heavy discharrow	5.5	7.7	10.9	17.3	24.4	4.6- 6.5	6.6- 9.0	9.6- 12.4	15.6- 19.1	22.4- 26.6
Field cultivator	5.8	8.2	11.6	18.3	25.9	4.9- 6.9	7.1- 9.5	10.3- 13.1	16.7- 20.2	23.9- 28.1
Discharrow	3.6	5.1	7.3	11.5	16.3	2.9- 4.5	4.3- 6.2	6.2- 8.5	10.2- 13.0	14.7- 18.1
Sucrubber	13.4	19.0	26.8	42.4	60.0	11.7-15.3	17.0- 21.2	24.4- 29.5	39.3- 45.7	56.3- 63.8
Centrifugal fertilizer	30.9	43.8	61.9	97.8	138.4	28.4-33.7	40.7- 47.0	58.3- 65.7	93.3-102.7	132.9-144.1
Universal planter (mech.)(*)	11.4	22.1	43.5	107.6	214.5	10.1-13.0	20.2- 24.2	40.8- 46.4	103.3-112.1	208.3-220.8
Universal planter (pneu.)(*)	1.7	3.0	5.5	13.1	25.8	1.2- 2.3	2.4- 3.8	4.6- 6.6	11.7- 14.7	23.8- 27.9
Channel plow (one per 40 m)	67.4	95.4	134.9	213.3	301.6	63.4-71.7	90.6-100.4	129.2-140.8	206.1-220.7	293.0-310.4
Rotary ridge maker	11.8	16.7	23.6	37.3	52.7	10.0-13.9	14.6- 19.1	21.0- 26.4	34.0- 40.8	48.8- 56.9
Leveller	8.4	11.8	16.7	26.5	37.4	7.3- 9.6	10.5- 13.3	15.2- 18.5	24.5- 28.6	35.0- 40.0
Rows cultivator	9.8	13.8	19.5	30.9	43.6	8.6-11.1	12.4- 15.4	17.8- 21.4	28.6- 33.2	41.0- 46.4
Rotary hoe (ground drived)	5.2	7.4	10.5	16.6	23.4	4.4- 6.3	6.4- 8.6	9.2- 11.9	15.0- 18.4	21.5- 25.5
Cultivator with fertilizer	6.4	9.1	12.8	20.3	28.7	5.5- 7.5	8.0- 10.4	11.5- 14.4	18.6- 22.2	26.7- 31.0
Field sprayer	17.3	24.5	34.7	54.8	77.5	15.9-18.9	22.8- 26.4	32.6- 36.9	52.2- 57.6	74.3- 80.8
Rotary cutter	2.9	4.0	5.7	9.1	12.8	2.3- 3.5	3.4- 4.8	4.9- 6.7	8.0- 10.2	11.6- 14.2
Optimum total Pto power level (kW)	36	64	121	289	568	-	-	-	-	-

(*): Planter width that complets operation in a day.

terns is usually the same as that for the single cotton pattern. An exceptional case would be that the pneumatic and sensitive sowing machines widely used in the region for corn seeding in the recent years world enter the machine park as an additional machine; or corn can be sown with help of the mechanical type universal sowing machines without the necessity for the former.

Generally, the optimum total machine widths change exponentially with farm size, and, in general, directly with the squareroot of the farm size. Total machine width increase with increasing number of operations in the crop patterns, and decreases with increasing annual tractor usage.

In such operations as sowing and harvesting with which timeliness is important, for a day in which the crop yield is the highest, or in other words, for a day when the crop losses are minimal, acquisition of the optimum sized machinery to complete the operations by the farm may necessitate a huge investment. Therefore, these optimum magnitudes which enable the operation to be completed in a single day must be divided by the optimum periods determined according to crop types and operation types taking into consideration an acceptable drop in crop yield. For example, the size of the optimum sowing machine in a farm having a production area of 200 ha where the cotton sowing operation of the crop pattern (A) is to be completed in one day with a maximum crop yield is 58,9 m for a tractor usage period of 750 hours/year. The machine or the machinery having such a size will necessitate an insurmountable amount of investment for the farm. Instead, by considering the fact that the optimum cotton sowing period in the regions is about 10 days, the optimum machine size which the farm should own will be 5,89 m. And, the size of such a magnitude is about two machines which could be provided easily by a universal sowing machine having 4 rows produced in Turkey, also.

The limits of close-to-optimum machine sizes are of such magnitudes as to enable the selection of the machine available in the ordinary market without encountering much difficulty. These limit values change depending on the arbitrary money values chosen at about 2% of the machine purchasing unit prices, or in short, they change depending on the purchasing prices of the machines. The variations of these limit values versus the tractor usage period are similar to those variations in the optimum sizes.

The optimum machine size and the power level values determined in relation to the crop pattern and the farm area indicate the total quantities needed in the farm. Therefore, these overall values obtained at farm levels must be divided by the values belonging to the models chosen among the ones available in Turkey, thus resulting in the optimum numbers of the machinery and the tractors needed by the particular farm.

