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FARM MACHINERY INDUSTRIAL RESEARCH CORP.

NEW TECHNOLOGY IN GRAIN POSTHARVESTING

by Ritsuya Yamashita
Professor emeritus of Kyoto University

This book contains the last lecture of professor Ritsuya Yamashita at his retirement by the age limit, which were summarized from his enormous researches for a long time, and supplementary recent new technologies of post harvesting. Therefore, topics in this book are extended to all techniques of postharvest processing and a lot of new findings and techniques are described from fundamental studies for their actual applications.

Details are explained especially on property of rice, low cost drying system of rice from the taste point of view, husking, whitening and polishing techniques and dynamic storage. This book is consisted of 9 chapters and 4 appendixes: Chapter 1 Introduction, Chapter 2 Harvesting, Chapter 3 Drying, Chapter 4 Husking, Chapter 5 Whitening and polishing, Chapter 6 Separation and rice mixing, Chapter 7 Storage, Chapter 8 Quality adjusting by moisture control, packing and distribution, Chapter 9 Conclusion (future technique), Appendix-1 Evaluation of rice taste by taste meter, Appendix-2 Numeric color expression by color difference meter, Appendix-3 Example of calculation of drying speed with temperature control and Appendix-4 Equations for respiratory type gas distribution to possible and necessary future techniques from quality, taste and low cost production of rice point of view.

The author is convinced that this book is surely useful as a guide for technicians, administrators and researchers concerning to the postharvest.

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EDITORIAL

Plowshares..Instead...of Guns

The above title is an old adage that decades ago, the peace advocates rallied the powers that be to turn the metals for the manufacture of guns instead to the fabrication of plowshares. As a figurative expression, the latter refer to the cutting part of the moldboard plow that is manifestly for tilling the soil, hence grow more food for everyone. On the other hand, the former refer to the armaments of war.

By and large, the message of the adage is still very much alive these days. When the 21st century ushered in, mankind anticipated peace and quiet with the end of the US-Soviet confrontation in the interest of cooperation. And yet, the worldwide terrorism cropped up sowing fear and destruction, the signs of war and the fear of mass destruction begin to occupy the minds and thoughts of many on what Iraq and North Korea are actually up to.

The fears and anxiety notwithstanding, the soil must indeed be tilled for greater productivity. The farmer deserves indeed the help that it can get, hence more than the plowshare should be made available to him. Agriculture is the lifeblood of mankind and must never be relegated to the background and that agricultural technology that employs mechanization should be a top priority.

Herein lies AMA's wish to utilize war monies instead to country by country cooperative enterprises for peaceful agricultural development.

Necessarily, a strong and effective communication must prevail wherein AMA reiterates its interest to help.

Yoshisuke Kishida

Chief Editor

Tokyo, Japan

December 2002

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Management of Primary Tillage Operation to Reduce Tractor Fuel Consumption

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Abstract

An experiment was carried out at the Mushaqar Agricultural Experiment Station, located approximately 30 km southwest of Amman. The objective was to study the effect of plow type (moldboard, disk and chisel plow) at three plowing depths, namely: shallow (10-15 cm); medium (15-20 cm); and deep (25-30 cm), at three levels of soil moisture content, θ, namely; dry (10.71%); moist (19.55%); and wet (31.47%), on tractor fuel consumption to perform a primary tillage operation. Results indicate that the lowest mean of fuel consumption for the three treatments of plowing depths and the three soil moisture levels was when using chisel plow (5.2 L/ha) compared to disk plow (11.5 L/ha), and moldboard plow (13.8 L/ha). Fuel consumption increased as plowing depth increased for all plows at each level of soil moisture content. It was 6.8 L/ha for shallow depth (10-15) cm, 9.4 L/ha for medium depth (15-20) cm, and 14.3 L/ha for deep plowing (25-30 cm). Dry soil (θm = 10.71%) showed higher fuel consumption (11.1 L/ha) compared to wet soil (θm = 31.47 %) which showed lower fuel consumption (10.3 L/ha). The lowest mean fuel consumption for all plows at all plowing depths (9.1 L/ha) was at soil moisture content (θm) of 19.55%. There was an interaction effect between plow type, plowing depth and soil moisture content on tractor fuel consumption. The lowest fuel consumption was when using chisel plow, for the three plowing depths at the three levels of soil moisture content. The fuel consumption when using moldboard plow was more than for disk plow, at all levels of plowing depth and soil moisture content. For all plows at each level of soil moisture content, fuel consumption increased by increasing the plowing depth. The level two of soil moisture content (θm = 19.55%) showed the lowest fuel consumption for all plows and plowing depths compared with soil moisture of 10.71% and 31.47%, where the level one of soil moisture (10.71%) consumed more fuel than level three (31.47%).

Introduction

The increase in fuel price in the world necessitates its efficient use in operating the agricultural machinery and equipment. There are numerous implements and implement types available for performing both primary and secondary tillage operations. These include moldboard; disk; and chisel plows. Approximately 20% of the total agricultural production energy is required for field operations (Stout, 1977). Energy input requirements for tillage vary appreciably with soil type, crop sequence, soil moisture content, type of plow, land topography, depth, and tractor ground speed (Stoskopf, 1981). Tillage energy evaluation should include measurements of operational energy required for various tillage implements on various soil types, through documentation of soil condition and reporting of both fuel consumption and draft data (Bowers, 1985). The draft force requirement for tillage implements has a great concern when designing tillage implements and deciding suitable tractor size. The draft force needed for chisel plow increased linearly with the increase of plowing depth (Gebresenbet, 1989). Any fuel saving in any agricultural operation would maximize profit and reduce the environmental pollution hazard. This experiment was conducted to study the influence of plow type, soil moisture content, and depth of plowing on tractor fuel consumption to perform primary tillage.

Materials and Methods

The experiment was carried out at the Mushaqar Agricultural Experiment Station, located approximately 30 km southwest of Amman. The location mean annual rainfall is about 350 mm. The soil was classified as very fine, smectitic, thermic, Typic Chromoxerert (Taimeh and Khresiat, 1988). The experiment started on August 1997. The study area covered approximately 3.0 ha. The treatments were arranged in a split-split plot design, with four replicates. The three types of plow in the main plots were: moldboard (1m wide); disk (1m wide); and chisel (2m wide).The three tillage depths in the sub-plots were: 10-15; 15-20; and 25-30 cm, and three levels of soil moisture content in the sub- sub plots were: 10.71%; 19.55%; and 31.47%. Two axles diesel tractor, Ford 1988 model 5610 with 72hp PTO power was used in all the tests. The fuel consumption (FC) measurements were made by using volume flow meter mounted on the tractor body, which consisted of graduated glass cylinder of 1000-ml volume. The flow meter was connected directly from its lower part (bottom) to the tractor fuel tank at one side and with the fuel pump on the other side. The upper part of flow meter was connected with the injectors which returned the excessive fuel back to the flow meter through a return pipe. A valve situated between the graduated cylinder and the fuel tank controlled the fuel in the cylinder. The measurements of fuel consumption were carried out for each sub-sub plot (2X100 m^2) by making two runs for moldboard and disk plow, 1m wide each, and one run for chisel plow (2m wide) for each plowing depth at each level of soil moisture content. The first level of soil moisture content (M_1) was on October 10, 1997 before rainfall. The gravimetric soil moisture content (θm) was 10.71% in the top 30 cm. The second level of soil moisture content (M_2) was on December 15, 1997 after rainfall of (51.5) mm. θm was 19.55% in the top 30 cm. The third level of soil moisture content (M_3) was on December 27, 1997, after receiving a total rainfall of (105.5) mm. θm was 31.47% in the top 30 cm of the soil.

Results and Discussion

Tractor fuel consumption when using chisel plow (5.2 L/ha) was less than that when using disk plow (11.5 L/ha) or moldboard plow (13.8 L/ha). This was because the chisel plow digs the soil without having to invert and pulverize it the way the moldboard and disk plows do. Thus, reducing the draft power required (Smith and Wilkes, 1977). The disk plow treatment showed less fuel consumption than the moldboard plow treatment, under the same conditions and by turning the same volume of soil (**Fig. 1**) due to free rotation of the disk, which was produced due to the frictional force between the disk and the soil.

Fuel consumption increased as the plowing depth increased (**Fig. 2**). Shallow plowing (10-15 cm) treatment resulted into the lowest fuel consumption (6.8 L/ha). While, deep plowing (25-30 cm) treatment resulted into the highest fuel consumption (14.3 L/ha), be-

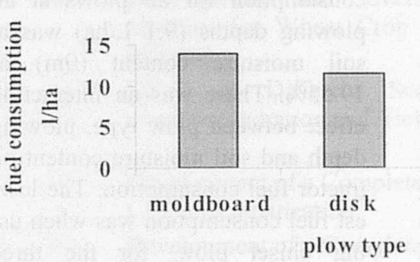

Fig. 1 Effect of plow type on tractor fuel comsumption (L/ha).

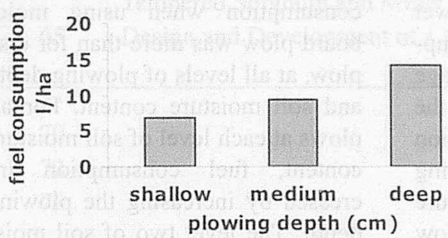

Fig. 2 Effect of plowing depth on tractor fuel comsumption (L/ha).

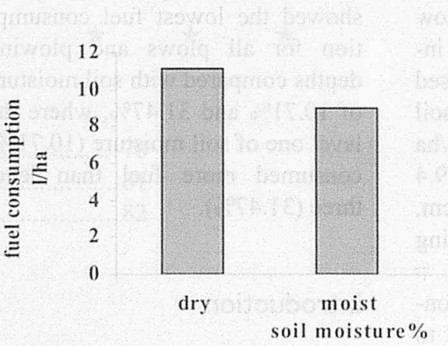

Fig. 3 Effect of soil moisture content at the time of plowing on fuel comsumption (L/ha).

cause each 1 cm depth of plowing means breaking and turning 100 m^3 of the soil per hectare.

When the soil moisture content (θm) was 10.71%, the tractor consumed the highest fuel amounts (11.12 L/ha) when compared to (9.1 L/ha) and (10.3 L/ha) at moisture contents of 19.55%, and 31.47%, respectively, (**Fig. 3**). This is due to the high specific draft that resulted from the attraction of soil particles to each other by cohesion. By increasing the soil water content the specific draft decreased then increased due to the attraction of liquids on solids or particles in contact with solids resulting from surface tension (adhesion). Therefore, this increased the fuel consumption due to the increase in power required (Baver *et al.*, 1976). There were interactions between types of plow, plowing depth, and soil moisture content, on fuel consumption (**Table 1**). The lowest fuel consumption was when using chisel plow at the three plowing depths (10-15), (15-20), and (25-30) cm, at the three levels of soil moisture content (10.71%, 19.55%, and 31.47%).

The fuel consumption when using moldboard plow was more than the disk plow at all levels of plowing depth and soil moisture content. For all plows at each level of soil moisture content, fuel consumption increased by increasing the plowing depth. The level two of soil moisture content (θm = 19.55%) showed the lowest fuel consumption for all plows and plowing depths compared with soil moisture of 10.71% and 31.47%. The level one of soil moisture (10.71%) consumed more fuel than level three 31.47%. Because when cohesion and adhesion are at minimum, there is sufficient moisture between the individual particles to minimize the cementation effects. On the other hand, there is not enough water present to cause the formation of distinct films around particle contacts to produce the cohesion (Baver *et al.*, 1976). The lowest fuel consumption (3.3 L/ha) was when using the chisel plow at shallow plowing depth (10-15 cm), where soil moisture content (θm) was 19.55% because the individual granules are soft, and cohesion is at minimum. The highest fuel consumption (21.5 L/ha) was when using moldboard plow at deep plowing (25-30 cm), for the dry soil (θm=10.71%), because of high cementation of soil particles with each others.

Table 1. Effect of plow type, plowing depth and soil moisture on fuel consumption

Plow type	Fuel consumption (L/ha)								
	Moldboard			Disk			Chisel		
Depth** / Moisture#	D1	D2	D3	D1	D2	D3	D1	D2	D3
M_1	10.0 j *	13.8 f	21.5 a	7.9 kl	11.1 hi	17.8 c	4.5 pq	5.8 o	7.8 m
M_2	8.3 k	11.3 h	16.8 d	6.4 n	9.8 j	15.7 e	3.3 s	4.2 qr	5.8 o
M_3	9.7 j	12.8 g	19.8 b	7.5 lm	10.7 i	16.7 d	3.9 r	4.9 p	6.9 n

* Means followed by the same letter do not differ significantly at the 5% level of probability according to Duncan Multiple Range Test (DMRT).

**D1=(10-15)cm; D2=(15-20) cm; and D3=(25-30) cm.

\# M1=(10.71%); M2=(19.55%); and M3=(31.47%)

Conclusions and Recommendations

The type of plow, plowing depth, and soil moisture content at the time of plowing played an important role in saving tractor fuel consumption. Fuel saving can be achieved by a good management of tillage operation which may include the proper choice of the tillage implement, since chisel plow had the lowest fuel consumption compared to moldboard and disk plow. The most fuel was consumed by moldboard plow treatment. Plowing depth at 15 cm is sufficient for plant growth while fuel consumption increased significantly as plowing depth increased. Therefore, for fuel saving, plowing depth should not be deeper than 15 cm and performing tillage operation at proper soil moisture content because fuel consumption was high in both dry and wet soil, while performing the tillage operation at optimum soil moisture (19.55% in this case) saved the fuel.

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Effect of Tillage and Fertilizer on Semi-arid Sorghum Yield

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Abstract

A researcher-managed experiment was conducted at Hombolo Research Station in Dodoma Region of central Tanzania for two consecutive rainy seasons in 1991-92 and 1992-93 with the objective of investigating the effects of tillage and fertilizers on yield of sorghum (*sorghum bicolor*). The experiment consisted of seven tillage treatments combined with four fertilizer treatments on a complete randomized block design with three replications. The treatments were zero tillage, flat cultivation, flat cultivation plus mulch, tied ridging, strip catchment tillage, tractor tillage and tractor tillage plus mulch. Fertilizer treatments consisted of no fertilizer (control), farm yard manure (FYM) at 10 t ha^{-1}, triple super phosphate (TSP) at 100 kg ha^{-1}, and FYM plus TSP at 5 t ha^{-1} and 50 kg ha^{-1}, respectively.

In two consecutive growing seasons, hand-hoe cultivation increased the bulk density of the soil except on tractor tillage without-and-plus mulch where there was a decrease of the bulk density. Deep cultivation (by use of tractor) increased the infiltration of water into soil mainly as a result of the reduction in bulk density. Crop performance, expressed as grain yield of sorghum, was better under deep tractor tillage than under shallow hand-hoe cultivation. In 1992-93 season, the FYM gave remarkable grain yield increases compared to other fertilizer combinations.

Introduction

Nearly two-thirds of Tanzania (with a total area of 939,701 km^2) can be described as semi-arid on the basis of having a probability of less than 25 % of receiving 750 mm of rainfall per year. The Dodoma Region, central Tanzania, is the driest area in Tanzania registering the lowest average annual rainfall (400-650 mm) and the longest dry season (8 months). Typical of low rainfall environments, the rainfall is unevenly distributed both spatially and temporally.

Agriculture is the basis of the population's mainly subsistence economy in the Dodoma Region. Farming is entirely dependent on moisture supply from rainfall, and the frequent occurrence of mid-season drought is one of the main constraints to production. The possibilities of irrigating to supplement rainfall for crop production are limited for reasons of both the expense and lack of perennial sources of surface water and ground water. The key, therefore, to mitigating the effects of low and unreliable rainfall and stabilizing food production is more effective management of rain water. Management strategies include reduction in run-off losses, the concentration of rain water where appropriate through either off-or-field water concentration practices and also improving the efficiency of utilization of water by crops. Very little systematic research has been done in Tanzania on these aspects.

The objective of this report is to describe the effects of tillage and fertilizers on the yield of sorghum (*Sorghum bicolor*) in a semi-arid environment.

Materials and Methods

A researcher-managed experiment was conducted at the Hombolo Research Station in the Dodoma Region of central Tanzania for two consecutive rainy seasons in 1991-92 and 1992-93. The experiment consisted of seven tillage treatments combined with four fertilizer treatments on a complete randomized block design with three replications. The treatments were zero tillage, flat cultivation, flat cultivation plus mulch, tied ridging, strip catchment tillage, tractor tillage and tractor tillage plus mulch. In the zero tillage plots, the standing vegetation was manually slashed before making holes for planting using cutlasses down to 5 cm depth. The flat cultivation to 10 cm depth was performed using a hand-hoe. Mulch (e.g., dead plant materials) were added uniformly to the plots after planting. Tied ridging was done first by making parallel ridges along the contour at 0.75 m, and then furrows were tied at 1.5 m intervals. Strip catchment tillage was performed by hand-hoeing a strip of 10 cm wide on both sides of a crop row. Tractor tillage was done using a disc plough down to a depth of 15 cm.

Fertilizer treatments consisted of no fertilizer (control), farm yard manure (FYM) at 10 t ha^{-1}, triple super phosphate (TSP) at 100 kg ha^{-1}, and FYM plus TSP at 5 t ha^{-1} and 50 kg ha^{-1}, respectively.

The test crop was sorghum (*Sorghum bicolor* cv Tegemeo) planted on 5 × 20 m plots laid out at 2% slope. Row spacing and within row spacing were 0.75 m and 0.30 m, respectively.

Soil bulk density and infiltration measurements were taken prior the initiation of the experiment and immediately after harvest in June according to Klute (1986). Grain yield was recorded at harvest.