In order to validate the developed model in a tangible way, two farms in the Çukurova Region whose peculiarities and machinery capabilities were well known were arbitrarily chosen, and their available tractor and agricultural machinery levels were compared with those computed by the model. By these comparisons and the resulting evaluations, it has been shown that findings of the model can be used reliably in mechanization plannings of the agricultural farms.

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An introduction to SUBSEC Plan

by
Sakae Shibusawa
Assoc. Prof.
Dept. of Environmental Science and Resources
Faculty of Agriculture
Tokyo Univ. of Agriculture and Technology
Fuchu, Tokyo 183, Japan

Abstract

Standing for Sustainable Bio-production Systems on Environmental Conservation, SUBSEC is the name of an interdisciplinary research project for agricultural engineers and scientists in designing a new bio-production technology.

This article describes the concept of SUBSEC and how to promote it. The concept of SUBSEC is based on combining four recycling sub-systems: Water-SPAC system, other biological system, production management system, and products consumption system. Decreasing waste entropy or materials in each sub-system will provide a better linkage among these sub-systems. An idea of SUBSEC region is also introduced.

Introduction

Acknowledgement: The author would like to thank Prof. T. Iwao of Shimane University, the leader of Shimane-to-Gyeongsang University Cooperative Research Project, for kind advice and encouragement to set up and promote SUBSEC plan. Prof. T. Mori and Prof. Y. Honda of Shimane University shared the author with valuable ideas and advice such as eco-technology and photo-ecology respectively. He gratefully acknowledges the helpful discussions with himself and Dr. T. Nonaka of Shimane University, especially in terms of how to promote SUBSEC plan. Prof. A. Sasao of Tokyo University of Agriculture and Technology provided suggestions and encouragement to develop SUBSEC plan in a wider scale beyond the confines of the academic circles.

Global environmental problems of today in addition to the world's population increase, are bringing about drastic changes in the industrial, economic, social and political environment. "Think globally, act locally" or "Sustainable development" becomes key-phrases on our today's activities. These impacts lead us to think about what agricultural engineers and scientists are responsible for. Now we have produced one idea associated with our agricultural studies, that is, SUBSEC.

The abbreviation SUBSEC stands for Sustainable Bio-production Systems on Environmental Conservation, the name of our interdisciplinary research project which was just proposed by agricultural researchers of Shimane University in 1991, including the author. The project plan was developed at the Shimane-to-Gyeongsang University Cooperative Research in 1992, supported financially by the Ministry of Education, Science and Culture of Japan. Moreover, the concept and activities on SUBSEC have been spreading over that cooperative research project, and this leads us to think of a new stage of agricultural studies and much more academic exchange among researchers of different research organizations in various countries. The author, therefore, would like to provide information about SUBSEC and to have academic exchanges through the AMA journal.

This article focuses on the concept of SUBSEC, how to promote SUBSEC plan and a vision of SUBSEC.

Concept of SUBSEC

Agricultural production systems can be interpreted through the analogy of a signal processing system as shown in **Fig. 1**. The signal processing system is represented by input-output relationship through the system box (or black box). Supplying energy, labor and technology into the system box as input yields many kinds of agricultural products as output. One of the conventional views about the system has been "Higher input makes higher output and more income" like the manufacturing industry. However, it might lead us to today's global environmental problems in a sense.

In the case of manufacturing industry, for example, we usually

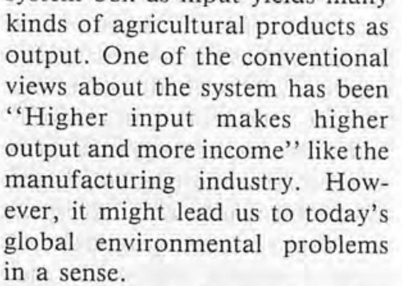

Fig. 1 An aspect of agricultural production system.

supply materials, technology and labor into a factory system, and then we can get industrial products. With clearly estimating all the process of production systems, we can count a prime cost. Comparing the prime cost with a marketing price expected helps us to decide whether it will pay or not. Environmental problems of today require the factory system to prepare waste control systems, and this has enhanced the prime cost more and more.

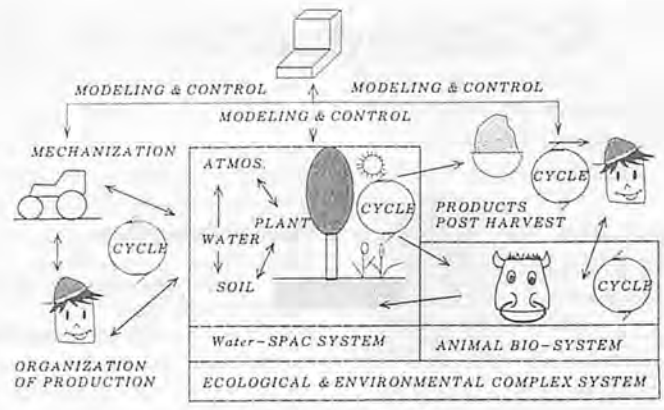

Fig. 2 Concept of SUBSEC.