Results and Discussion

Soil physical properties

The soil bulk density for all hand-hoe cultivated plots were higher than the pre-cultivation density even after two years since the initiation of the experiment (**Table 1**). Under tractor tillage treatments, there was a 0.7% decrease in bulk density for both tractor tillage and tractor tillage plus mulch at top (0-5 cm) soil depth. At 10-15 cm soil depth, however, the decrease in bulk density for both tractor tillage and tractor tillage plus mulch was 6%. The highest decrease in soil bulk density (11%) was observed at 15-20 cm depth for tractor tillage plus mulch treatment.

During 1992-93 cropping season, the 3-h cumulative infiltration values for both hand-hoe cultivation and tractor tillage treatments are shown in **Table 2**. Compared to the 1991-92 season, the cumulative infiltration increased by 4.3, 8.1, 10.2% for flat cultivation, flat cultivation plus mulch and tractor tillage plus mulch, respectively.

The results show that deep cultivation (using a tractor or otherwise) increases the infiltration of water into the soil mainly as a consequence of the reduction in bulk density of these naturally occurring hard-setting and crusting soils (MaCartney et al., 1971; Kayombo, 1993).

Crop Response

Sorghum grain yield was significantly affected by both tillage treatments (**Table 3**) and tillage cum-fertilizer treatments (**Table 4**).

In the 1991-92 cropping season, hand-hoe cultivation treatments recorded higher grain yields than tractor tillage plots, with tied ridging registering over 2000 kg ha^{-1} (**Table 3**). Low yields in tractor tillage plots were attributed to late planting on these plots. Of tillage cum-fertilizer treatments, strip catchment tillage- FYM (1/2) + TSP (1/2) treatment gave the highest grain yield followed closely by the tied ridging – fertilizer combinations (**Table 4**). Positive grain yield responses of strip catchment tillage – fertilizer combination could be attributed to harvesting of water along the crop row from the uncultivated/trafficked inter-row space (Willocks, 1994). Although the infiltration rate did not increase appreciably, the tied ridges facilitated rainfall infiltration into the soil by retaining a major proportion of rainfall received on-site (Kayombo, 1992, 1993).

In the 1992-93 cropping season, the highest yields were obtained from tractor tillage both without-and-plus mulch (**Table 3**). When fertilizer was isolated as a factor influencing yield, the FYM gave the highest sorghum grain yield compared to the no-fertilizer or FYM-TSP combinations (**Table 5**). Of the tillage cum-fertilizer treatments, the tractor tillage plus mulch-FYM combinations gave the highest significant grain yield followed by the tractor tillage plus mulch-FYM (1/2) + TSP (1/2) treatment (**Table 3**).

These results show that the crop performance was relatively better under deep tillage than under shallow cultivation. Furthermore, crop performance in this semi-arid environment was considerably improved by the application of FYM, although it is not yet known whether this effect is due to improved soil water retention or plant nutrients.

Table 1. Effect of Tillage on Soil Bulk Density (Mg m^{-3}) Immediately after Harvest, 1992-93 Season

Tillage method	Depth (cm) 0-5	5-10	10-15	15-20
Prior experiment	1.45	1.50	1.52	1.52
Zero tillage	1.56	1.54	1.53	1.43
Flat cultivation	1.55	1.55	1.56	1.53
Flat cultivation + mulch	1.58	1.56	1.48	1.58
Strip catchment tillage	1.46	1.49	1.61	1.49
Tied ridging	1.48	1.49	1.50	1.41
Tractor tillage	1.45	1.44	1.43	1.45
Tractor tillage + mulch	1.45	1.44	1.43	1.37

Table 2. Effect of Tillage on cuMulative Infiltration (cm) Immediately after Harvest

Tillage method	1991-92	1992-93
Zero tillage	68.5	62.8
Flat cultivation	77.0	80.3
Flat cultivation + mulch	88.6	95.8
Strip catchment tillage	79.9	107.5
Tied ridging	43.2	39.7
Tractor tillage	115.8	119.3
Tractor tillage + mulch	128.3	141.4

Table 3. Effect of Tillage Methods on Grain Yield of Sorghum (kg ha^{-1})

Tillage method	Crop season 1991-92	1992-93
Zero tillage	1909 b	1462 b
Flat cultivation	1995 b	1689 b
Flat cultivation + mulch	1760 c	1252 b
Strip catchment tillage	1961 bc	1379 b
Tied ridging	2006 ab	1641 b
Tractor tillage	756 e	1693 b
Tractor tillage + mulch	1005 d	2143 a

Note: Letters a-e denote significance at 5% level using Duncan's new multiple range test. Means with the same letter are not significantly.

Table 4. Effect of Tillage Cum Fertilizer Treatments on Sorghum Grain Yield (kg ha^{-1})

Tillage	Fertilizer	Crop season	
		1991-92	1992-93
Zero tillage	Control (no fertilizer	1952 abc	949 fg
	Farm yard manure (FYM)	1862 abcd	1655 bcdefg
	Triple superphosphate (TSP)	1954 abc	1739 bcdefg
	FYM (1/2) plus TSP (1/2)	1869 abcd	1849 bcdef
Flat cultivation	Control	1289 afgd	1405 cdefg
	FYM	2252 ab	2356 abc
	TSP	2044 abc	1164 defg
	FYM (1/2) plus TSP (1/2)	1995 abc	2246 abcd
Flat cultivation plus mulch	Control	1829 bcde	1427 cdefg
	FYM	1981 abc	1628 bcdefg
	TSP	1569 defg	891 fg
	FYM (1/2) plus TSP (1/2)	1863 abcd	1358 cdefg
Tied ridging	Control	2142 ab	2105 abcde
	FYM	2137 ab	2057 abcde
	TSP	2037 ab	1086 efg
	FYM (1/2) plus TSP (1/2)	2155 ab	1702 bcdefg
Strip catchment tillage	Control	1267 fg	665 g
	FYM	2152 ab	2102 abcde
	TSP	2037 abc	1407 cdefg
	FYM (1/2) plus TSP (1/2)	2386 a	1667 bcdefg
Tractor tillage	Control	493 hi	1116 efg
	FYM	903 ghi	2313 abc
	TSP	454 i	1487 bcdefg
	FYM (1/2) plus TSP (1/2)	1174 fg	2239 abcd
Tractor tillage plus mulch	Control	1002 gh	1795 bcdef
	FYM	918 ghi	2657 a
	TSP	828 ghi	1768 bcdef
	FYM (1/2) plus TSP (1/2)	1273 fg	2555 ab

Note: Letters a-i denote significance at 5% level using Duncan's new multiple range test. Means with the same letter are not significantly different.

Table 5. Effect of Fertilizer on Sorghum Grain Yield (kg ha^{-1})

Fertilizer	Crop season	
	1991-92	1992-93
Control (no fertilizer)	1424 b	1351 c
FYM	1743 ab	2109 a
TSP	1560 b	1363 c
FYM (1/2) plus TSP (1/2)	1816 a	1945 ab

Note: Letters a-c denote significance at 5% level using Duncan new multiple range test. Means with the same letters are not significantly different

Conclusions

The following conclusions were drawn from the study:

1. In two consecutive growing seasons in 1991-92 and 1992-93, deep tillage reduced soil bulk density and increased infiltration of water into the soil.
2. Crop performance under deep tillage was better than under shallow cultivation.
3. Farm yard manure (FYM) gave remarkable yield increases compared to other fertilizer combinations.

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Effects of Tillage Methods on Soil Physical Conditions and Yield of Beans in a Sandy Loam Soil

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Abstract

The effects of tillage methods on soil physical properties, weeds and yield performance of three bean varieties (*Phaseolus vulgaris L.*, Canadian Wonder, Selian Wonder and TMO 216) were investigated for a sandy loam soil at Morogoro, Tanzania. Nine tillage treatments were compared in the 1990 season: hand hoeing (HH), minimum tillage (MT), minimum tillage with mulch (MTM), moldboard plowing (M), moldboard plowing followed by disc harrowing once (MH1), moldboard plowing followed by disc harrowing thrice (MH3), disc plowing (D), disc plowing followed by disc harrowing once (DH1) and disc plowing followed by disc harrowing thrice (DH3). In the 1991 season MTM was withdrawn and two tillage treatments were added, namely; moldboard plowing with draft animal power (DAP) and moldboard plowing with single axle tractor (SAT). The effects of tillage treatments on soil physical conditions for the establishment of beans were better quantified by soil bulk density and soil water content (% w/w) rather than by cone resistance. However, the cone index was better in identifying the plow pan development under all the "tractorised" treatments. The DH3 was found to be the best overall tillage method in relation to bean yield of all three test varieties.

Introduction

Tillage is usually defined as the mechanical manipulation of the soil aimed at improving soil conditions affecting crop production. Three primary aims are generally attributed to tillage: control of weeds, incorporation of organic matter into the soil, and improvement of soil structure (Hillel, 1980). Very little information exists in Tanzania at the moment which can be used to assist in the equipment design, selection and use to effectively meet these aims under different soil-and-climatic conditions and crops. Yet, crop cultivation constitutes the most important (economic) activity in the country.

Crops are often grouped into cereals, row crops, root crops, etc., and it is assumed that species within groups respond alike to tillage treatments. Yet we know, for example, that row crops vary in their soil moisture and other requirements (Jackson, 1989). Differences among soil types is an important factor in crop and water management response to a given tillage treatment. We need to consider what crop and soil responses we want on each soil type and then tailor tillage practices to meet the specific objectives. In tillage research more attention, therefore, needs to be paid to the specific crop, soil and climate involved. Furthermore, the response of a crop to a given tillage treatment on a particular soil often depends on the weather during the year. Tillage practices, therefore, need to be tested over a number of years.

This paper describes the effects of various tillage treatments on soil structure and yield of three bean (*Phaseolus vulgaris L.*) varieties, during two consecutive seasons.

Experimental Methods

Location, Soil and Weather

The experiment was conducted at the Sokoine University of Agriculture (SUA), Morogoro, Tanzania, during the March – June growing seasons of 1990 and 1991. The SUA is located 6°05' S and 37°37' E at an elevation of 525 m a.s.l. The soil at the site is sandy to loam sand. Prior to the initiation of the experiment, the site was under vegetation fallow for two years. The rainfall and evaporation data during the two growing seasons is shown in **Table 1.** The total growing season rainfall varied from 521 mm in 1990 to 490 mm in 1991.

Treatments and Experimental Design

The tillage implements used in the field experiment were the hand hoe, disc plow, moldboard plow and disc harrow. In 1990 the tillage treatments were: hand hoeing (HH); minimum tillage (MT); minimum tillage with mulch (MTM); moldboard plowing only (M); moldboard plowing followed by disc harrowing once (MH1); moldboard plowing followed by disc harrowing thrice (MH3); disc plowing only (D); disc plowing followed by disc harrowing once (DH1); and disc plowing followed by disc harrowing thrice (DH3).

In 1991, the MTM treatment was withdrawn and two tillage treatments involving the use of a moldboard plow were added. In one treatment the plow was pulled by draft animal power (DAP) and the other by a single axle tractor (SAT).

Tillage treatments were laid out on a complete randomized block design with three replications. Each plot measured 4 × 25 m.

Soil and Crop Management

The each tillage plot was divided into three equal portions measuring 4 × 8 m each. Each portion was planted to either Canadian Wonder, Selian Wonder or TMO 216 at a spacing of 60 cm between rows and 10 cm within rows. Planting was done in the first week of April 1990 and the third week of March 1991. One seed per hole was sown and gap filling was done a week after planting. Only phosphate fertilizer was applied at a rate of 60 kg P_2O_5 per hectare in the form of triple super phosphate (TSP). Weeding was done manually twice, at 14 days interval from day of planting.

Soil and Crop Measurements

Immediately after planting the crop, and every two to three weeks thereafter, bulk densities were measured using soil cores at three positions per plot from 5 cm to 20 cm depth in 5 cm increments. The values of soil cone index were measured immediately after planting and every two to three weeks thereafter using a cone penetrometer. Measurements were made at 6 positions in each plot from 0 cm to 25 cm depth. Using a screw auger, moisture contents (% w/w) were taken from 0 cm to 30 cm depth in 10 cm increments at positions corresponding to all bulk density and cone index measurements. In 1991, however, moisture samples were taken in the 0 – 10 cm depth only. Weed types and populations were measured with a 0.1 m^2 quadrant at 6 random positions per plot two days before the scheduled weeding. All bean pods from each portion within a plot were harvested, sun-dried, threshed, and the grain graded and weighed at maturity. The cost per hectare of each treatment was determined by considering the retail hire rate that the farmer would pay.

Results and Discussions

Soil Bulk Density

Soil bulk density values after planting during the March – June 1990 season are shown in **Table 2a**. Soil bulk density increased with depth under each tillage treatment as the growing season progressed, but the change was more pronounced under moldboard and disc plowing with one or three harrowings. As expected, the bulk density of the surface soil was high under minimum tillage (MT). Minimum tillage with mulch (MTM) was a result of other tillage treatments due to a negligible disturbance of the soil under minimum tillage.

Bulk density measurements taken during the March – June 1991 growing season are shown in **Table 2b**. Soil bulk density increased with depth and with advance in the growing season under all tillage treatments, but as in the previous season there was a pronounced increase in bulk density under moldboard plowing plus harrowing thrice (MH3) and disc plowing plus harrowing once (DH1) and thrice (DH3) on 2 May 1991. This could be attributed to rainfall impact and surface sealing during the growing season. There was an increase of over 10 % in bulk density values of all tillage treatments in 1991 when compared to the values in 1990. These results agree with earlier findings (Agboola, 1981) that the more intensity the tillage, the higher the bulk density of the surface and sub-surface soil. Bulk density values under animal plowing (DAP) and single axle tractor plowing (SAT) were similar to those under hand hoeing (HH). The cone index values taken during the March-June 1990 growing season are shown in **Table 3a**. Generally, values did not show any consistent trend in regard to tillage treatment, although index values increased in all tillage treatments on 15 May 1990 as the soil dried up with diminishing rainfall.

The cone index values taken after planting during the March-June 1991 season are given in **Table 3b**. Two things come out clearly from the results. Firstly, cone index val-

Table 1. Growing Season Rainfall, Open Pan Evaporation and Air Temperature at SUA

	Growing Season 1990					Growing Season 1991				
	March	April	May	June	Total	March	April	May	June	Total
Rainfall (mm)	146.4	250.4	112.7	11.7	521.2	229.1	193.6	56.8	10.8	489.7
Departure* (mm)	21.7	56.6	16.8	-8.5	86.6	98.6	-0.2	-37.0	-9.4	52.0
Open pan evaporation (mm)	160.0	96.0	74.0	78.0	408.0	119.0	110.0	112.0	92.0	433.0
Mean air temperature (℃)	25.9	24.9	23.9	21.9	-	25.2	25.4	24.0	22.3	-

*: Departure from a 17 – year average.

ues in all tillage treatments were greater than those taken in 1990, which may be attributed to continuous cropping (Agboola, 1981; Kayombo and Lal, 1994). Secondly, with the exception of hand hoeing (HH) and minimum tillage (MT), the cone index values in all tillage treatments increased to a maximum value at 10-20 cm depth and then decreased with increasing soil depth. This could be attributed to the development of a subsoil plow pan as a result of plow-sole compaction (Roth et al., 1988; Guerif, 1994). The early identification of the existence of the plow pan after only two consecutive cropping seasons, shows that the cone index is also a sensitive indicator of soil compaction (besides bulk density). Similar observations have been reported elsewhere (Onwualu and Anazodo, 1989; Lindstrom and Voorhees, 1994).

Soil Moisture Content

Soil moisture contents (%w/w) taken during the March-June 1990 are shown in **Table 4a**. In all the periods of measurement, moisture contents for minimum tillage and minimum tillage with mulch were much higher than those for moldboard-and-disc plowed treatments. This was attributed to less evaporation losses in minimum tillage treatments (Khatibu and Huxley, 1979). Moisture content values taken during the March-June 1991 season showed no consistent trend in regard to tillage treatments, partly due to inadequate sampling to deeper soil depths (**Table 4b**).

Weed Dominance

Weed infestation was monitored in all tillage treatments during the two consecutive growing seasons. In both seasons, broad-leaf weeds were dominant on moldboard-and-disc plowed plots with one or three harrowings. Thin-leaf weeds were common on non-tractorized tillage treatments, especially hand hoeing (HH) and minimum tillage (MT). These observations appear to be common in all annual cropping systems (Acland,1972).