The comparison between agriculture and the manufacturing industry provides a fundamental difference between them. Calculable prime cost, that is, all the well-known artificial process is a basic feature of manufacturing industry. In the case of agriculture, the system box which we have to deal with here is surmised to be intricate and complicated bio-systems. This gives rise to the difficulty in estimating all the production process and to evaluate the real prime cost. Moreover, there are few techniques for waste control such as agricultural chemicals that diffused infields. Hence we should have a new distinctive way of thinking about agriculture compared with other industries.

We are today responsible for preserving/supporting landscape diversity/amenity and biological diversity, conserving agricultural fields combined with urban and mountainous areas, promoting any other environmental conservation activities, and, of course, gaining much more in safe, healthy and high-quality agricultural products. These issues are becoming new limiting factors or parameters of the output required in today's and future bio-production systems, which is why the ideas of SUBSEC has been developed.

SUBSEC needs much more information and intelligence about the complicated bio-system in order to develop a new technology for today's and future needs. SUBSEC plan also requires the support of high technology and the integration of data and information in many study regions.

SUBSEC plan provides an approach to the bio-production system through roughly dividing into four kinds of sub-systems as shown in **Fig. 2**. The first sub-system is Water-Soil-Plant-Atmosphere continuum system (Water-SPAC system) which is the main system for bio-production followed by the potential of preserving landscape amenity, water pollution control, and the like. It might be considered as a relatively self-supported system. The second is the other biological system, including domestic animals, where the water and products supplied from the first sub-system are consumed, and meat, wastewater, sewage sludge and so on are also produced. The third is the management system for bio-production, including mechanization, farmers' organization, political support and so forth. This system becomes the subject of putting SUBSEC plan into practice. The fourth is the products consumption system which produces wealth and cultural activities as well as water pollution and others in socio-economic linkages with urban areas' activities.

How to combine and control those systems is an important issue. SUBSEC needs the concept that each sub-system behaves as a relatively independent and cyclic system of energy, mass, information and so forth, and that decreasing waste-entropy or waste-matters from these systems makes for a sustainable total system with less environmental pollution, even if a large amount of mass is recycling in the each system.

When it comes to having the concept, consideration needs technology to monitor the behavior of those systems, and also needs integration of many kinds of modeling techniques and information based on mathematical, physical, biological, chemical and any other methodologies. This situation requires, in particular, agricultural engineers to organize academic and practical research activities towards SUBSEC.

How to Promote SUBSEC Plan

Where to locate SUBSEC plan in our academic activities is a basic issue when we promote it. We need to assume here that a SUBSEC plan is a kind of philosophy to encourage our studies and at the same time a practical action project as shown

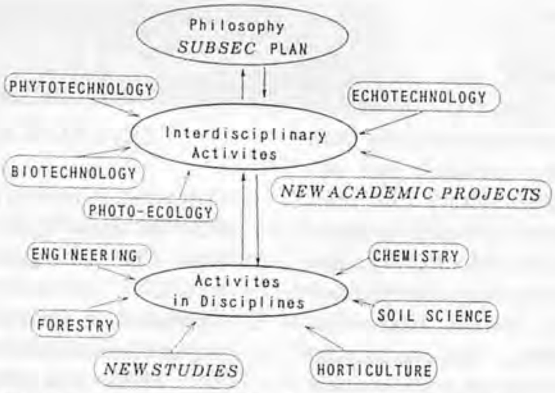

Fig. 3 Position of SUBSEC plan on academic activities.

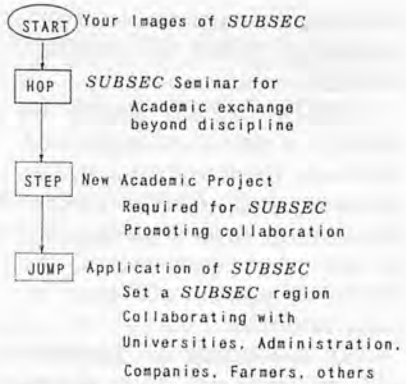

Fig. 4 How to promote SUBSEC plan.

in **Fig. 3**.

We usually take part in some interdisciplinary projects such as phytotechnology[2], ecotechnology[3], biotechnology, photo-ecology[4] and the like, associated with our concerns in academic disciplines. Integrating some interdisciplinary project usually needs or provides a new scientific philosophy. In the same way, researchers should have access to SUBSEC plan through some kinds of interdisciplinary activities. It is difficult to make a direct access to SUBSEC plan from an individual research considering that the plan is still in its conceptual stage.

There are three stages in promoting SUBSEC plan as shown in **Fig. 4**. Having some understanding about SUBSEC leads us to the start line of this research. In the first stage, we are going to make academic exchange among many disciplines. Holding a series of seminars on SUBSEC is one avenue in identifying interdisciplinary issues of wide interest for cooperative research projects. In the second stage, a new interdisciplinary study project will be required for promoting the SUBSEC plan. Until the second stage, the studies on SUBSEC will be mainly for researchers of universities. The third stage appears as application of SUBSEC research when setting up a SUBSEC region in collaboration with many kinds individuals of university, administrative organization, farmers, consumers and other groups. This stage implies the application stage of SUBSEC.