Table 2a. Effects of Tillage Treatments on Dry Soil Bulk Density (kg/m^3) (March-June 1990 Growing Season)

Date	2 April 1990				24 April 1990				15 May 1990			
Depth (cm) / Treatment	0-5	5-10	10-15	15-20	0-5	5-10	10-15	15-20	0-5	5-10	10-15	15-20
HH	0.96	1.01	1.18	1.30	1.06	1.13	1.20	1.31	1.13	1.19	1.21	1.35
MT	1.20	1.29	1.30	1.40	1.21	1.25	1.31	1.40	1.22	1.24	1.32	1.40
MTM	1.20	1.30	1.31	1.30	1.21	1.31	1.32	1.35	1.22	1.29	1.34	1.39
M	1.10	1.14	1.08	1.28	1.20	1.26	1.29	1.40	1.25	1.29	1.31	1.45
H1	1.10	1.16	1.19	1.20	1.21	1.26	1.32	1.39	1.25	1.30	1.33	1.49
MH3	0.97	1.10	1.20	1.20	1.24	1.30	1.33	1.41	1.29	1.36	1.41	1.50
D	1.01	1.10	1.20	1.25	1.18	1.21	1.27	1.36	1.23	1.29	1.33	1.42
DH1	1.10	1.19	1.23	1.26	1.19	1.26	1.31	1.43	1.21	1.31	1.42	1.52
DH3	0.93	1.00	1.20	1.00	1.10	1.08	1.21	1.36	1.25	1.36	1.39	1.51

Table 2b. Effects of Tillage Treatments on Dry Soil Bulk Density (kg/m^3) (March-June 1991 Growing Season)

Date	22 March 1991				3 April 1991				2 May 1991			
Depth (cm) / Treatment	0-5	5-10	10-15	15-20	0-5	5-10	10-15	15-20	0-5	5-10	10-15	15-20
HH	1.10	1.16	1.36	1.49	1.21	1.29	1.37	1.49	1.30	1.37	1.39	1.55
MT	1.38	1.48	1.49	1.61	1.37	1.44	1.50	1.62	1.40	1.43	1.52	1.61
MTM	1.19	1.25	1.34	1.43	1.26	1.32	1.42	1.48	1.34	1.40	1.49	1.54
DAP	1.20	1.31	1.35	1.39	1.32	1.40	1.46	1.50	1.39	1.47	1.52	1.56
M	1.26	1.31	1.37	1.47	1.36	1.44	1.47	1.50	1.44	1.48	1.51	1.67
MH1	1.27	1.33	1.37	1.38	1.37	1.43	1.50	1.56	1.44	1.49	1.53	1.71
MH3	1.12	1.26	1.38	1.40	1.41	1.48	1.50	1.59	1.48	1.56	1.61	1.73
D	1.16	1.27	1.38	1.44	1.34	1.38	1.42	1.55	1.41	1.48	1.53	1.63
DH1	1.26	1.37	1.41	1.45	1.36	1.43	1.46	1.61	1.39	1.51	1.63	1.75
DH3	1.07	1.15	1.27	1.38	1.23	1.38	1.46	1.54	1.44	1.56	1.60	1.74

Table 3a. Variation of Soil Cone Index (Kpa) as Affected by Tillage Treatments (1990 Season)

Date	2 April 1990				24 April 1990				15 May 1990			
Depth (cm) / Treatment	0-10	10-15	15-20	20-25	0-10	10-15	15-20	20-25	0-10	10-15	15-20	20-25
HH	0.05	0.09	0.06	0.07	0.04	0.06	0.10	0.09	0.09	0.21	0.22	0.18
MT	0.08	0.07	0.08	0.06	0.04	0.08	0.10	0.08	0.09	0.14	0.12	0.22
MTM	0.05	0.07	0.09	0.03	0.06	0.07	0.05	0.08	0.24	0.19	0.22	0.20
M	0.02	0.06	0.05	0.05	0.02	0.05	0.08	0.08	0.09	0.12	0.22	0.20
MH1	0.03	0.07	0.04	0.06	0.02	0.07	0.06	0.09	0.03	0.14	0.13	0.18
MH3	0.01	0.05	0.02	0.06	0.02	0.08	0.06	0.09	0.09	0.10	0.19	0.21
D	0.01	0.03	0.04	0.04	0.02	0.05	0.08	0.07	0.13	0.26	0.25	0.22
DH1	0.01	0.07	0.06	0.05	0.01	0.07	0.07	0.07	0.08	0.10	0.12	0.28
DH3	0.01	0.06	0.05	0.05	0.03	0.06	0.08	0.10	0.09	0.23	0.19	0.19

Table 3b. Variation of Soil Cone Index (Kpa) as Affected by Tillage Treatments (1991 Season)

Date	22 April 1991				3 April 1991				2 May 1991			
Depth (cm) / Treatment	0-10	10-15	15-20	20-25	0-10	10-15	15-20	20-25	0-10	10-15	15-20	20-25
HH	0.22	0.20	0.16	0.14	0.09	0.14	0.16	0.17	0.41	0.23	0.17	0.15
MT	0.44	0.23	0.17	0.14	0.06	0.11	0.14	0.13	0.39	0.34	0.26	0.15
MTM	0.31	0.40	0.29	0.20	0.11	0.18	0.19	0.19	0.33	0.23	0.15	0.15
DAP	0.38	0.36	0.24	0.18	0.08	0.13	0.14	0.15	0.45	0.38	0.30	0.29
M	0.16	0.31	0.27	0.22	0.06	0.10	0.13	0.12	0.56	0.34	0.26	0.36
MH1	0.28	0.26	0.21	0.16	0.11	0.17	0.14	0.16	0.50	0.40	0.31	0.35
MH3	0.16	0.22	0.19	0.17	0.10	0.13	0.21	0.13	0.61	0.50	0.46	0.51
D	0.20	0.40	0.32	0.25	0.09	0.09	0.07	0.07	0.76	0.60	0.51	0.26
DH1	0.16	0.25	0.33	0.18	0.07	0.11	0.14	0.14	0.44	0.28	0.20	0.16
DH3	0.12	0.19	0.16	0.15	0.10	0.15	0.16	0.15	0.48	0.40	0.29	0.30

Grain Yields

Tillage treatments affected the bean yields of the three test variet-

Table 4a. Variation of Moisture Content (% w/w) as Affected by Tillage Treatments (1990 Season)

Treatment	2 April 1990	24 April 1990	15 May 1990
HH	33.1	17.9	18.7
MT	36.3	20.1	17.5
MTM	37.5	21.0	22.0
M	26.2	16.2	17.1
MH1	20.0	15.1	16.3
MH3	16.3	15.0	15.5
D	28.4	17.5	15.4
DH1	21.2	16.5	15.0
DH3	18.9	15.0	14.8

Table 4b. Variation of Moisture Content (% w/w) as Affected by Tillage Treatments (1991 Season)

Treatment	22 March 1991	3 April 1991	2 May 1991
HH	20.8	23.8	21.6
MT	18.8	23.1	19.6
SA	19.2	25.0	16.5
AP	20.1	22.7	20.3
M	20.5	25.1	19.1
MH1	19.7	22.6	18.7
MH3	19.6	25.3	19.5
D	19.2	24.5	16.0
DH1	19.1	24.6	19.2
DH3	19.6	25.1	22.7

ies in the March-June 1990 season (**Table 5**).

It can be seen that moldboard-and-disc plowing with three harrowings (i.e.; MH3 and DH3) produced the highest grain yields for both Selian Wonder and Canadian Wonder varieties. The highest yields for the TMO 216 variety were produced from moldboard plowing with one harrowing (MH1) and disc plowing with three harrowings (DH3).

In the March-June 1991 season, the yield of beans in all tillage treatments was less than 50 % of that obtained in the previous growing season (**Table 5**). This may be attributed to the moisture sensitivity of the bean crop. Planting was done in March when rainfall was nearly 100 mm above the normal average (**Table 1**). This adversely affected the percentage emergence. This was further exacerbated by restricted plant establishment and growth brought about by below average rainfall in April and May (Table 1). Inspite of this the yield of beans was significantly affected by tillage treatments. Disc plowing with three harrowings (DH3) produced the highest grain yield in all bean varieties. This was followed by DH1, MH3 for both TMO 216 and Canadian Wonder varieties. In the March-June 1991 season, disc plowing with three harrowings (DH3) increased bean yields by 126% in Selian Wonder, by 209% in Canadian Wonder and by 230% in TMO 216, compared to the yield of minimum tillage (MT) plots.

The highest yields recorded in moldboard (MH1, MH3) and disc (DH1, DH3) plowed treatments are attributed to the good seedbed preparation provided by the harrow. Similar results have been reported elsewhere for maize (Gumbs and Summers, 1985). The relatively rapid development of a plow pan in the subsoil together with raindrop splash and subsequent surface sealing on this finely tilled soil, means that progressive soil structural deterioration is bound to occur in successive seasons. To sustain bean production on this soil counter measures such as rigorous use of rotations and periodic subsoiling and/or chiselling may be necessary.

The cost analysis presented in **Table 6**, however show that the extra benefit of tillage above minimum tillage (MT) exceeded the costs only in moldboard plowing (M) and harrowing once (MH 1) and disc plowing and harrowing once (DH 1). This may be attributed to the general low yields from the experimental plots perhaps due to low husbandry inputs.

Conclusions

The following conclusions were drawn from the study:

1. MH1, MH3, DH1 and DH3 increased markedly the soil bulk density of the subsoil as the growing season progressed.
2. The soil cone index was a better parameter than soil bulk density in quantifying the presence of a plow pan in the second year of experimentation.
3. DH3 was found to be the best overall tillage method in relation to bean yield of all three test varieties.

(Continued on page 22)

Table 5. Effects of Tillage Treatments on Bean Grain Yield (kg/ha)*

Treatment	March-June 1990			March-June 1991		
	Selian Wonder	Canadian Wonder	TMO 216	Selian Wonder	Canadian Wonder	TMO 216
HH	500 bc	379 d	518 cd	148 cd	118 ab	214 ab
MT	491 bc	378 d	480 d	107 d		104 b
MTM	462 c	550 ab	502 cd	-	-	-
M	560 abc	512 bc	700 ab	226 ab	139 ab	235 ab
MH1	501 bc	520 abc	801 a	185 abc	138 a	280 a
MH3	672 a	609 a	690 abc	206 abc	176 a	310 a
D	539 abc	428 cd	512 bcd	234 a	157 ab	237 ab
DH1	611 ab	570 ab	660 abcd	223 abc	189 a	324 a
DH3	680 a	560 ab	710 a	242 a	201 a	345 a
SAT	-	-	-	156 bcd	128 ab	159 b
DAP	-	-	-	165abcd	130 ab	164 b

*: Means followed by the same letters are not significantly different at $P_{0.05}$

Table 6. Comparison Tillage Costs and Benefits (1990 Season)

Treatment	Cost of tillage (US$/ha)	Extra bean yield (kg/ha)	Extra value (US$/ha)	Benefit:cost ratio
HH	4.60	15.0	2.88	0.63
MT	0	0.0	0	0.00
MTM	0	55.0	0	-
M	16	141.1	25.40	1.59
MH1	28	157.7	28.39	1.01
MH3	52	207.3	37.31	0.72
D	16	43.3	7.79	0.49
DH1	28	164.0	29.52	1.05
DH3	52	200.3	36	0.69
SAT	11.20	-	-	-
DAP	8.20	-	-	-

Technical Evaluation of an Indigenous Conservation Tillage System

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Abstract

An evaluation was undertaken in 1994-97 to examine the technical aspects of an indigenous conservation tillage system called ngoro, a farming system which has evolved over some 200 years, compared to ridge cultivation on 15, 40 and 45% slopes. Two types of ridging were studied, one with organic matter incorporated (R + OR) and one without organic matter incorporated (R –OR). The technical investigations included climatic monitoring, organic C determination at 0-20 cm depth, soil moisture monitoring with neutron probe and speedy moisture (calcium carbide) meter, soil surface profile monitoring (monthly) during the rainy season, and plant development and yield of maize and beans.

On a seasonal basis no statistical differences were observed in the volume of water stored under ngoro, R + OR or R –OR. However, more detailed analyses of the data sets at each site showed that ngoro were always slightly wetter than the ridges, particularly during the dry season. Although the monitoring period was not long enough to detect any major differences in soil chemistry, levels of organic C were slightly higher under R+OR than the other two systems. In ngoro much of the of eroded soil was redeposited into the pit, whereas on ridges it was transported elsewhere. Over three seasons of observation, the ngoro consistently yielded more maize and beans than either of the ridged systems. Maize yields on R+OR were higher than R-OR.

Introduction

The ngoro is a local name for the pitting system of the Matengo tribe in Mbinga District, SW Tanzania. The system is an indigenous means of land cultivation on steep slopes. It consists of a series of regular pits, traditionally a 1.5 m square and 10 –15 cm deep, which from a distance, resemble a honeycomb. Crops are grown on the ridges around the pits.

Ngoro construction is carried out in March/April as follows: Grass is slashed and laid in a matrix of discrete squares with dimensions ranging from 1.5 to 3 m. After drying, the grass lines are covered with soil which has been dug from the centre of each square, forming bunds on all sides with a pit in the centre. The bunds thus consist of a layer of grass sandwiched between a layer of top soil and the original soil surface underneath. Unless an extended fallow is used, the pits are reformed every two years after a 6-8 month short fallow in such a way that what was previously a pit becomes a bund and vice versa.

The main strengths of the ngoro system are soil fertility enhancement due to the continual incorporation of plant residues into the soil, soil and water conservation as a result of water being trapped in the pits thereby reducing the erosion of runoff while encouraging infiltration and sedimentation. The increased soil organic content should encourage granulation and hence aggregate stability while increasing the soil's water holding capacity, as humus on a weight basis, can hold 4-5 times more water than silicate clays (Brady, 1990). The ngoro are also likely to create a sheltered microclimate, with a stable air/water interface thereby reducing evaporation from the pit bottom. A combination of these factors allows beans, planted towards the end of the rains, in March /April, to be cropped on residual soil moisture.

The Matengo are still the main users of this unique system which is primarily used for maize and bean production on steep lands within a slope range of 2% to 65%. Other African pitting systems include the basins and planting pits of the Dogon Plateau, Mali (Kassogue et al., 1990), the *deshek* basins in Bay Region, Somalia, the *Kofyar* of the Jos plateau, Nigeria (Critchley et al., 1994) and *katumani pitting* developed by Gichangi et al. (1989) in Kenya. However, these systems differ from ngoro in that crops are planted in the pit or on the sides of the ridge as opposed to solely on top of the ridges, as in ngoro.

Although the ngoro system of cultivation has been in use for at least 200 years, little research has been carried out into ngoro since some preliminary investigations into yields in the 1940's (Berry and Townshend, 1972) and 1950's (Allan, 1965). The need for research has become rather urgent with a significant increase in population pressures. In densely populated areas, ngoro are used without an extended fallow period for 6-7 years decreasing to 4 years in less populated areas. The average fallow period is currently estimated to be only 1.5 years. A general consensus amongst farmers and extension workers is that fallow periods are declining. Due to shorter fallows, the sustainability of the ngoro system of cultivation (which relies on fallows for soil fertility enhancement) has decreased.

The objective of this study was to examine the technical aspects of the ngoro compared to ridge cultivation on 15, 40, and 45% slopes.

Materials and Methods

Three experimental sites (**Table 1**) were selected in March 1995. The following indigenous conservation tillage (ICT) methods were investigated:

(i) Ngoro (N);
(ii) Ridges with incorporated organic residues (R+OR); and
(iii) Ridges with no incorporated organic residues (R-OR).

At each site the three ICT treatments, each measuring 22 x 60 m, lay side by side, separated by tied ridges and with a cutoff drain at the top and bottom. The three sites chosen for the study had previously been under fallow and were planted to beans (broadcast) in April 1995, harvested in June 1995, and then weeded and planted to maize after the first rains in December 1995, which were then harvested in July 1996. The plots were then left fallow until March 1997, when the ngoro were reformed and a second bean crop planted and harvested in June 1997.

Daily rainfall was measured at each site from November 1994 using a locally made rain gauge (standard Meteorological Office, 5" Snowdon patent). In May 1995, soil moisture measurements were taken with a Speedy Moisture (calcium carbide) Meter in all fields under beans at Mhekela, 22 days after the last rainfall. In November 1995, 54 neutron probe access tubes were installed. Soil water content profiles were then determined with a Wallingford Neutron Probe Moisture Meter, calibrated for the three sites, at weekly intervals from November 1995 to February 1997. At each site, measurements were made on three ngoro at four positions, that is one access tube in the centre of the bottom bund, one in the centre of the side bund and one in each bottom corner, at depth intervals of 10 cm to maximum of 20 cm. Three tubes were installed in each ridge plot at the three sites. These were supplemented by volumetric sampling of the top 15 cm of the soil profile.

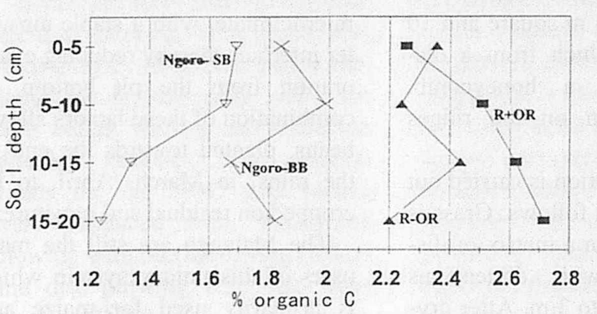

Fig. 1 Levels of soil organic carbon at Mhekela.

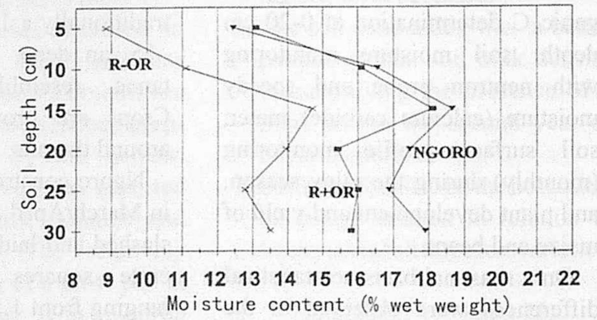

Fig. 4 Soil moisture content at Mhekela in May 1995.

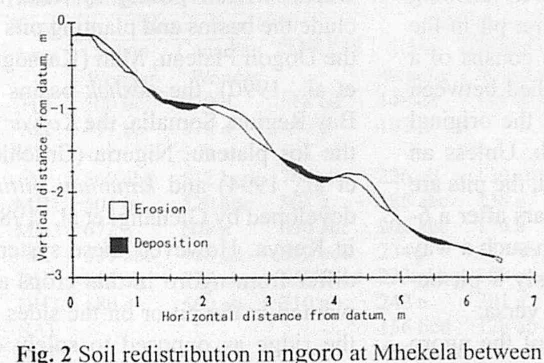

Fig. 2 Soil redistribution in ngoro at Mhekela between May 1995 and March 1996.

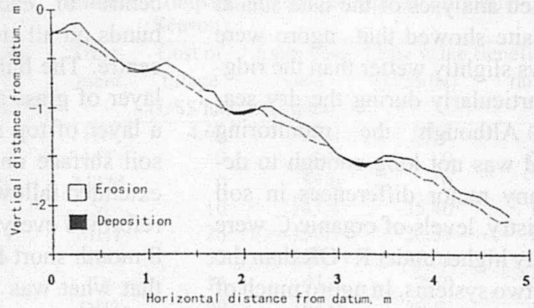

Fig. 3 Soil redistribution in ridges with organic matter incorporated (R+OR) between May 1995 and March 1996.