The progress of SUBSEC plan should be recognized with long-term implications, because even the first stage works will need at least a few or more years and the main issue of academic exchange between Shimane-to-Gyeongsang universities is to just step into the first stage. It is, however, important to bridge the apparently existing gaps between plan and action and between research and practice. This needs to take account of exchange among many people in many fields beyond the universities.

SUBSEC Region

An idea of SUBSEC region is introduced here as one vision of SUBSEC plan. Discussing a vision of SUBSEC leads us to think about what Prof. Mori of Shimane University, in his presentation at the first seminar on SUBSEC at Gyeongsang University, August 5, 1992, introduced an idea of eco-police, eco-town and SUBSEC area, considering water pollution control, distinctive culture, the balance among population, industry and nature. An example of SUBSEC region as shown in **Fig. 5** is similar to Mori's SUBSEC area.

It will be necessary for a SUBSEC region to integrate the four recycling sub-systems as shown in **Fig. 2**, in order to make it a self-sustaining region. A river basin region from river head to front will be a good site proposal. Because such a scale of region can contain at least the four sub-systems with the folloing features: (1) producing a variety of agricultural products such as rice, vegetables, fruits and meat corresponding to various consumers' needs; (2) providing water pollution control systems of nature on the basis of landscape diversity/amenity and biological diversity as a complex continuum system; (3) giving an interface area between urban and mountainous areas; and (4) having a scale for

Fig. 5 SUBSEC regions in linkage with urban and mountainous areas.

expecting the support of local self-governing bodies to integrate SUBSEC policies.

SUBSEC regions should be linked to a plan of eco-police and eco-town. Because if the activities in urban areas produce tremendous wastes beyond the capacity of the urban areas means, the SUBSEC regions will have to come into play.

The promotion of SUBSEC will require much more efforts than traditional agriculture. Engineers should estimate the prime cost for SUBSEC activities as follows: (1) to obtain a variety of agricultural products, (2) to preserve the landscape amenity, (3) to conserve the biological diversity, (4) to maintain waste control systems, and (5) to make environmental remedies. The question here is how the prime cost should be estimated and who has to bear the prime cost.

Conclusion

The SUBSEC plan should be assumed as a kind of philosophy because of easy access to the plan through some available and ongoing interdisciplinary projects. The concept of SUBSEC is mainly based on the ideas of; (1) combining four recycling sub-systems: Water-SPAC system, other biological system, bio-production management system and products consumption system; (2) decreasing the amount of waste entropy and matters from each subsystem; and (3) enhancing the potential of both bio-production and waste-control activities, especially in the Water-SPAC system. Promoting SUBSEC plan requires three stages: an academic exchange stage; an interdisciplinary project stage, and a practical application stage. SUBSEC regions should be developed as avenues for putting SUBSEC plan into practice.

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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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Hydrogeological Potentiality of an Intensive Tubewell Area in a Barind Tract Groundwater Basin in Bangladesh: Mohammad Abdus Sattar, Research Fellow, Soil & Water Sciences, IRRI, P.O. Box 933 Los Baños, Laguna Philippines.

This study was conducted in the intensive tubewell area of Barind tract in Bogra, Bangladesh to assess the hydrogeological potentiality of the groundwater basin. It was found that the intensity of the wells are 5 per sq. kilometer with a discharge capacity of about 200 li/sec. The study indicated that there is significant direct relationship among rainfall, groundwater table fluctuation and stream flow. It is also observed that the stream flow of the rivers around the sutdy area are effluent in character through the year except in rainy season. Lithological investigation from secondary data showed that the coarser material (good water bearing material) which has 100% screenable potential lies 21 m from the ground surface. A field test boring up to 60 m revealed that 100% screenable material lies 12 m from ground surface and extend up to 60 m depth. Aquifer characteristics were determined from pump test data by using Jacob method. The transmissivity values were 4 562 m^2/day, 4 214 m^2/day and 2 900 m^2/day by time-drawdown, recovery and distance-drawdown method, respectively. Similarly, storage values were 0.000648 and 0.000527 by time-drawdown and distance-drawdown methods. These values indicate that the aquifer has good potential for ground water development.

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Evaluation of Animal-drawn Plough-seeder Developed for Traditional Rainfed Agriculture in Sudan: Omar A. Rahama, Assistant Professor, Dept. of Agric. Engineering, Faculty of Agric. Sciences; Mohamed N. Hussein, Associate Professor, Dept. of Economics, Faculty of Econ. & Rural Dev., respectively, University of Gezira, P.O. Box 20 Wadmedani, Sudan.

An animal-drawn implement (plough-seeder) was field-evaluated for the purpose of determining its future socio-economic impact. Its effect in increasing crop yield and its contribution in vertical and horizontal expansion of the traditional agriculture was studied. its use in a controlled experiment gave approximately 30% and 24% yield increase for sorghum and groundnuts, respectively.

109

Value Addition to Agricultural Products Through Agro-processing Complex — A Case Study: R.K. Jain and Sivala Kumar, Harvest and Post Harvest Technology (ICAR) Scheme, Post Harvest Technology Centre, IIR, Kharagpur-721 302 India, respectively.