Table 1. Site descriptions

Area fallow	Slope (%)	Average ngoro dimensions (m)	Average ridge spacing (m)	Previous period (years)
Lipumba1	15	2.39 × 2.37	1.12	1
Lipumba2	45	2.60 × 2.25	1.00	4
Mhekela	40	2.33 × 2.06	1.41	1

Table 2. Variation in pit depth with slope

Slope class (%)	Depth range (cm)	Averagedepth(cm)
2-10	22-40	30
15-25	8-36	21
>40	5-20	14

Table 3. Crop yield responses to ngoro and ridge cultivation

Crop /Date	Ngoro	Treatment R+OR	R-OR	S.E.D
Beans June 95	107.70	66.50	88.50	13.77
Maize July 96	656.63	561.72	402.77	132.60
Beans June 97	273.14	154.64	161.32	41.16

Table 4. Slope effects on crop response to ngoro and ridge cultivation

Slope	Treatment	Seasonal crop yields (kg/ha) Beans June 95	Maize July 96	Beans July 97
Rainfall mm		958	1080	910
14% lipumba	Ngoro	NH+	872	179
	R+OR	NH	595	134
	R-OR	NH	668	92
45% lipumba	Ngoro	82	746	442
	R+OR	44	682	233
	R-OR	44	230	230
Rainfall, mm		1030	1301	1091
40% Mhekela	Ngoro	133	352	199
	R+OR	89	408	97
	R-OR	133	311	-
Seasons S.E.D		9.74	76.59	25.21

+NH= No Harvest.

The organic carbon content (to 20 cm soil depth) was determined by the Walkey-Black technique. Variations in soil surface relief were determined using a locally manufactured soil surface profile gauge down and across the slope. Measurements of elevation were made at three locations in each plot, at the same distance downslope at monthly intervals during the rainy season. To assess the volume of soil moved in ridges compared to ngoro, profiles were taken just prior to and immediately after the formation of each. Ngoro depth was recorded on 15 newly formed ngoro at each site. The growing area per hectare in each field/plot was calculated and grain yields at 12.5% (w/w) moisture content were determined.

Results and Discussion

Total rainfall and its seasonal distribution at Lipumba and Mhekela varied considerably over the three cropping seasons and between the two areas. Rainfall at Lipumba during the 1994/95 season was 958 mm compared to 1030 mm at Mhekela, increasing to 1104 and 1334, respectively, during the 1995/96 season, which was the wettest. The last season, 1996/97 was driest of the three seasons at Lipumba with 910 mm of rain recorded, compared to 1091 mm at Mhekela, confirming Lipumba to be the drier site.

Although the monitoring period was not long enough to detect any major differences in soil chemistry, levels of organic carbon were slightly higher under the R+OR, 1.3% compared to 1.24% under R-OR and 1.25% under the ngoro (**Fig. 1**), although these differences were not statistically significant. If the same amount of residue is buried under ngoro ,and ridges, the larger volume of soil disturbed in the ngoro bunds may dilute the effects and result in lower levels of % C.

The effective depth of the pit varied considerably from a few centimetres to as much as 45 cm. As slope increased the effective depth of a given size of ridge decreased significantly (**Table. 2**). Depth also decreased throughout the season as the pit became filled with residue thrown into it and with soil eroded from the surrounding bunds.

Soil surface profiles taken in the period May 1995 to March 1996 showed that the majority of ngoro and ridges had degraded into flat or gently sloping terraces (**Figs. 2** and **3**). The amount of deposited sediment in pits of a ngoro field at Mhekela 40% slope was large (**Fig. 2**). Similar observations were made for the two sites at Lipumba. In the ridged fields at the three sites, however, the degree of deposition in the furrows was small as is shown in **Fig. 3** for the Mhekela site, suggesting a net loss of soil to the system.

On a seasonal basis no statistical differences were observed in the amount of water stored under ngoro, R+OR or R-OR. However, more detailed analyses of the data sets at each site showed that ngoro were always slightly wetter than the ridges, particularly during the dry season, as demonstrated at Mhekela (**Fig. 4**). Ngoro at Mhekela 40% slope had more moisture than the ridges, especially below 15 cm. These are the most important results as beans are grown at this time on residual soil moisture whereas the neutron probe values were taken whilst maize was growing, from December to February, when there was little water stress. Moisture reached a maximum at 15 cm which corresponds with the centre of the organic layer and is presumably due to the organic residues causing an increase in the soil's water holding capacity.

Although no statistical differences were observed in seasonal crop yields (**Table 3**), over the three seasons of observation the ngoro consistently yielded more beans and maize than either of the ridged systems, which produced similar quantities of beans (**Table 4**). Maize yields on the R+OR were higher than under R-OR.

Conclusions

On a seasonal basis no statistical differences were observed in the amount of water stored under ngoro, R+OR or R-OR. Ngoro were, however, always slightly wetter than the ridges, particularly during the dry season. Levels of organic C were slightly higher under R+OR than the other two systems. In ngoro, the majority of eroded soil was redeposited into the pit, whereas on ridges it was transported elsewhere. Over three seasons of observation, the ngoro consistently yielded more maize and beans than either of the ridged systems. Maize yields on R+OR were higher than R-OR.

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(Continued from page 18)

Effects of Tillage Methods on Soil Physical Conditions and Yield of Beans in a Sandy Loam Soil

4. The TMO 216 variety excelled in yield performance irrespective of the tillage method used.
5. In order to sustain bean production by tillage methods which involve tractor plowing followed by harrowing, periodic subsoiling or chiselling and use of rotations may be necessary to minimize soil compaction hazards.

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Evaluation of Drum Seeder in Puddled Rice Fields

by

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Abstract

An experiment was conducted during 1996 and 1997 wet seasons at Nizamabad district, A.P., India to evaluate the performance of drum seeder in farmers' fields. Crop established with a drum seeder resulted in higher mean grain yield (4.63 t/ha) which was at par with transplanting (4.25 t/ha) and superior over broadcasting (3.34 t/ha). Not only the yield, but also the highest net revenue of $ 304/ha with benefit cost ratio of 1.30 was also recorded by the drum seeder, providing the crop establishment equivalent to traditional transplanting method. Proper leveling of land before sowing, careful water management in the first fortnight after sowing, use of effective herbicide 4 days after sowing of pre-germinated seed and mechanical weeding with rotary pushhoe after first top dressing of nitrogen fertilizer (25 DAS) is a recommended package for drum seeding technology. So far more than 60 units were distributed to co-operators and farmers through the Crop Resource Management Network (CREMNET) IRRI-DRR Programme. Still some-more modifications of the seeder is required for different soils.

Acknowledgement

Authors are thankful to Dr. K. Krishnaiah, Project Director, Rajendranagar, Scientists- Drs. S.P. Singh, R.M. Kumar, Er. I.S.R.P. Sarma and Mrs. K. Padmaja of Directorate of Rice Research, Rajendranagar, Hyderabad and progressive farmers Mr. M. Narayana Reddy and Mr. K. Gangaram of Nizamabad district for their cooperation and timely help.

Introduction

Uncertainity in the release of canal water, non-availability of labour on time and hike in labour charges made transplanting less remunerative and less attractive these days. In addition, invariably contract labour usually plant less number of hills (25-35 hill/m^2) per unit area to complete the planting quickly as against recommended number of 50-60 hills/m^2) in transplanted crop. In such situation direct seeding is becoming increasingly popular in India due to less labour requirement and less time consumption and low cost of cultivation due to skipping of nursery raising and transplanting, maintaining recommended plant population and also early crop maturity by 7 days.

To overcome the disadvantage of high seed requirement in direct seeding, the Directorate of Rice Research, Hyderabad, India has developed an 8-row drum seeder (Modified IRRI model). There was a lot of imbalanced strain involved in soft puddle while operating in the field conditions. Hence, single wheeled seeder converted into double wheel seeder with two field floats (to prevent from bogging in soft puddled soil) from initial single centered wheel seeder. Therefore, there is every need to improve the performance of the drum seeder and to popularize it among farmers to reduce the cost of cultivation.

Materials and Methods

A field experiment was conducted at the Krishi Darshan Kendra and Checki Camp, Nizamabad Dist., A.P., India. The treatments imposed were direct wet seeding by broadcasting with a seed rate of 125 kg/ha (T_1); direct wet seeding by a drum seeder using 55 kg/ha

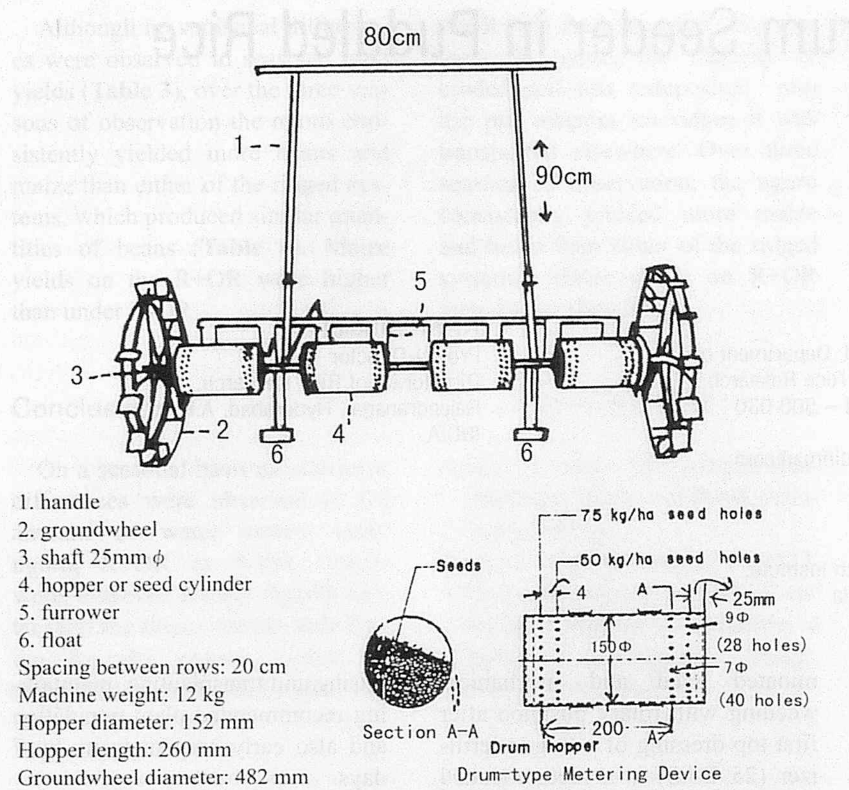

Fig. 1 Rice drumseeder.

seed (T_2) and farmers practice of transplanting (T_3) in which 50 kg/ha seed was used to raise the nursery. The experiment was laid out in randomized complete block design, with three replications. Seeds of Phalguna variety as per treatment were soaked first for 24 hours in water followed by seed incubation for next 24 years for direct seeding treatments, while soaked seeds were incubated for 36-48 hours for nursery raising for transplanting. Incubated seeds were sown by a drum seeder by maintaining a spacing of 20 x 3 cm, at 1-2 cm depth, broadcasting and transplanting were done as per treatments, respectively. The incubation of soaked seeds for more than 24 hours will result in intertwinning of roots and prevent free flow of seeds, through the hole of hoppers in the paddy row seeder. Thin film of water was maintained in the beginning and butachlor + safener was used to kill weeds in all treatments uniformly.

The paddy row seeder is provided with two lugged ground wheels on either side with 482 mm diameter. The ground wheels are mounted on shaft of 25 mm diameter. This seeder has four hoppers or seed cylinders having 152 mm diameter and 260 mm length and each has eight furrow openers with 9 mm diameter holes numbering 25 each and spaced at 20 cm. It has a handle to pull the machine in the puddled field. The handle is of 80 cm wide and 90 cm long. A float is provided at the bottom of the machine to facilitate smooth running of the machine in soft puddled field (**Fig. 1**). Pre-germinated seeds filled up to one-half the full capacity of the hopper, will fall in 8 lines. Since the machine is light, it is easy to pull manually with minimum draft (one man). In an average day one hectare of land can be sown by this drum seeder with two persons (Rama Rao 1998). 8-row drum seeder requires 16 man hours to sow pre-germinated seed while transplanting requires 347 man hours/ha. The cost of the row seeder is about $50.

Results and Discussion

Studies on direct seeding under puddled conditions in different sites have shown that the system is as good as transplanting in the areas where levelled water and weed management are good. Growing the rice crop by direct seeding reduces the crop maturation by 10 days because of the absence of transplanting shock. The grain yield is equal or sometimes more than transplanting under good management (De Datta, 1986). Experiments conducted at national research farms at different parts of the country indicated that grain yield obtained by direct seeding under puddled conditions were equal with transplanting at most of the places and higher in other stations.

Table 1. Effect of Methods of Establishment of Rice Growth and Yield Attributes

Methods of Establishment	Panicle height (cm)			Panicle/m^{2+}			Panicle dry weight g/m^2		
	Kharif '96	Kharif '97	Mean	Kharif '96	Kharif '97	Mean	Kharif '96	Kharif '97	Mean
Broadcast	109	84.3	101.7	532	531	531.5	458	723	590.5
Drum seeder	101	82.7	91.9	480	577	528.5	712	1111	911.5
Transplanting	98	85.3	91.7	396	505	450.5	700	734	717
C.D. (0.05)	4	NS		18	50		59.3	109	

Table 2. Effect of Method of Establishment on Grain Yield and Straw Yield

Methods of Establishment	Grain Yield (t/ha)			Straw Yield (t/ha)		
	Kharif '96	Kharif '97	Mean	Kharif '96	Kharif '97	Mean
Broadcast	2.97	3.70	3.34	5.83	6.77	6.30
Drum seeder	4.35	4.90	4.63	6.52	7.08	6.80
Transplanting	4.10	4.40	4.25	6.42	6.40	6.40
C.D. (0.05)	0.58	0.74		0.37	NS	

Table 3. Effect of Method of Establishment on the Economics of Rice

Treatment	Cost of cultivation $/ha		Gross returrn $/ha		Net Retun $/ha			Benefit Cost Ratio BCR		
	Kharif '96	Kharif '97	Kharif '96	Kharif '97	Kharif '96	Kharif '97	Mean	Kharif '96	Kharif '97	Mean
Broadcast	270	270	370	455	100	185	242	0.37	0.68	0.53
Drum seeder	235	235	500	578	265	343	304	1.13	1.46	1.30
Transplanting	249	249	474	520	225	271	248	0.91	1.09	1.00

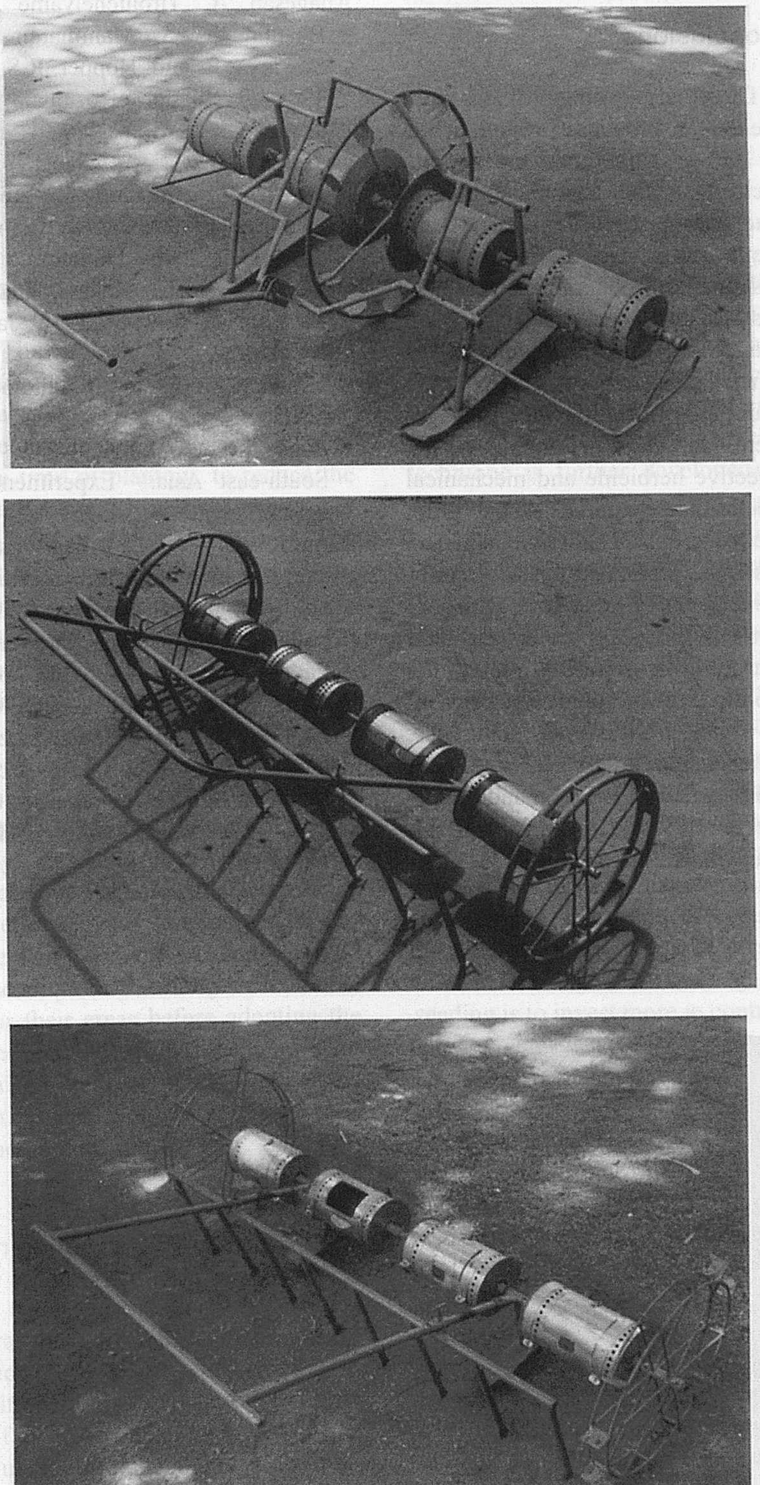

Fig. 2 Three types of rice drumseeder.