Rural economy is primarily based on agricultural production. The farmer is compelled to sell his products to the middle man or processor with a small margin of profit. To retain major share of profit with the producer/grower, primary processing has to be done at the rural threshold. Therefore, there is need to establish an agro-processing complex in the rural areas for value-addition. This paper also deals with the economics of the established agro-processing complex.

111

Development and Testing of a Revolving-Blade Type Dung Collector: B.C. Thakur, Res. Engineer and D.P. Dhingra, Prof., respectively, in the Dept. of Processing and Agric. Structures, P.A.U., Ludhiana, Punjab, India.

A revolving-blade type, three-wheeled, dung collector with a working width of 69 cm and operated by two persons has been developed and extensively tested on concrete as well as brick floors in animal sheds. The dung collection capacity of dung collector was observed to be 32.8% higher on concrete floor and 24.28% on brick floor in comparison to conventional method of dung collection. The subjective studies indicate that the workers suffered from less fatigue while operating the present model as cmpared to the fixed-blade type dung collector.

112

Modelling Timeliness Losses for Forage Harvesting: S.M. Ward, and P.B. McNulty, Professor, respectively, Agricultural & Food Engineering Department, University College Dublin, Dublin 2, Ireland; M.B. Cunney, Head, Agricultural Engineering Department, An Foras Taluntais, Carlow, Ireland.

A model of the crop timeliness losses associated with delayed forage harvesting is presented. The algorithms of the model evaluate the reduction in the net energy value of silage caused by late harvesting. Crop timeliness losses are calculated as the cost of additional concentrate feed stuff required to compensate for this net energy deficiency. A microcomputer based program was developed to facilitate application of the model at farm level. Results indicate that crop timeliness losses can account for up to 44 per cent of the total system cost, and high output systems are less sensitive to timeliness losses.

113

Composting Structures for Homestead Use in Bangladesh: Akhter Ahmed, Senior Agril. Engineer, Agril, Enginering Division, Bangladesh Rice Research Institute, Joydebpur, Dhaka, Bangladesh; Md. Abdur Rashid, Associate Professor, Dept. of Agril. Engg. & Basic Engg., Bangladesh Agricultural University, Mymensingh, Bangladesh.

An investigation was made on the effectiveness of different types of homestead composting structures for making compost with domestic garbage, water hyacinth and cowdung. The 'self aerated' composting method, simply operated and without turning, was adopted for this project work. Experiments were set for garbage and water hyacinth with and without cowdung in five different structures.

On the basis of the quality of compost produced, initial investment for the structure and the availability of construction materials. Bamboo fencing structure, rectangular in shape was found to be effective and suitable for the environment of Bangladesh. No skilled labour or advanced technology is needed for constructing such structures and composting operations.

114

An Animal Drawn-cum-engine Operated Vertical Conveying Reaper-Windrower — Part I. Design and Development: N.K. Bansal, Assistant Professor, Dept. of Agril. Engineering, H.A.U., Hissar, India; Bachchan Singh, T.K. Bhattacharya, T.P. Singh, respectively, Professor and Assistant Professors, Dept. of Farm Machinery and Power Engineering, G.B.P.U.A. & T., Pantnagar-263145 (U.P.), India.

A single animal drawn-cum-engine operated vertical conveying reaper-windrower was designed, developed and evaluated for harvesting cereal crops. The machine was designed for proper utilization of draught animal power and a 3.73 kW diesel engine. The machine basically has been designed and developed for harvesting wheat and paddy crops and, subsequently, delivering it in the form of a windrow to one side of the machine.

115

Cutting Energy of Safflower Stem by Pendulum-Type Impact Tester: M.M. Ghotankar, Agric. Engineer, Nath Seeds, Aurangabad, India; S.H. Adhaoo, Dean (Agric. Eng.), P.K.V., Akola 444104, Maharashtra, India.

To optimise the value of bevel angle, blade velocity and moisture content, experiments were carried out. The effect of stem-diameter of safflower stem on cutting energy was studied (1987-88).

A pendulum-type impact tester was fabricated to determine the cutting energy requirement of the safflower stem using the TARA variety for experiment.

Knife bevel angle of 25° and knife velocity of about 2.33 m/sec were shown to be optimum. The cutting energy was directly proportional to the stem diameter and inversely proportional to the moisture content of the stalk. Multiple regression analysis supported the fact that stem diameter is a most significant independent variable.

117

Mechanized Cultivation Decision by Linear Programming: A.K.M. Shirin, Graduate Student, Asian Institute of Technology, G.P.O. Box No. 2754 Bangkok, Thailand; A. Karim Chaudhury, Chief Agricultural Engineer, Bangladesh Sugar & Food Industries Corporation, Adamjee Court, Motijeel C/A Dhaka, Bangladesh.

A linear programming model was developed to aid managerial decision in sending tractors of varying capacities for mechanized cultivation in different farms or zones having different soil and cultivation characteristics. The LP model is solved by using QSB, a PC package and SAS, a mainframe software. The LP model was used in a farming system of a sugar industry and a renting network of a private company. It was found that the distribution of the tractors as per the developed information of the model increased total output of the farming system by 6.85% and of the renting network; by 2.44% over the result obtained from multiflication of average of maximum output of each tractor, and by average of available days for cultivation in each farm/zone and number of tractors.

■■

EIMA — International Agricultural Machinery Manufacturers Exhibition

November 6-10, 1993
Bologna, Italy

The 24th Edition of EIMA this year will have a new calendar schedule: it will open on Saturday and close on Wednesday and thus will be open to the public on the first three days and reserved to those with special invitation on the last two. This was an organizational choice for the '93 Edition for technical reasons: since the first Wednesday of November is the 3rd this meant it would be impossible for the exhibitors to arrange for the transport for their machinery in the pre-Fair period coinciding with a weekend.

A weekend at the beginning of the exhibition should encourage the number of visitors, particularly from abroad and permit the large growing number of nature and gardening enthusiasts to take advantage of these free days to survey the new features proposed by manufacturers.

Innovation has always been the theme of EIMA evidenced by the full programmes over the years with exhibits, symposia and international conferences on public and private research in this sector. The annual Exhibit of new Technological Developments, reserved to EIMA exhibitors, represents the ideal link in a long chain which clearly demonstrates the committment of industry in refining production standards and developing innovative technologies for the needs of users who are ever more discriminating.

EIMA also stands for information and image, the most complete possible, on mechanization today and for the future, current interests and trends. This is a unique occasion for manufacturers and economic operators, industry and users to come together to meet not only for business purposes but also to discuss and participate in the prospectives which mechanization offers as a decisive means for the solution of technical and economic problems in agriculture and in the environment as well.

Technical data

Bologna's Fair neighbourhood covers a total surface of 250,000 square metres; 18 covered air-conditioned pavilions for an exhibition of 104.000 square metres.

Airport at 6 kms, railway station and town centre at 2 kms; the super-highway exit directly to the fair (n. 8); parking for 4,200 cars.

Data XXIII edition ('92)

- Exhibitors 1,498, of which 356 foreign;
- Machinery on exhibit 15,000;
- Visitors: 76,047 of which 6,224 from 98 different countries;
- Official Missions from 15 countries.

Product sectors

I - Endothermic engines
II - Land-reclamation and forestry equipment
III - Tractors, walking tractors, motor hoes, motor mowers, and multipurpose farm vehicles
IV - Soil-working, sowing and fertilizer-distribution equipment
V - Plant and crop protection equipment
VI - Irrigation equipment
VII - Harvesting machines
VIII - Threshing, selection and conditioning equipment
IX - Livestock husbandry equipment
X - Product processing and Dairy-work equipment
XI - Crop transportation equipment
XII - Components and accessories
XIII - Gardening equipment, small powered and manually-operated machines
IX - Miscellaneous equipment

XII C.I.G.R. World Congress and AgEng '94 Conference on Agricultural Engineering

August 29 — September 1, 1994
Milano, Italy

The 12th CIGR World Congress and AgEng '94 Conference on Agricultural Engineering, jointly organized by the CIGR (International Commission of Agricultural Engineering) and EurAgEng (European Society of Agricultural Engineering), will be held at the University of Milan from 29 August to 1 September 1994.

This will be the year's most important and significant scientific, technical and professional event in this field. Over 800 scientists and experts from 63 countries have already registered to participate, with the presentation of more than 500 scientific papers and/or posters.

The subjects covered will include all the classic areas of agricultural engineering: land and water, rural building, farm machinery, ergonomics and safety, energy and post-harvest processing. The Joint Event is intended to take two different subject approaches:

- A general strategic approach related to the role that agricultural engineering must play in the future, in order to aid the social and economic development of world agriculture and protect the environment;
- Specific scientific and technical papers reporting the state of the art in the different branches of agricultural engineering research and development.

In addition, numerous study groups will meet and discuss topics of particular immediacy and relevance. For further information, and the call for papers, contact the Conference Secretariat at: Istituto di Ingegneria Agraria, Via Celoria 2, 20133 Milano

(Italy); telephone 39/2/70600181, telefax 39/2/26680322.

News from Asian Association for Agricultural Engineering

AAAE Board Formed

The statutes of AAAE were approved in the General-Body meeting held in December 1992. As per the statutes, the AAAE Board was to be formed for this purpose. Nominations were invited through the last Newsletter (Vol. 2, No. 1, 1993). Japan and the U.S.A. responded to this. In the abscence of nominations, the members on the AAAE Board from other countries were decided by the Executive Committee after thorough discussion. The full AAAE Board Membership is listed below.

1. Prof. G. Singh, President
2. Dr. G. Quick, Vice-President
3. Mr. Y. Kishida, Vice-President
4. Dr. V.M. Salokhe, Secretary General
5. Dr. S.G. Ilangantileke, Treasurer
6. Prof. D. Gee-Clough, Editor of AEJ
7. Prof. Guiseppe Pellizzi, CIGR President
8. Dr. D.G. Hapase - India
9. Dr. A.M. Syarief - Indonesia
10. Prof. N. Ito - Japan
11. Mr. Felip Butlig - Philippines
12. Prof. Lu Zhongmin - P.R. China
13. Dr. Surin Phongsupasamit - Thailand
14. Prof. Ramesh Kanwar - U.S.A.