Plant height was highest in the broadcast method and it is superior over the drum seeder and transplanting method of crop establishment during Kharif 1996, where it is non-significant in Kharif 1997. The mean over two seasons, broadcast method recorded increased height of plants. Panicle/m^2 were higher in the broadcast method in Kharif 1996 and it is higher in the drum seeder method in Kharif 1997. The mean panicles/m^2 over two seasons were the highest in the crop established by the drum seeder method (**Table 1**). The highest grain and straw yields were recorded in the drum seeder method and were at par with transplanting. This might be due to sowing in proper depth, avoidance of root injury and transplanting shock, quicker tiller initiation leads longer tillering period made it possible to record greater number of tillers of heavier weight which might have contributed to higher grain yield with the drum seeder method (**Table 2**). In the drum seeder method, the highest net return of $304 and benefit cost ratio of 1.30 were obtained whereas the transplanted rice recorded Benefit Cost Ratio (BCR) of 1.0 and for the broadcast method it is 0.53, which meant that the drum seeder method gained 30% profit over the transplanting and 77% over the broadcast method (**Table 3**). This was further supported by recording higher net income obtained from the drum seeded rice $161 against as transplanted crop $106 at Agaram Village, Pondicherry, India (Alagesan *et al.,* 1998). Also reported that the highest net return of $415.6 was obtained from the drum seeded rice whereas transplanted rice registered a net return of $380.3 which in turn contributed a benefit cost ratio of 1.84 for the drum seeded rice. The experiments conducted at Bodhan (Cheki Camp) showed that higher tillers and panicles were recorded for the crop established by the broadcast method, however, the grain yield of rice variety Erramallelu was higher under the drum seeder method of cultivation perhaps less panicle size and more sterility per cent which might have resulted lower yields in the broadcast method (**Table 3**). There was a considerable reduction in cost of cultivation in the drum seeding method. It is clear from this data that drum seeder found to be as efficient as transplanting. This could be the reason the demand for drum seeding technology is gaining momentum in Andhra Pradesh, Tamil Nadu and Karnataka States.

In Karnataka province the performance of the drum seeder was evaluated by the staff of the Regional Rice Research Station, Mandya at 18 locations in which 15 are in Mysore district and the remaining in Mandya district. Seeing the progress of direct seeding, the Karnataka government has already announced 50% subsidy for the benefit of farmers. Now, under subsidized rates, the drum seeder along with the rotary weeder costs about $25.

Table 4. Effect of Method of Establishment on Tillers, Yield Attributes and Yield of Rice Cheki Camp at Boadhan, Andhra Pradesh

Treatments	Tillers/m^2	Panicles/m^2	Panicle Length (cm)	Grain Yield (t/ha)
Broadcast	1232.5	1138.0	21.8	4800
Drum seeder	890.2	879.5	24.0	5560
Transplanting	546.0	542.0	24.2	5420

Conclusions

Direct wet seeding provides more yield than broadcast system while at par or sometimes more grain yield than the transplanted crop. The row-seeder/drum-seeder technique can provide definitely more sustainable production in those areas where labour is costly and availability is less which affects timely planting of rice by transplanting. Careful water management in the beginning, using effective herbicide and mechanical weeder are required in the drum seeded crop. The implement can easily be fabricated by local entrepreneurs at cheaper rate which in turn can provide more employment in rural/urban areas. At present the modified row seeders are fabricated by M/s. Viswakarma Industries, Katedan, Hyderabad, Andhra Pradesh and M/s. Dayananda Engineering Works, M.C. Road, Mandya, Karnataka, India.

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Fig. 3 Growing rice in a paddy field seeded with drum seeder.

Direct Seeding Options, Equipment Developed and Their Performance on Yield of Rice Crop

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Abstract

The tedious labour intensive rice transplanting operation is to be replaced by other methods to tackle the problem of labour scarcity at the time of planting, to reduce the cultivation cost and achieve proper and timely crop establishment. The seeding of rice in fields is the technique, which can help the farmers greatly in establishment of crop especially as high yielding rice varieties are available. The herbicides are there to control the weeds. The seeding techniques have been developed as dry seeding for uplands and rainfed lowlands and wet seeding, especially where there is control on irrigation and drainage. Hence the rice farmers should understand the various methods and techniques of seeding rice suitable for their areas before adopting the seeders and seeding techniques for raising the rice crop on their farms to reduce the cost of production and increase the productivity.

Introduction

The tedious labour intensive transplanting operation for raising rice crop is to be replaced by other alternatives to tackle the problems of labour scarcity, high cost of production by achieving better crop establishment at farmers' fields. The farmers planting rice crop in rainfed lowlands and in irrigated areas have two choices. They can sow the seeds in nurseries and then transplant the seedlings or they can plant the seeds directly into the rice fields. The direct seeding of rice technique is further developed as dry seeding i.e., dry seeds in aerobic soil conditions or wet seeding i.e., wet seeds in anaerobic or aerobic soil conditions, the choice depends upon the circumstances prevailing in the area. With dry direct seeding farmers can cover the upland areas, the rainfed lowlands and the flood prone areas, thus covering about 25-m hectares of paddies in India. Direct dry or wet seeding can also cover the irrigated rice. It has the advantage of using less water as the seedbed preparation occurs in dry or moist conditions. The major disadvantage of seeding is to invest more in controlling weeds by use of herbicides or human labour or combination of both. In the case of wet seeding which is practiced in most of the developed countries, pregerminated seeds are broadcast on the wet soil, which may or may not have been puddled. This wet seeding technique is used for irrigated rice and for rice grown in favourable lowlands. The wet seeding reduces the labour requirements substantially but other problems which are to be tackled are control of weeds, better management of water to avoid waterlogging during crop establishment. This involves levelling of fields, drainage as well as better methods of application of fertilizer etc. Therefore, while recommending the direct seeding of rice, the package of practices are to be followed for achieving a high level of productivity. The research work on direct seeding has been going on at the Central Rice Research Institute (CRRI), Cuttack; Directorate of Rice Research, Hyderabad; Central Rainfed Rice Research Station at Hazaribagh; State Agricultural Universities and ICAR Institutes in India; IRRI, Philippines and many Asian countries, including Japan and developed countries.

The aim of rice scientists at CRRI during the green revolution (1966-70) and in other places was mainly to help the farmer to improve the productivity of the traditional rice farming system. Hence the technology transfer was mostly related to propagation of high yielding variety seeds suitable for the ecosystem prevailing in the area. It was followed up with the use of fertilizers (inorganic and organic) to maintain the soil nutrient levels and increase crop yield levels. As rice is grown in the high rainfall areas the weeds are the main problem to establish the crop. The control of weeds by mechanical means and use of herbicides was recommended. As use of engineering inputs started increasing on the farms, the farmers were further advised to go for line sowing of crops instead of broadcasting the seeds. This has given boost to the development of number of seed drills, seeders, seed cum fertilizer drills at various institutes in India (Devnani 1984) and abroad for the benefit of line sowing of crops by farmers during the last 30-35 years. The seed drills have mechanized the sowing operation in upland conditions. The current recommendation is for the dry or wet seeding of rice so that the farmer has alternative options for the transplanting operation.

Direct Seeding Terminology

The rice is a crop raised in many Asian countries as dry or wet seeded crop. In order to avoid confusion of terminology Balasubramanian and Morales (1998) defined the various seeding systems based on the physical conditions of seedbed and seeds. Wet seeding is divided into three subgroups as aerobic wet seeding, anaerobic wet seeding and water seeding based on the oxygen level in the vicinity of germinating seeds. The classification is given in **Table 1**.

The above classification does not take into account the type of machine and the source of power used to operate them. The performance of sowing device depends upon the type of seed metering and seed placement device (furrow opener) used to place the seeds in the soil. Thus for different patterns of seed placement the machines are classified as follows (Devnani 1991):

1. Broadcaster - A machine used for throwing or scattering seeds on the surface of field or seedbed. It can be done manually, by powered machine or by an aeroplane.
2. Dibbler - A device to place a small number of seeds (3 to 5) in the hole made in the seedbed. It can be manual dibbling, using dibbling stick or jabber manually-operated or multi-row type dibbler with or without covering devices.
3. Line sowing device - A device to make a furrow or furrows to place seeds in seedbed along rows. It can be manual pulled type; multi-row type, animal-drawn multi-row type or power operated unit. The seeds are dropped in the furrows by the operator and thus spacing is controlled by operator.
4. Seeder - A device to drop the seeds in rows or all along the width of machine on the surface of seedbed from the seed hopper when it is operated. They are manually / animal and power pulled units.
   The dry seeder means the machine which sows dry seeds at specified rates on seedbed.
   The wet seeder means the machine that uses wet seeds (soaked and incubated seeds) and spread seeds on wet seedbed on wet puddled soil.
5. Seed drill - A machine to sow the seeds at specified seed rate, makes furrows in the soil or drops the seeds at the desired depth and covers it.
   These are known as manual, animal-drawn and power-operated machines.
6. Seed cum-fertilizer drill - A machine which meters seeds and fertilizer according to specified rates, makes furrows in the soil drops seeds and fertilizer in the furrows separately at the desired depth and covers them with soil.
7. Special seed drills, i.e., machines like seed drills for sowing on beds, ridges and furrows.

Table 1. Classification of Direct Seeded Rice Systems

Direct seeding methods	Seedbed condition	Oxygen level	Seeding pattern
Dry seeded rice (DSR)	Dry soil	Mostly aerobic	Broadcasting, drilling or sowing in rows
Wet seeded rice (WSR)	Puddled soil	Aerobic/ anaerobic	Various-line sowing methods or dibbling in rows
Aerobic wet seeding	Puddled	Mostly aerobic	Broadcasting on puddled soil surface, row seeding open furrows or on flat soil surface
Anaerobic wet seeding	Puddled soil	Mostly anaerobic	Broadcasting and covering with a thin layer of settling mud. Row seeding in furrows and covering with soil and no covering of seeds
Water seeding, WSR on water	In standing water	Mostly anaerobic	Broadcasting of seed on field with water

(Balasubramanian and Morales, 1998)

Dry Seeded Rice

The sowing of rice by broadcasting, row-seeding with country plough, drilling of seeds in the rows with seeddrill or dibbling of ungerminated dry seeds in well prepared dry soil is termed as dry seeding. Dry seeded rice is a traditional practice commonly followed by farmers in rainfed uplands, in areas of rainfed lowlands and deep-water ecosystems. In dry seeded rice fields, seeds are sown before the start of rainy season permitting the use of early rains for establishment of the crop. When the rice crop is grown in upland conditions until harvest, it is called upland rice. With accumulated standing water in the field for significant part of crop growth period in rainfed lowlands, it is called rainfed lowland rice and when the standing water in the field is more than 75 cm deep it is called deepwater rice.

The benefits of dry seeding of rice are many, like savings in labour, improved crop establishment, risk in yield reduction is less and reduced water requirements. The use of early maturing rice varieties enhance the chances of taking up of double crop or help in practicing rice-based farming system to increase productivity.

The work on development of seeding machines, seeders and sowing devices has been going on in India since 1965 at ICAR institutes, state agricultural universities and other organizations. This resulted in the development of large numbers of designs of seed drills and planters (Srivastava and Panwar (1984) and Alam (1999)). The work was also reviewed by Devnani (1984 and 1991). At the CRRI the first seed drill for rice was developed and reported by Pradhan in 1968. The development of drum seeder for rice at Orissa took place around the same time. Biswas (1981) reviewed the work done on seeders and pregerminated seed drills and reported the development of number of machines in India and at IRRI, Philippines. The CRRI (during 1988 to 1991) released designs for commercial production in Orissa of manually-pulled 2-row, 3-row seed drills and 5-row animal-drawn seed drill and a 9-row tractor-mounted seed drill for dry sowing of seeds under upland soil condition or for lowlands (**Figs. 1** and **2**).

The number of experiments on line sowing was conducted at the CRRI. It was conclusively proved that yield level could be increased from 1.5 ton/ha to 2.5 to 3.5 ton for line-sown crop using improved practices. The effect of seed drill was shown to at least increase the yield by 25%. The results were published in bulletin "Produce More Rice from Rainfed Uplands" CRRI 1989.

The Central Rainfed Upland Rice Research Station at Hazaribagh, Bihar India published Upland Rice Research Achievements and Perspectives (1995) confirmed the 4.0-ton/ha high levels of yields from crop when sown in rows at 20-cm row spacing using chemical fertilizer and controlling weeds by mechanical and chemical methods.

The studies conducted in Pakistan by Abdul Majid et al. (1989) showed that direct drilling of paddy on dry soil is superior than broadcasting of soaked seeds on puddled soil. The yield of 4.5 tons/ha was reported for dry line sown crop. It was further pointed out that the date of sowing had a significant influence on the grain yield.

The performance of bullock-drawn upland direct paddy seeder for sowing of ADT 36 paddy variety has been reported by Jesudass et al. (1996) at C.A.E., TNAU, Coimbatore under clay loam soil. It is a six-row unit with 15-cm row spacing and mounted on the sides with seed placement depth of 2 cm. It was reported that the plant stand of paddy was better for direct seeded crop as compared to manual broadcasting or broadcasting by centrifugal type machine. The plant stand reported was 50-plants/m length as compared to 37 and 34 plants/m length of row respectively. The draft of drill was 40 kg and field capacity was 1.3 ha/day.

Routray and Methanker (1998) reported studies on dry seeding of rice (IR 36) with three seed drills (1) conventional seed cum fertilizer drill, (2) TNAU seeder, and (3) CRRI seeder (tractor operated type). The crop was sown in June 1997 at Bhopal. The crop was irrigated to overcome the dry spell and weeded to control weeds. The yield reported was 3.9 tons/ha. No significant effect in yield due to different machines was reported. The plant stand for the above yield was 49 hills per sq.m. They concluded that high yield level is possible when improved management practices are followed.

Thus for direct seeding of rice the technique of line sowing with seed drills should be adopted by the farmers. In order to obtain high yields the application of fertilizer (organic and inorganic) and control of weeds with chemical and mechanical weeders is must along with preparation of good seedbed and timely sowing of seeds during the season.

Wet Seeded Rice

Wet seeding, specifically aerobic, wet seeding is practiced in irrigated and favourable rainfed lowlands. In most of the developed countries rice crop is established by wet seeding. On the technical side, the short duration rice varieties are preferred. Availability of selective herbicides for weed control and knowledge of fertilizer management have favoured for the wet seeding for establishment of the crop. The other advantages are as follows: faster establishment of crop, more efficient water use, sav-

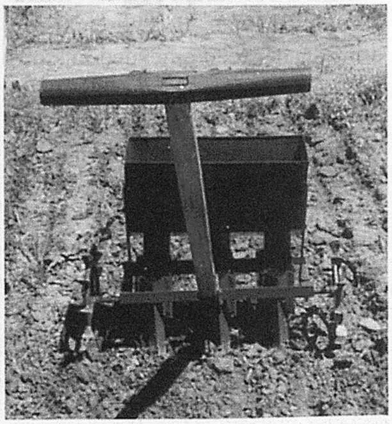

Fig. 1 3-row manually pulled CRRI seed drill.

Fig. 2 5-row drum seeder of CRRI (manually pull type).

ing in cost of production, and increased possibility of crop intensification. Further savings in the seeds due to the use of reduced seed rate, uniform crop stand, weeding is easier because of row spacing is set and easy application of fertilizer is possible to achieve higher yield levels.

Techniques of wet seeding

The sowing techniques for wet seeding adopted and practised on small farmers are: hand broadcasting or broadcast by motorized duster, spot seeding or dibbling manually or use of dibbler, and drum seeding or use of seeders or seed spreaders.

Broadcasting

Hand broadcasting is the most common method. The farmers use pregerminated seeds (24 h of soaking and 24 h of incubation) and seeds are broadcast on the surface of well puddled soil with little standing water with 1 to 3 days after puddling of fields. The puddled wet soil should be able to bury the seed in the soil layer with little of seed exposed to air.

In the case of sowing on soil with standing water, the field is drained after seeding operation. Seeding late after one day after puddling could reduce seedling emergence. The farmer sowing seeds with broadcaster (machine) must walk backwards to avoid making depressions in the field which collect water. A seed rate of 60 to 100 kg/ha is enough for broadcasting but many farmers use 150 to 200 kg/ha to guard against poor germination and damage due to biotic or abiotic factors.

Broadcasting by Motorized Duster

This is a popular technique of rice seeding in Malaysia. Pregerminated seeds soaked for 24 h and incubated for 12 h are broadcast over puddled soil with 5-cm layer of water using 3.5-hp duster attached to a long blow pipe or 2.0 m long shower pipe. With walking speed of 0.6 to 0.8 m/sec. the seed rate is 45 to 90 kg/ha. Low seed rate is applied for high tillering varieties and high seed rate for medium tillering varieties of rice.

Spot Dibbling

Pregerminated seeds (24 h soaking and 24 h incubation) are manually sown on a moist puddled soil at spacing of 20 × 20 cm or 25 × 20 cm. The crop establishment and maintenance of population density are good and weed control is easier by this method. Spot dibbling is practiced in small field plots with the manually-operated dibbler or using rope with beads for sowing at equal spacing. Spot dibbling is practised at the CRRI farm and has been found to be a suitable method.

Drum Seeding

For wet seeding pregerminated seeds, 24 hours of soaking in water followed by 12 hours of incubation are sown on to a puddled soil 1-2 days after puddling using a perforated drum seeder. Water should be drained from the field before seeding. The seeder should be pulled backward. The seed rate is 50 to 75 kg/ha. Uneven seed delivery may be there along the rows, but the overall performance reported is good. It is a very simple, lightweight machine.

Drum Seeder for Aerobic Wet Seeding

The pregerminated paddy seeders were developed for sowing seeds in wet soils during 1968 to 1978 at Orissa, I.I.T., Kharagpur and Pantnagar, Rajendranagar as reported by Srivastava and Panwar 1985. These seeders were 2-, 4-, 5- and 6-row machines. Their performance was reported to be good. Recently, the IRRI reported the development of lightweight 8-row drum seeder, which has given very good performance in many places. The details of this machine are as follows:

IRRI-8-row drum seeder - manually pulled type. It is an eight-row drum seeder recommended for sowing of dry/wet paddy seeds in the well-puddled levelled seedbed. The weight of unit is reported as 11 kg and 8 kg of seed are loaded in the seed drums, row spacing is 20 cm and seeder can cover one-hectare area with labour requirement of 14 man-hours. It requires 9 kg of pull to operate the machine (**Fig. 3**).

This IRRI seeder was taken up for evaluation in India under the CREMNET project (1998). The Directorate of Rice Research, Hy-

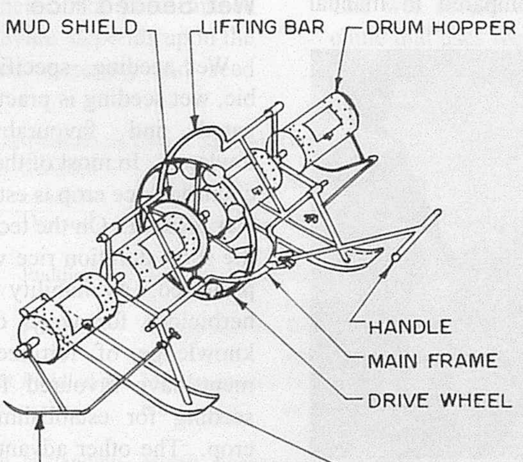

Fig. 3 8-row drum seeder (IRRI design).

derabad further modified it and took up production through local industry. An 8-row modified seeder was developed 1997-98, Krishnaiah (1999). The cost of seeder is about Re.2000, and weighs 12 kg (**Fig.** 4). The single drum with 8-rows of holes is mounted on two wheels at the ends. The seed rate is adjustable for 50-75 kg/ha. Two workers are used for operating the machine in the field. The seeds are soaked for 24 hours and incubated for 24 hours before they are sown in the field. The performance of the machine was reported during the CREMNET project workshop organized in 1998 and the results of multilocation trials are summarized as follows:

Performance of Drum Seeder (DRR Design)

1. The M. S. Swaminathan Research Foundation conducted field trials at Pondichery for two crop seasons, January-May 1997 (Navarai) and May-August 1997 (Kuruvai) and reported yield levels of 6034 kg/ha with cost benefit ratio of 1.84 under the CREMNET programme.
2. Soil and Water Management Research Institute, TNAU, Thanjavur raised rice with 8-row seeder during Kuruvai and Samba seasons and reported satisfactory performance. Some modifications in the seeder were desirable.
3. The University of Agricultural Sciences, Dharwad in north Karnataka India reported results of 5-year trials with seeder and reported that for Amruth variety, yield levels of 6.9 tons/ha were achieved and the seed rate was 80 kg/ha with the seeder. The application of Butachlor and Fluchloralin at 10 DAS was safe for the crop.
4. The Directorate of Rice Research (DRR), Hyderabad reported that for puddled soils the varieties for seeding sprouted seeds were, Vikas, Nidhi and Krishna Hamsa. For early duration the varieties were Tulasi, Ravi and Aditya.
5. The DRR, Hyderabad reported the tillage of wet soils (150-200 mm) by puddling with tractor was carried out. The cone index for tractor puddling required was 7 kg/cm^2 and the 8-row seeder required 10-14 man-h/ha for sowing operation.
6. It was also reported that land should be well puddled, levelled and soil-settling time for machine operation was 24 hours. Thin layer of water is maintained in the field for seeding. Soil cracking after seeding, particularly in rabi season, when temperatures are low leads to low plant stand.
7. For herbicide application in standing water of 3.0-cm depth is essential for the control of weeds. Weed control by Butachlor and Safener and Pretilachlor and Safener give 50 to 40% higher yields over Anilosophos when applied 3 to 6 days after sowing. Comparable yields were obtained with two hand weeding. For water requirement studies indicated (Ravi variety of 120 days) use of 117 cm of irrigation water under shallow submergence and 72 cm for cyclic submergence giving water use productivity (WUP) of 41 kg/ha-cm to 64 kg/ha-cm of water respectively at Hyderabad.
8. The IRRI, Philippines reported nitrogen application rates of 100 to 114 kg/ha for irrigated, direct wet seeded rice for grain yield of 6848 and 6830 kg/ha for broadcast and row wet seeded rice. The tiller density was 662/m^2 in the test plot.

Rajendran et al. (1998) further evaluated the modified 8-row drum seeder (DRR) for studies to raise rice crop along with green manuring crop in alternate row (*Sesbania aculeata*) so as to help the resource poor farmers to obtain high yield level with biofertilizer. The results of trials reported that wet biomass raised in 36 days after sowing of crop can be easily incorporated in

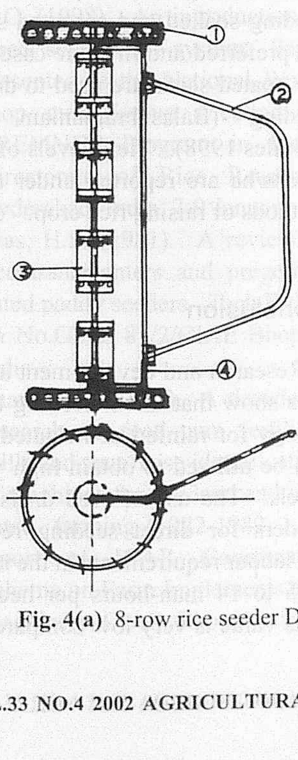

Fig. 4(a) 8-row rice seeder DRR design.

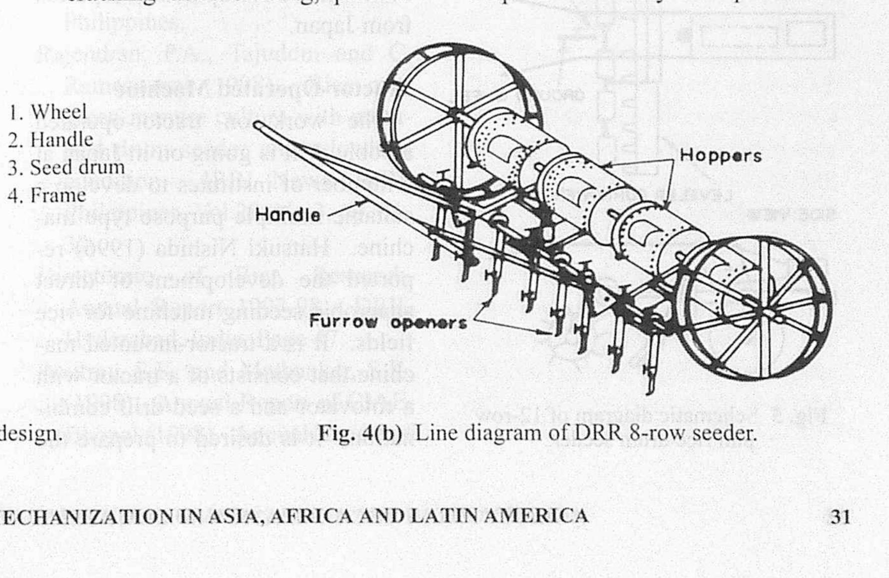

Fig. 4(b) Line diagram of DRR 8-row seeder.

the soil. This is reported as useful technology for small farm holders under rainfed lowland ecosystem. The study on drum seeding of rice at the CRRI indicates that it is suitable for raising crop in Rabi (winter) season. Thus it is concluded that the manual drum seeder can do the wet seeding of the rice in puddled fields.

Anaerobic Wet Seeding

The sowing of pregerminated rice seeds in the puddled soil surface is termed as anaerobic wet seeding. Seeds are broadcast or drilled in rows. Seeds sown below the soil surface have better and uniform crop establishment as they are not damaged by birds, disturbed by rain or desiccated by drought or lodging due to poor root anchorage.

Anaerobic broadcast seeding is achieved by broadcasting pregerminated seeds 24 hours of soaking and 24 hours of incubation immediately after puddling and allowing the mud to settle and form thin (1 to 2 mm) protective cover over the seeds. There is no need to drain the water. Anaerobic broadcasting of seeds can be done by coating them with calcium peroxide. This is a good technology but the cost of seed coating is extra, it is mostly recommended in Japan.

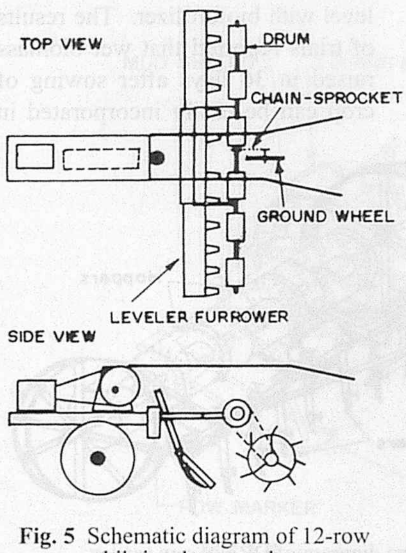

Fig. 5 Schematic diagram of 12-row phil rice drum seeder.

Power Tiller-operated Anaerobic Wet Seeder

Sawamura (1995) and a team of Japanese scientists under the Japan International Cooperation Agency (JICA) were working with scientists at the Philippines Rice Research Institute, Philippines for the development of anaerobic type paddy seeder in 1994-98. A design of power tiller-mounted type, 12-row seeder was conceptualized, developed, evaluated, modified and finalized (1999). The seeder has a field capacity of 3 to 5 ha/day, seed rate is adjustable from 40-120 kg/ha, with 20 cm row spacing, the central two rows are at 30 cm space apart so that operator can walk easily (**Fig. 5**). The weight of the machine is 70 kg and is provided with ridge type furrowers. The Phil Rice Institute reported that the seeder is ready for commercialization.

Anaerobic Drill Seeding Method

The pre-germinated seeds (24 h soaking and 12 h incubation) can be sown in rows 1-2 days after puddling by an anaerobic seeder fitted with furrow opener with a covering device. There should be no water on the surface at the time of row seeding by this machine. Such type of machine development is reported from Japan.

Tractor-Operated Machine

The work on tractor-operated aerobic drill is going on in Japan at a number of institutes to develop a suitable multiple purpose type machine. Hatsuki Nishida (1996) reported the development of direct anaerobic seeding machine for rice fields. It is a tractor-mounted machine that consists of a tractor with a rotovator and a seed drill combination. It is desired to prepare the wet seed bed with a rotovator of shallow type and drop the seeds in the furrow, the seeds are covered with soil. The machine can do the rotovating and broadcasting of wheat seeds. Thus it is made multi-purpose type, useful for rice-wheat cropping system.

Water Seeding

Traditional water seeding method: This is a technique where pregerminated seeds (24 h soaking and 24 h incubation) are sown in standing water which will recede with time. Seeds must be heavy to sink in standing water. This is practiced when water can not be drained out from the field and seedlings can survive and elongate rapidly at water depth of 3 to 10 cm in the field. The farmers in eastern Madhya Pradesh raise the crop of Kesaridhal (a pulse crop) by this method before the rice crop is harvested.

Modern water seeding: This is the most common seeding method used in developed countries. It is practiced in Italy, Australia and United States. Modern rice seeding is done by aircraft in large fields in USA. In Italy the tractor-mounted broadcast seeders are used to cover small fields (size 20 ha). For water seeding soaked and sprouted seeds are preferred and in some cases the dry coated seeds are used to do the seeding (Balasubramaniam and Morales 1998). Yield levels of 7 to 8 tons/ha are reported under these methods of raising rice crop.

Conclusion

Research and development activities show that direct seeding technology for rainfed or irrigated rice can be utilized to obtain high yield levels. The use of seed drills and seeders for direct seeding reduce the labour requirements in the range of 5 to 14 man-hours per hectare. This value is very low compared to

300 man-hours required for transplanting of rice seedlings under wet conditions. The experiments in India have shown that up to 4 to 5 tons per hectare yields are possible for dry seeded rice and 6 to 7 tons/ ha for wet seeded crop. However, it is pointed out that for high yield level it is essential to follow all the agronomic practices and provide good water management. Therefore, while transferring the technology of direct seeding to the farmers the aim should not only be to provide a seeder or seed drill but the improved package of practices and water management to achieve the high level of productivity.

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Development and Evaluation of Combined-operations Machine for Wheat Crop Establishment in Sudan Irrigated Schemes

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Abstract

A combined-operations machine for wheat seeds drilling and ridges setting in a one single pass was developed for use in irrigated heavy clay soil schemes. Construction and design specifications are mentioned. It was fabricated to save the seeding machine requirement, to enhance wheat-seeding method in the shorter winter season, to reduce the cost of wheat crop establishmet and to improve the crop growth performance. It was tested against the traditional sowing method, which is the use of wide level disc equipped with a seeder box + 80 cm ridges. The results indicated that the designed combined-operations machine can cut down the time for wheat seeding operation by 35%, and the cost of crop establishment by 56%, with a net savings of 25% of the recommended seed rate. Moreover, the use of the fabricated combined-operations machine resulted in a higher crop emergence, a higher plant population and a higher grain yield in the research station farm and in farmers' fields in comparison with the traditional sowing method. Hence, the fabricated combined-operations machine could be used successfully for wheat crop establishment in irrigated heavy clay soils in the Sudan.

Introduction

Wheat is a strategic commodity in the Sudan. It is exclusively produced under irrigation. Traditionally, wheat has been produced on small areas along the Nile in the north of Sudan, using animal-drawn implements and hand tools. For national self-sufficiency, wheat production has been introduced in central clay plain in irrigated governmental schemes of Gezira (168 000 ha), New Halfa (25 200 ha) and Rahad (18 900 ha). The soil is Vertisols and the climate is semi-arid. The crop is grown in the winter season during the period November to March. The winter season is shorter and warmer than those of traditional wheat producing areas in the world, and has frequent hot spells.

According to availability of seeding equipment in irrigated schemes, there are various methods for wheat crop sowing after land preparation. In the Gezira and Rahad schemes, farmers are used to broadcasting seeds manually. For the coverage of seeds with soil, some farmers use 80-cm spaced ridges and others use a local-made tractor mounted heavy tool bar with corrugations for combing the soil. Manual broadcasting results in uneven distribution of seeds. Moreover, the covering of seeds with corrugated heavy tool bar results in shallow and poor seed coverage with the soil, which causes the washing out of seeds during the first irrigation. Due to the adverse effects of these sowing methods, the recommended seed rate for all irrigated schemes is 143 kg/ha (Technical packages, 1991). Earlier investigations and recent findings (A/Wahab et al, 1994) indicated that the seeding rate as lower as 95 kg/ha can be sown without yield reduction with the use of wide level disc with a seeder box and seed drill. With the same seed rate (129 kg/ha), the use of seed drill resulted in significantly higher crop emergence in comparison with the use of wide level disc equipped with a seeder box, but no differences in number of heads or yields were detected (El-Awad, 1993). Because of the tillering capacity of the wheat crop, the use of lower seed rate is agronomically feasible with the use of seeding machine and economically sound due to high cost of seeds.

Wheat crop is fully mechanized in New Halfa scheme. For wheat crop establishment, all farmers tend to use the wide level disc equipped with a seeder box followed by the setting of 80-cm spaced ridges. The objectives of ridges setting were to faciltate field irrigation and to allow the crop growth on ridges top. Seeding machines had been introduced to the scheme by the government in 1970s to improve the timeliness of wheat crop operations, especially the sowing date. These machines became obsolete and scraped. Then the farmers were faced with the shortage of seeding machines and, consequently, a delay in wheat crop establishment and a reduction in crop yields.

Wheat crop establishment is a major problem that faces wheat production in irrigated schemes. The problem arises from the bad distribution of the first irrigation water into the fields. As the soil is a heavy clay with very low infiltration rate, water stands for a long period of time thus causing germination failure as the result of aeration impairment (Ageeb, 1986). Wheat seed drilling as well as ridging after broadcasting resulted in significantly greater yields than broadcasting alone (Dawelbeit and Babiker, 1997). Moreover, the recommendation is to grow crop on 60-cm ridges in fields of compact soil and with difficulties in irrigation management (Babiker et al, 1997). Crop harvesting in all irrigated schemes is done using self-propelled combine harvesters. Hence, the use of 60 cm spaced ridges (small and narrow ridges) would be easier for maneuverability of combine harvester in the field compared to the 80 cm spaced ridges (big and wide ridges).

Owing to the limited number of available wheat seeding machines and tractors, the simultaneous two operations for wheat crop establishment, which are seeding operation and ridge making, are always attributed with delay in optimum crop sowing date. Therefore, a combined-operations machine for wheat seeds drilling and 60 cm ridges setting in a one single pass was designed and evaluated. The objectives were: 1) to save the seeding machine requirement; 2) to enhance wheat-seeding method in the shorter winter season; 3) to reduce the cost of wheat crop establishment; and 4) to improve the crop growth performance.

The fabrication of combined-operations machine and the experimental work was carried out at New Halfa Research Station in New Halfa scheme, which is between latitudes 15°05'S (approx.) and 15°30'N. The River Atbara forms the eastern boundary. The clay layer is 2 m or thicker. The clay content is 45 – 60% (Blokhuis, 1962).