G. Singh awarded Fellowship of ISAE

Prof. Gajendra Singh, AAAE President and Foundation Member, was awarded a Fellowship of the Indian Society of Agricultural Engineers, during the ISAE Convention at Bhopal, India.

Ravindra Kaul Receives Kishida International Award

Ravindra N. Kaul, professor and program leader, Agricultural Mechanization, Institute for Agricultural Research, Nigeria, is the recipient of the 1993 Kishida International Award.

The award presented by the American Society of Agricultural Engineers (ASAE) during the Society's International Summer Meeting, June 20-23, at the Spokane Center, Spokane, Washington. 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. Initiated in 1978, the award consists of a plaque and a cash award of $1,000.

He has been instrumental in establishing confidence in equipment relevant to the farming system in Nigeria, and has trained several engineers who now have assumed leadership roles at institutions in India, Nigeria, and beyond.

Kaul has championed the role of women in agriculture, pioneering the measurement of workload on women for selected farm tasks and promoting the need to develop tools specifically designed for women. Under his supervision, several theses have demonstrated the energy and anthropometric needs of women. Tools developed as a result of this research have been adopted by women throughout Nigeria.

Norman R. Scott Elected President of ASAE

Norman R. Scott, vice president, research and advanced studies, Cornell University, has been named President of the American Society of Agricultural Engineers (ASAE).

Scott was inaugurated at the Society's International Summer Meeting, June 20-23, at the Spokane Center, Spokane, Washington. As president of the society, he is primary spokesperson for over 9,000 members in 50 states, 10 provinces, and 110 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 at Cornell, Scott is responsible for coordination of university-wide research. His research, teaching and administrative efforts have focused on the integrated application of structural theory, thermodynamics and biological sciences to the synthesis of structural systems, and electronic instrumentation techniques in biological systems.

The results of some of Scott's research exist in the three patents he holds on electronic techniques for automatic identification and estrus detection in dairy cattle. He has authored or co-authored 90-plus research publications.

Scott's 33-year membership in ASAE has been marked by many years of active service, including technical vice president, 1989-92, director of the professional development division, 1987-89, and chair of numerous committees. ■■

Technological and Socioeconomic Changes in Agriculture

(India)

By B.S. Ojha, J. Singh and J.P. Gupta

This book is an in-depth study of the various aspects of the geography and economics of farming in Haryana. It covers the periods 1975-76 and 1986-87, and is a repeat survey of an earlier work titled *Determinants of Agricultural Productivity: a sample study of operational holdings for land use planning* which covered the period 1975-76. The present work is a comprehensive farm management study based on data of 3,000 operational holdings located in 142 villages placed in different cropping regions of Haryana.

The main features of this work are to describe and analyze size-classwise the economics of agriculture at the spatio-temporal scale, and to map and interpret the geographical patterns and dynamics of farm inputs, the reasons for the currently changing agricultural cropland occupancy, etc., particularly the changes that have taken place during the second phase of the so-called green revolution since 1975-76.

The dominant crop production orientations have been identified, agricultural planning regions have been delimited and recommendations for agricultural development have been made. Moreover, areas of agricultural prosperity/backwardness and areas of agricultural dynamism /stagnation have been highlighted. A geonomic approach is maintained throughout this study.

This work would be invaluable to policy makers, planners, executors, administrators, politicians, and to students to geography, economics, botany and agricultural sciences.

Size: 25 cm × 18 cm, 237 pp, hardcover. Price Res. 350.00
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John Deere Tractors and Equipment Volume Two 1960-1990

(U.S.A.)

By Don Macmillan and Roy Harrington

This book covers the entire worldwide product line of the largest tarm equipment manufacturer in North America, with more than 850 photos. Although based on a specific company's products, it chronicles in detail what and why changes were made in the last thirty years in the equipment used to operate farms in North America. In less detail, it goes back to the origins or most important farm tools. The book also relates some of the similarities and differences in equipment used in other countries.

The relative importance of equipment is illustrated through a variety of tables. Equipment on U.S. farms and industry sales are given. John Deere sales in the U.S. and Canada for 1975 are given for each tractor model and each equipment type. Sales numbers are also given over time to trace the changes in demand from corn pickers to corn heads, moldboard plows to chisel plows, and similar changes.

The book reveals how engineers changed design goals as the wants of one decade become the economic needs for greater productivity in the next decade. In spite of the best team efforts, many new products failed in the marketplace. Causes described include inadequate customer base, more attractive alternatives, suitable materials or components not available, equipment not tested long enough in enough conditions, or size mismatched to customer requirements. The book describes even more products that were developed and not placed on the market than those that failed when sold. Examples include a gas turbine tractor, a mechanical-infinitely-variable tractor transmission, using rear tractor tires for a fuel tank, a farm truck, and a rear-engine compact tractor developed in the forties followed by another in the seventies.