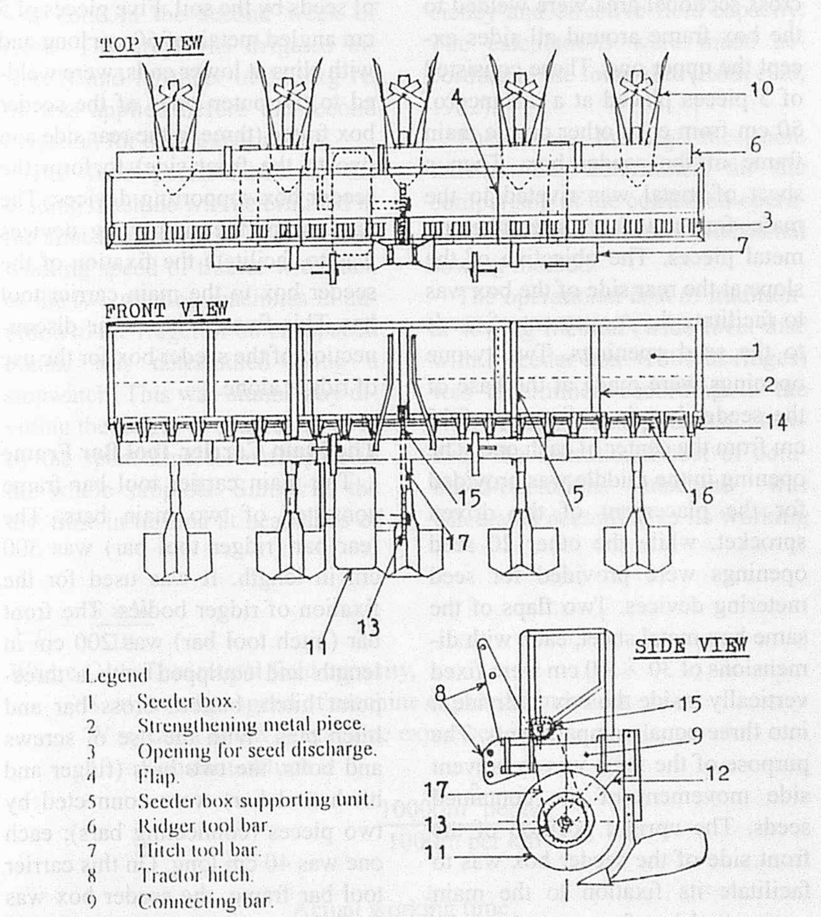

Fig. 1 Sketch of the main parts of combined operations machine for wheat crop sowing.

Materials and Methods

The Design of Combined-operations Machine

The following main parts of the combined-operations wheat-seeding machine as shown in **Fig. 1** were designed and rearranged:

1. The seeder box.
2. The main carrier tool bar frame for seeder box and ridger bodies.
3. Rearrangement of ridger bodies.
4. The seed metering system.

The combined-operations machine was assembled and attached to the tractor by the 3-point linkages to work as a fully mounted seeding machine (**Fig. 2**). The 5th ridger body to the left-hand side of the machine was obtained from other different ridger tool. The specifications of the main parts were the following:

The Seeder Box

Firstly, a box frame was constructed. It was made of 3.5 cm angled metal. The length was 310 cm. The width was 40 cm. The height of the front side was 50 cm, but the height of the rear side was sloped after 30 cm from the top. The slope length was 33 cm to give 13 cm base width. Additional strengthening metal pieces of 3.8 × 0.6 cm cross sectional area were welded to the box frame around all sides except the upper one. These consisted of 5 pieces placed at a distance of 50 cm from each other on the main frame of the seeder box. Then a sheet of metal was riveted to the main frame and to strengthening metal pieces. The objective of the slope at the rear side of the box was to facilitate the movement of seeds to the seed openings. Twenty-one openings were made at the base of the seeder box in a distance of 15 cm from the center of each one. The opening in the middle was provided for the placement of the driven sprocket, while the other 20 seed openings were provided for seed metering devices. Two flaps of the same box metal sheet, each with dimensions of 30 × 40 cm were fixed vertically inside the box to divide it into three equal compartments. The purpose of the flaps was to prevent side movement of the contained seeds. The upright position of the front side of the seeder box was to facilitate its fixation to the main carrier tool bar frame, as the front side of the tool bar was equipped with a three-point hitch. Moreover, the position of the front side was to facilitate the drilling of seeds in front of the ridger bodies, which were attached to the rear side of the tool bar, to secure proper coverage

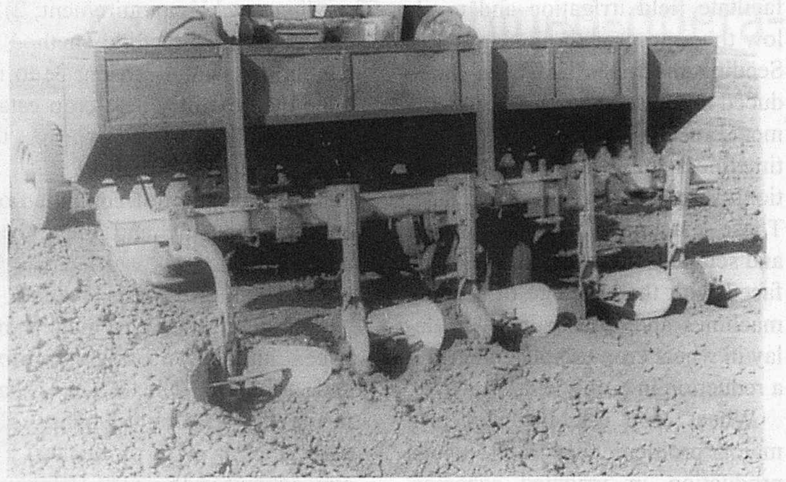

Fig.2 The fabricated combined operations machine for wheat crop sowing in working.

of seeds by the soil. Five pieces of 5 cm angled metal, of 60 cm long and with clips at lower ends, were welded to the outer sides of the seeder box frame (three to the rear side and two to the front side) to form the seeder box supporting devices. The purpose of the supporting devices was to facilitate the fixation of the seeder box to the main carrier tool bar. This fixation eases the disconnection of the seeder box for the use of ridger alone.

The Main Carrier Tool Bar Frame

The main carrier tool bar frame consisted of two main bars. The rear bar (ridger tool bar) was 300 cm in length. It was used for the fixation of ridger bodies. The front bar (hitch tool bar) was 200 cm in length and equipped with a three-point hitch, bottom cross bar and hitch pins. With the use of screws and bolts, the two bars (ridger and hitch tool bar) were connected by two pieces (connecting bars); each one was 40 cm long. On this carrier tool bar frame, the seeder box was fixed using the seeder box supporting devices to keep the seeder box base 10 cm high from the main carrier tool bar frame.

Rearrangement of Ridger Bodies

Five ridger bodies with adjustable mouldboards (wings) were chosen. Then the distance between the ends of the two wings was reduced to 34 cm for each body. Thereafter, the five bodies were placed at spacing of 60 cm apart to the ridger tool bar (the rear bar of the main frame) to give 60 cm spaced ridges and 300 cm working width.

Seed Metering System

A ground meter wheel with circumference of 164 cm was chosen and assembled with center rod and bearings. A 19-tooth drive sprocket (broad splines) was bolted to one end of the center rod and the other end was welded to hard steel bar. Then the hard steel bar was fixed with screws and bolts to the rear side of carrier tool bar (the ridger tool bar). Twenty units of double-run metering system were provided from Massey Ferguson seeder box and fixed to the base of the designed seeder box. A 10-tooth driven sprocket (broad splines) was allocated in the middle of double-run feed countershaft, which was equipped with counter-shaft bearing. The distance between the center of the lower sprocket (drive sprocket) and the upper one (driven sprocket) was 50 cm. The two sprockets were jointed by double-pitch roller drive chain. By this metering system, the seed rate was determined to be 107 kg/ha. The ground meter wheel was fixed at 5 cm above the level of ridger cutting shares in order to give the wheel tyre opportunity in attaining the maximum thrust to power the double-run feed countershaft in a ploughed land with loose soil surface.

Other Characteristics of the Designed Seeding Machine

This machine could be used to sow other field crops such as sorghum, maize and sunflower on the recommended 80 cm spaced ridges. This could be achieved through the use of seed-tubes and 4-body ridger if the double-run feed mechanism was replaced by fluted roller feed mechanism to regulate the seed rate with the covering of unnecessary seed feed devices.

Comparative Performance of the Combined-operations Machine

The fabricated wheat-seeding machine with the seed rate of 107 kg/ha was compared and evaluated with the traditional sowing method of wheat crop in the scheme. The traditional sowing method is by using the wide level disc equipped with a seeder box to sow the recommended seed rate of 143 kg/ha followed by the use of 4-body ridger for 80 cm ridges setting. The experimental work was carried out on-station during 2000/2001 and 2001/2002 seasons and on-farm (farmer-managed trial) in 2001/2002 season.

The design of the on-station experiment was randomized complete block design with four replications. The subplot size was 9 × 40 m. the manual harvested area was 8 rows × 5 m for 60 cm ridges and 6 rows × 5 m for 80 cm ridges, in order to give an area of 24 m^2. The on-farm trial was randomized complete block design with two replications. The whole farmer's field represented subplot size of 2.1 ha. The combine-harvested yield of the field was used in the analysis.

The research station has no wide level disc and there were difficulties in hiring one to perform the traditional sowing method in the optimum sowing date (November month). Therefore, the crop germination was commenced in the last week of December and the first week of January for the first season (2000/2001) and the second season (2001/2002), respectively, for the on-station experiment. In the farmers' fields the crop germination was commenced in the first week of November. Harvesting in the two seasons for both experiments (on-station and on-farm experiment) was done in the second week of April. The crop was irrigated bi-weekly and fertilizer of 143 kg N/ha was applied before the second irrigation for both experiments.

The field performance of the seeding machine was determined in the first season only. The average working speed of tractor with each of the two seeding machines in addition to the ridger of 80 cm spaced bodies was determined using a stopwatch. This was attained by dividing the length of subplot of 40 m by the spent time for each pass in the whole subplots. Similarly, the lost time in turning at headlands of subplot was determined. Then by considering the farmer's field (2.1 ha) as one cultivated unit, which is 280 m long and 75 m wide, the number of passes and turnings at field headlands were obtained by dividing the width of the field (75 m) by the working width of each machine. The working width of the designed machine, the wide level disc and the 4-body ridger was 3, 4.5 and 3.2 m, respectively. Therefore, the respective number of passes and turnings were determined to be 25, 16 and 23. Then the effective working time and lost time in turning was calculated to find out the theoretical field capacity, field efficiency and effective field capacity. The calculations were made according to the **formulae** (Roth et al, 1982).

Then from the C_E, the spent time/ha was determined for the comparison of the combined-operations machine with the traditional sowing method.

The operational cost of traditional sowing method (wide level disc with a seeder box + 80 cm ridges) was determined according to the New Halfa scheme price list. However, the operational cost of combined-operations machine was calculated according to its working

$$C_T = \frac{S \times W}{10}$$

Where C_T = Theoretical field capacity,
S = Average speed of machine expressed in km/hr,
W = Rated width of machine expressed in m,
10 = Constant, which is

$$\frac{10000m^2 \text{ per ha}}{1000m \text{ per km}}$$

$$E_f = \frac{\text{Actual working time}}{\text{Total time (actual working time + turning time at headlands)}}$$

Where E_f = Field efficiency expressed in decimal form.

$$C_E = \frac{S \times W \times E_f}{10} \text{ ha/hr}$$

Where C_E = Effective field capacity.

Formulae

width in relation to the width of wide level disc with a seeder box multiplied by the rated operational cost of wide level disc.

For both experiments, 10 random readings per subplot were taken for determining the crop emergence per m^2 after the 2nd irrigation, using 25 × 40 cm steel frame. The height of the ridges was determined in the first season only for on-station experiment after the 3rd irrigation, by taking 10 random readings, using a ruler to measure the height from the furrow bottom to the ridge top, after putting straight and long stick on the top of adjacent two ridges.

For the number of seeds per head, 100 random heads were collected and the number of seeds was counted after manual threshing and separation. For plant height, 50 random plants per subplot were measured. While for plant population at crop maturity, 5 readings per subplot were taken using steel frame of 25 × 40 cm.

Results and Discussion

On-station Experiment

The field performance data of wheat seeding machines for the first season is shown in **Table 1**. The comparison of the executed ridging operation of combined-operations machine with the 4-body ridger indicated that the use of the 5-body ridger resulted in higher operation speed of 7.0 km/hr, which was 15% higher than the use of 4-body ridger. As expected, the use of the 4-body ridger resulted in highly significantly (P=0.01) ridges height compared to the 5-body ridger (**Table 1**). The increase in operation speed was due to the lower soil draught with narrower ridger bodies. This result agrees with El-Awad (1998 a) who found that the 5-body ridger with 60 cm spaced ridges resulted in higher tractor speed, lower wheel slip and higher work rate in comparison with 4-body ridger with 80 cm spaced bodies. However, the effective field capacity and the field efficiency of combined-operations machine and 80-cm ridging operation were almost similar (**Table 1**).

The use of the wide level disc resulted in the highest operation speed, highest effective field capacity, highest field efficiency and lowest machine requirement (**Table 1**). However, its usage in connection with the 4-body ridger in the traditional sowing method (two passes of the tractor) for wheat crop establishment increased the machine requirement to 51 min/ha compared to 33 min/ha with the use of combined-operations machine. This indicated a machine savings of 35% compared to the traditional sowing method. The sowing date in farmers' fields was classified by the Department of Planning and Economics Research (1999) as early, medium and late sowing dates, which were the periods November 1 to November 30, November 30 to December 21 and after December 21, respectively. It was found that the average reduction in the wheat yields in the scheme compared to the early sowing amounted to 8 and 26% with medium and late sowing, respectively. Therefore, the savings in time in association with the reduction in the required tractor numbers and the amount of fuel needed with the use of combined-operations machine (one pass of the tractor), could lead to improvement in timeliness of crop sowing date and, consequently, an increase in wheat yields.

The cost of crop sowing with the combined-operations machine was determined to be US$ 4/ha as compared to US$ 9/ha with the traditional sowing method ($ 6 and $ 3 per ha for the wide level disc and ridger, respectively), thus resulting in net savings of 56%.

The mean effects of the seeding machine on wheat crop growth parameter are shown in **Tables 2** and **3**. The combined-operations machine resulted in 39 and 37% higher crop emergence/m^2 in the first and second seasons respectively. The difference was significant (P=0.05) in the first season only. The reduction in crop emergence with the traditional sowing method was due to the fact that the seeds imposed on the same harrowing and ridging actions. Thus, resulting in variable seed depths, therefore, some seeds could not germinate as a result of high depth and others as the result of improper seed-soil contact and coverage. The combined-operations machine drills the seeds on the soil surface, which has to be raised upwards as a result of soil wedge formation of head to the ridger bodies and then covered with the displaced soils forming the narrow ridging of 60 cm apart.

The combined-operations machine resulted in 27% higher plant population/m^2 for the first and second seasons (**Tables 2** and **3**). However, the difference was significant (P=0.05) in the second season only. For the plant height and number of seeds/head, no significant differences were evident between the com-

Table 1. Performance of Wheat Seeding Machine (first season, 2000/2001)

Seeding machine	Operation speed (km/hr)	Effective field capacity (ha/hr)	Field efficiency (%)	Machine requirement (min/ha)	Operation cost (US$/ ha)	Ridges height (cm)
Combined-operations machine	7.0	1.8	88	33	4	8
Wide level disc + 80 cm ridges	9.6+6.1	3.9+1.7	90+88	51	9	10
Means	/	/	/	/	/	9
SE±	/	/	/	/	/	0.8**

** = Significant at the 1% significance level.

bined-operations machine and the traditional sowing method for the two seasons (**Tables 2** and **3**).

Higher grain yields were obtained with the use of combined-operations machine with the seed rate of 107 kg/ha as compared with the traditional sowing method with the recommended seed rate of 143 kg/ha. This resulted in net savings of 25%. The increase in yields was 41 and 20% for the first and second seasons, respectively, but the differences were not statistically significant. These results are in line with El-Awad (1998 b) who found that the coverage of hand broadcasting wheat seeds with the use of 60 cm spaced body ridger resulted in the greatest wheat yields compared to the coverage with the use of 80 cm spaced body ridger and disc harrow. Generally, the obtained wheat yields were low as the result of the delay in crop sowing.

On-farm Trial

In the farmers' fields, none of the growth parameters (crop emergence, plant population, plant height, number of seeds per head and grain yields) were significantly affected (P=0.05) by the two sowing methods (**Table 4**). However, the combined-operations machine resulted in 19% higher crop emergence/m^2, 18% higher plant population/m^2, 15% higher number of seeds/head and only 8% higher grain yields in comparison with the traditional sowing method (**Table 4**).

The obtained wheat yields in farmers' fields were higher than those obtained in the experimetal research farm for the first and second seasons (**Tables 2** and **3**) as a result of sowing in the optimum time (November).

Table 2. Effects of Seeding Machine on Wheat Crop Growth (first season, 2000/2001)

Seeding machine	Crop emergence (no/m^2)	Plant population (no/m^2)	Plant height (cm)	No. of seeds/head	Grain yield (kg/ha)
Combined-operations machine	419	644	57	25	1372
Wide level disc + 80 cm ridges	301	508	59	28	972
Means	360	576	58	27	1172
SE±	33.0*	71.2	2.9	2.4	230.1

*= Significant at the 5% significance level.

Table 3. Effects of Seeding Machine on Wheat Crop Growth (second season, 2001/2002)

Seeding machine	Crop emergence (no/m^2)	Plant population (no/m^2)	Plant height (cm)	No. of seeds/head	Grain yield (kg/ha)
Combined-operations machine	436	571	55	30	910
Wide level disc + 80 cm ridges	319	448	60	28	759
Means	378	510	58	29	935
SE±	44.6	30.9*	1.9	1.1	97.4

*= Significant at the 5% significance level.