Size: 8-1/2 × 11 in., 400 pages, hardbound. Published by the American Society of Agricultural Engineers 2950 Niles Road, St. Joseph, Michigan 49085-9659, U.S.A.

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C Rojanasaroj

T.P. Ojha
Dy. Director, General, Indian Council of Agricultural Research, Krishi Bhawan, Dr. Rajemdra Prassad Road, New Delhi-110001. Inida

S.R. Verma
Prof. of Agricultural Engineering, College of Agril. Engg., Punjab Agricultural University, Ludhiana - 141004, India

Soedjatmiko
Head of Subdirectorate of Agric. Engineering, Ministry of Agriculture, Jakarta, Indonesia

Mansoor Behroozi-Lar
President, Iranian Society of Agricultural Machinery Engineers, P.O. Box 31585-574, Karaj, Iran

Jun Sakai
Professor, Dept. of Agric. Engineering, Faculty of Agriculture, Kyushu University 46-05, Hakozaki, Higashi-ku, Fukuoka 812, Japan

Bassam A. Snobar
Professor & chairman, Plant Production Dept., Faculty of Agriculture, University of Jordan, Amman, Jordan

Chang Joo Chung
Professor, Dept. of Agric. Engineering, College of Agriculture, Life Science, Seoul National University, Suweon 441-744 Korea 170

Chul Choo Lee
Research Professor, Seoul Woman's University, Mailing Adress: Rm. 514 Hyundate Goldentel Bld. 76-3 Kwang Jang Dong Ku, Seoul, Korea

Imad Haffar
Assistant Professor of Agric. Mechanization, Dept. of Soils, Irrigation and Mechanization, Faculty of Agriculture and Food Sciences, American University of Beirut, Beirut, Lebanon

Muhamad Zohadie Bardaie
Associate Professor, Faculty of Engineering, Universiti Pertanian Malaysia, 43400 UPM, Serdang, Selangor, Darul Ehsan, Malaysia

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

Mohammad Afzal
Senior Engineer (Mechanization Engineer), Farm Machinery Institute, National Agric. Research Centre P.O. NIH, Islamabad, Pakistan

Allah Ditta Chaudhry
Associate Professor & Charman, Dept. of Farm Machinery and Power, Agric. Engineering and Technology, University of Agriculture, Faisalabad, Pakistan

A.Q. Mughal
Professor, Faculty of Agricultural Engineering, Sind Agriculture University, Tandojam, Sind, Pakistan

Reynaldo M. Lantin
Agricultural Machinery Expert, Regional Network for Agricultural Machinery, c/o United Nations Development Programme P.O. Box 7285 ADC Pasay City Metro Manila, Philippines

Ricardo P. Venturina
President & General Manager, Rivelisa publishing House, 215 F, Angeles St. cor Taft Ave. Ext., 1300 Pasay City, Metro Manila, Philippines

S. Illangantileke
Head, Dept. of Agric. Engineering, Faculty of Agriculture, University of Peradeniya, Sri Lanka

Sen-Fuh Chang
Professor, Agric. Machinery Dept. National Taiwan University, Taipei, Taiwan

Surin Phongsupasamit
Associate Professor, Dept. of Mech. Engineering, Faculty of Engineering, Chulalongkorn University, Ban 10330, Thailand

Chanchai Rojanasaroj
Research and Development Engineer, Dept. of Agriculture, Ministry of Agriculture and Cooperatives, Bang-Khen, Bangkok 10900, Thailand

Gajendra Singh
Professor of Agric. Engineering, Div. of Agricultural & Food Engineering, Asian Institute of Technology, GPO 2754, Bangkok 10501, Thailand

Yunus Pinar
Associate Professor, Agric. Engineering Dept., Faculty of Agriculture, University of Ondokuz Mayis, Kurupelit, Samsun, Turkey

—EUROPE—

Anastas Petrov Kaloyanov
Professor & Head, Research Laboratory of Farm Mechanization, Higher Institute of Economics, Sofia, Bulgaria

Pavel Kic
Associate Professor, University of Agriculture Prague, Faculty of Agric. Engineering, 165 21 Praha 6-, Suchdol, Czechoslovakia

Henrik Have
Prof. of Agric. Machinery and Mechanization at Institute of Agric. Engineering, Royal Veterinary- and Agricultural University, Agrovej 10 DK2630 Tastrup, Denmark

Giuseppe Pellizzi
Director of the Institute of Agric. Engineering of the University of Milano and Professor of Agric. Machinery and Mechanization, Via G. Celoria, 2-20133 Milano, Italy

Aalbert Anne Wanders
Staff Member, Dept. of Development Cooperation, Netherlands Agricultural Engineering Research Institute (IMAG), Wageningen, Netherlands

John Kilgour
Senior Lecturer in Farm Machinery Design at Silsoe College, Silsoe Campus, Silsoe, Bedford, MK45 4DT, UK ■■


G Singh


Y Pinar


P Kic


A P Kaloyanov


H Have


G Pellizzi


A A Wanders


J Kilgour

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