Table 4. Effects of Seeding Machine on Wheat Crop Growth in Farmers' Fields (2001/2002 season)

Seeding machine	Crop emergence (no/m^2)	Plant population (no/m^2)	Plant height (cm)	No. of seeds/head	Grain yield (kg/ha)
Combined-operations machine	478	507	70	38	1619
Wide level disc + 80 cm ridges	402	430	69	33	1500
Means	440	469	70	36	1560
SE±	31.5	6.0	1.5	7.5	23.0

Conclusion

By using this combined-operations machine, the machine requirements of wheat crop establishment can be cut down by 35%, thereby timeliness of crop sowing date could be improved, and hence, higher crop yields would be obtained. Also, the cost of sowing can be cut by 56% and seed rate by 25% in comparison with the traditional sowing method.

The fabricated combined oprations machine for wheat crop establishmen resulted in 39, 37 and 19% higher crop emergence/m^2 in the first season, second season and in farmers'fields, respectively. However, this was only significant in the first season. Also it resulted in 27% higher plant population/m^2 for the first and second seasons and in 18% in farmers' fields, which was significant in the second season only. The increase in wheat grain yields with the use of fabricated combined-operations machine amounted to 41, 20 and 8% in the first season, second season and in farmers' fields, respectively. These were not statistically significant. No significant differences were evident for plant height and number of seeds per head during the testing period in the research station farm and in farmers' fields.

Therefore, the developed combined-operations machine for wheat seeds drilling and ridges making in a one single pass is suitable for wheat crop establishment in irrigated schemes of heavy clay soils and shorter winter season.

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(Continued from page 42)

Effect of Different Seed Spacing Practices on the Evapotranspiration and Yield of Faba Bean

Conclusions

1. Although the triangular method showed the highest yield, on the average, the differences in yield among the three plating patterns were small and statistically insignificant .
2. Both narrow row spacing planting methods, on the mean, showed lower evapotranspiration compared with the conventional method. The triangular method showed the lowest evapotranspiration. Although these differences statistically were not significant, the square planting method showed significant difference (at the 10% level) in the moisture content at soil depth of 10 cm in comparison with the conventional method.

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Effect of Different Seed Spacing Practices on the Evapotranspiration and Yield of Faba Bean

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Abstract

Water resources in Jordan are in short supply. Large quantities of water are lost by the evapotranspiration process during the growing season of the crops. The objective of this research was to adopt a planting system that helps in reducing the evapotranspirated water and hence improving the efficiency of using water. Faba beans were planted in two narrow spacing methods (rectangular and triangular arrangements) and one conventional method of larger row spacing. Blocks of equal seed population were planted to provide four replications of each treatment. Soil moisture contents were measured to provide information about the relative evapotranspiration. The statistical t-test is conducted to evaluate the effect of the proposed planting systems on the yield and evapotranspiration.

Introduction

Water resources in Jordan are in short supply. In addition, much of the country lies in a semi-arid to arid region where the annual average rainfall is below 200 mm. This rainfall is insufficient to provide good reserves of surface or ground water to meet the drastic increase in water demand for the expanding industry and irrigated agriculture. Large quantities of water are lost by evapotranspiration process during the growing season of the crops.

Many research workers have investigated various methods of evapotranspiration reduction. The methods include field geometry effects (McCanley et al, 1978; Demmel et al, 1999): irrigation water amount and frequency effects (Abu-Awwad, 1986; Tolk et al, 1999): and mulching effects (Jone et al, 1977). Mulching reduces soil evaporation and hence, the crop water requirements. Moreover, plastic mulching is considered one of the best weed control methods (Kipps, 1983). The use of plastic mulches may add to the cost of crop production.

The objective of this research was to adapt a planting system that helps in reducing the evapotranspired water and hence improving the efficiency of using water.

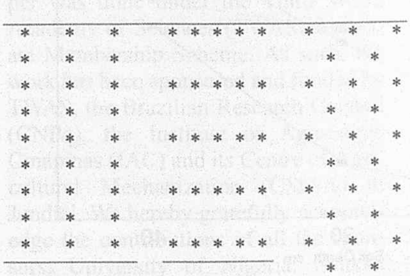

Fig. 1 The three equal population Faba bean planting systems used in the experiment.

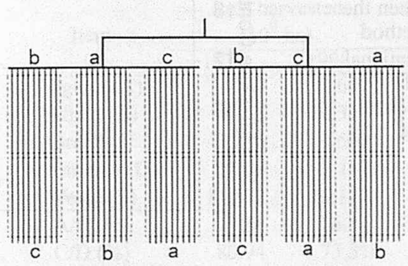

Fig. 2 Layout of irrigation lines and treatment blocks.

Materials And Method

Faba beans were planted on the 28th of Nov. 1999 in three different seed spacing planting systems (**Fig. 1**). The first method represent the conventional planting system used in Jordan in which the row spacing is 40 cm and the seed spacing within the row is 10 cm. The seeds in the second and third

Table 1. Means of Soil Moisture and Yield Data for the Three Planting Systems

Planting system	Soil moisture content at depths of: 10 (cm)	20 (cm)	40 (cm)	Yield (kg/plot)
Conventional	14.12	15.10	17.88	20.95
Square	15.98	17.79	18.39	20.57
Triangular	15.43	17.53	19.57	21.02

Table 2. Means of Evatranspiration Data for the Three Planting System

Planting method	ET (seasonal) (cm)	ET(daily) (mm/day)	ET(seasonal) (m3/hectare)
Conventional	41.34	2.79	4134
Square	40.55	2.74	4055
Triangular	40.43	2.73	4043

method planted in narrower row spacing (20 cm) and larger seed spacing within the raw (20 cm). The seeds were placed in such a manner that they form a square shape in the second method and triangular shape in the third method.

Twelve plots of equal seed populations were planted to provide 4 replication of each treatment (**Fig. 2**). Each plot which is 3.6 m wide and 6 m long was irrigated by 9-drip irrigation hoses spaced 40 cm apart. At the end of the growing season (April 23, 2000), the crop was harvested and weighed. Soil moisture content at different depths for each plot were measured using the gravimetric method.

The evapotranspiration ET was calculated from the water budget equation as follows.

$$ET = I + P - (Df - Di)$$

Where

ET= Evapotranspiration(mm)

I = Irrigation (mm)

P = Precipitation (mm)

Di = Initial depth of water stored in soil (pre-planting)

Df = Final depth of water stored in soil (end-season)

The surface runoff and deep percolation were assumed to be zero.

Table 3. Statistical t-test Comparing Soil Moisture Content at Soil Depth of 10-cm between the Conventional Method and Square Method

	Square	Conventional
Mean	15.9825	14.1175
Variance	0.6516916667	2.684025
Observations	4	4
Pooled variance	1.6678583333	
Hypothesized mean difference	0	
df	6	
t	2.0422751566	
P(T<=t) one-tail	0.0435846774	
t Critical one-tail	1.4397557479	
P(T<=t) two-tail	0.0871693547	
t Critical two-tail	1.94318028	

Results and Discussion

The crop yields and soil moisture content data for each plot were recorded. The average of the four replications of each treatment is listed in **Table 1**. The triangular method of planting showed the highest yield followed by the conventional and the square methods. However the differences in yield were small and were not significant as confirmed by a t-test. The relative distribution of soil moisture content with depth at the end of the season for the three planting method is shown in **Fig. 3**. The triangular and square methods showed higher remaining moisture content than the conventional method.

The total seasonal amount of irrigation water applied to the field was 81 cubic meter. Assuming that this volume of irrigation water is evenly distributed over the total area of the 12 plots, the depth of irrigation water will be I = 31.25 cm. The total amount of precipitation as recorded by the weather station during the growing season was P = 13.62 cm. Using the moisture content data at the beginning and the end of the season at different depths of the soil, the average evapotranspiration ET for each treatment was calculated and the results are shown in **Table 2**. The conventional planting method showed the highest evapotranspiration relative to the other narrow row spacing methods (square and triangular). This may be due to the relatively high evaporation of soil water from the wider row spacing of the conventional method, where the soil is more exposed to the environment. The triangular planting method showed the lowest evapotranspiration and this may be related to the fact that the plants in this method occupy the spaces more efficiently (less exposure of the soil to the environment) compared with the square method. Statistical t-test showed that these differences in the evapotranspiration were not significant. However, the moisture content at soil depth of 10 cm for the square planting method showed significant difference at the 10% level in comparison with the conventional method, as confirmed by the t-test shown in **Table 3**.

(Continued on page 40)

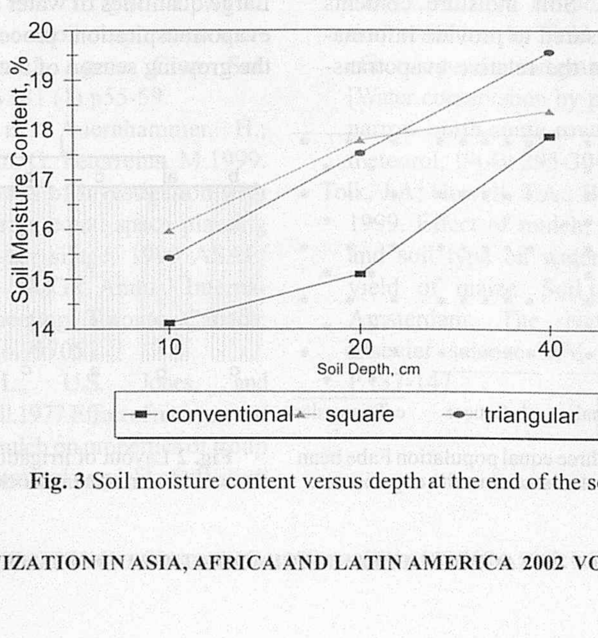

Fig. 3 Soil moisture content versus depth at the end of the season.

Development of a Complete Cassava Harvester: I - Conceptualization

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Abstract

This is a special report on an applied research work currently being done under the Third World Academy of Sciences (TWAS) Associate Membership Scheme. The paper is to be presented in several parts. This Part I first presents a technical analysis of the state-of-the-art in mechanization of cassava harvesting. It shows that no commercial cassava harvester is currently available on the world market, and that the available cassava harvesting aids can only do a good job of loosening the soils around the cassava root bunches. It then gives details of a concept (based on the existing cassava harvesting aids), designed to remove identified gaps in the technology of mechanized cassava harvesting, involving the lifting of the loosened cassava root bunches out the soil and loading them into a truck or trailer. The proposed concept comprises a cassava harvesting aid, an uprooter/lifter system, a collector/channelling chute and an elevator/loader system.

Acknowledgement

The research work reported in this paper was done under the Third World Academy of Sciences (TWAS) Associate Membership Scheme. As such, the work has been sponsored and funded by TWAS, the Brazilian Research Council (CNPq), the Institute of Agronomy, Cmapinas (IAC) and its Centre of Agricultural Mechanization (CMAA) in Jundiai. We hereby gratefully acknowledge the contributions of all the sponsors. University of Nigeria, Nsukka (UNN) is also acknowledged for granting researofessor Odigboh to facilitate his participate in the co-operative research work.

Introduction

Cassava is a very important crop in many tropical countries because it is both a chief staple food and a source of valuable industrial raw materials. Currently, its importance is further enhanced because many developed countries in Europe are targeting it as an energy source for livestock feed, and as a valued source of starch, sometimes in preference for cereal products. This preference is due to, not only a significantly more favourable competition in prices, but also to certain superior quality properties, especially of the cassava starch over cereal starches.

All available records show that Nigeria and Brazil are the world leaders in cassava production. The FAO Production Yearbook Data, as given in **Table 1**, show that over 30% of the world's cassava production takes place in Nigeria and Brazil alone and that about 70% of its total production in the world takes place in Africa and South America. This serves as a confirmation, if one is necessary, that mechanization of cassava production field operations (planting and harvesting, especially) is important for both Nigeria and Brazil.

Our review of literature reveals that worldwide R & D efforts to develop a cassava harvester have not succeeded in putting a commercially viable machine on the world

Table 1. 1977 and 1998 Cassava Production Data* for Nigeria/Africa, Brazil/South America and the World

Item	Area harvested (10^3 ha)		Yield (Tonnes/ha)		Total production (10^6 tonnes)	
	1977	1998	1977	1998	1977	1998
Nigeria (A)	1,100	2,697	9.6	10.60	10.60	30.41
Africa (B)	6,731	10,317	6.6	44.26	44.26	85.94
Brazil (C	2,233	1,552	11.9	26.51	26.51	20.11
S America (D)	2,759	2,117	11.6	32.02	32.02	27.11
World (E)	12,572	16,177	88	110.17	110.17	160.66
A/B (%)	16.34	26.14	-	23.95	23.95	35.39
C/D (%)	80.94	73.31	-	82.79	82.79	74.18
C/E (%)	17.76	9.59	-	24.06	24.06	12.52
(A+C)/E (%)	26.51	26.27	-	33.68	33.68	31.45
(B+D/E) (%)	75.49	76.86	-	69.24	69.24	70.37

*Adapted from FAO 1997 and 1990-98 Production Yearbook Records.

market. Based on this fact, the Third World Academy of Sciences (TWAS) was convinced that to undertake necessary applied research to develop a complete cassava harvester makes a great deal of economic sense for Nigeria and Brazil. Consequently, the research work reported here has been done under the TWAS Associate Membership Scheme, with the Centro de Mecanizacao Automacao Agricola (CMAA) of the Institute of Agronomy, Campinas (ICA) in Sao Paulo, Brazil, as the hosting Centre of Excellence.

Mechanized Harvesting of Cassava

Naturally, mechanization of cassava harvesting has attracted a great deal of research attention, but with very modest successes reported. Catalogues of agricultural machines produced by Brazilian manufacturers contain no cassava harvesters. What exist in Brazil, as elsewhere in the world, are few models of cassava harvesting aids in limited production and on trial use by a few farmers.

There are many problems associated with cassava harvesting. Some problems arise from the serious difficulties created by the random growth patterns of the roots and the equally random branching of the stems. In addition, cassava does not have a specific harvesting season. Therefore, an effective harvester must be able to operate in the parched hard soils of the dry season, the drenched muddy soils of the tropical rainy season, as well as in soils the consistencies of which vary between those two extremes. The cassava crop matures between 9 and 24 months after planting. At maturity, depending on the variety and the soil fertility status, the above-ground stems and branches are 1.0 to 1.75 m high or higher and have a mass that varies from 1 to 6 kg per plant. There are 3 to 8 roots or more per plant, weighing 1 to 6 kg together. The roots develop at depths of 150 to 450 mm with a radius of spread varying between 100 to 250 mm. Thus, the harvester has to handle up to 0.225 m^3 of soil to harvest one metre length of row of the cassava crop. All these unique characteristics must be appropriately considered to design an effective harvester.

Field Observation of Cassava Harvesting with Existing Harvesting Aids

As part of our search for information on mechanized cassava harvesting, we, on 22nd September 1999, visited a farm in Bataguassu in Southern Mato Grosso State of Brazil to observe some cassava harvesting aids in operation. We actually made a videotape recording of the operations. We observed the harvesting of two varieties of cassava in two separate fields, using two different types of the 2-row cassava harvesting aid both of which were integrally mounted to the tractor.

The first type, shown in **Fig. 1**, was a heavy, robust machine with two cutting blades set apart in such a way as to straddle the two rows of cassava to be harvested, such that each blade cuts from the outer side of a row inwards and downwards to a zone below the cassava root bunches. The implement was quite effective in its performance, especially as operated at 6 km/h in the sandy soil condition of the field. The blades cut through and moved below the cassava root bunches which were observed to be lifted up as the blades passed under them, and dropped back in place when the blades passed on. This means that the implement effectively loosens the soil around the cassava root bunches, but leaves the bunches virtually in the same place as it passes. After the implement had made a pass, the worked rows looked essentially the same before and after the passage. However, the cassava root bunches were easily pulled out of the soil without much effort beyond what was required to overcome their weight. The field could be described as medium trashy, but the implement performed well, nevertheless. The planting distances were 80 cm and 60 cm between and within rows, respectively. No breakages or damages were observed of the cassava tubers that could be attributed to the implement.

The second type of harvesting aid was a lighter equipment consisting of a 110^o vee-shaped pair of cutting blades sweeping back from the direction of forward travel, and mounted on one single central shank curving away from and concave to the point of the vee as shown in **Fig. 2(a)**. The soil cutting blades were 85 cm long and 10 cm wide and were fixed at an angle of 30^o to the horizontal in the direction of forward travel. A notched 40 cm diameter coulter was located centrally ahead of the blades, just at the point of the vee of the blades. The performance of this second implement, which was also operated at 6 km/h, compared favourably with that of the heavier two-shank two-separated-blade type. To operate, the point of the vee was located at the mid-point between the two rows of cassava to be harvested. Thus, the right and the left blades of the vee worked on the right and the left rows, respectively, cutting from the left flank and right flank of the rows, respectively. The blades went well below the zone of the cassava root bunches, just like the first type of implement. The maximum depth of penetration of the blades was measured and found to be about 25 cm. But additional weights were necessary to achieve penetration.

At our suggestion, the *Ikeda* Company developed and recently field-tested a single-shank two-row cassava harvesting aid illustrated

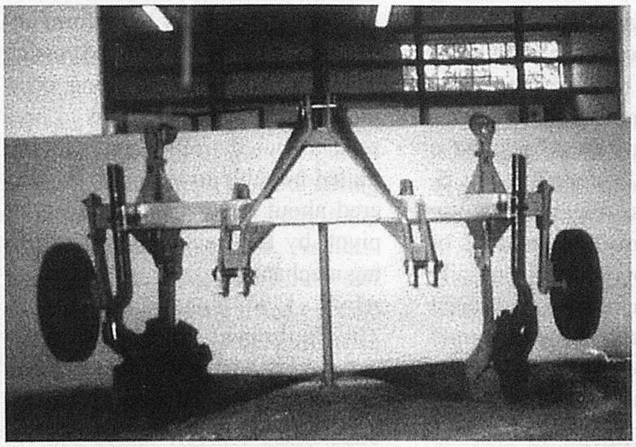


Fig. 1 Photograph of two-row two-shank cassava harvesting aid from the *Ikeda* Copmpany.

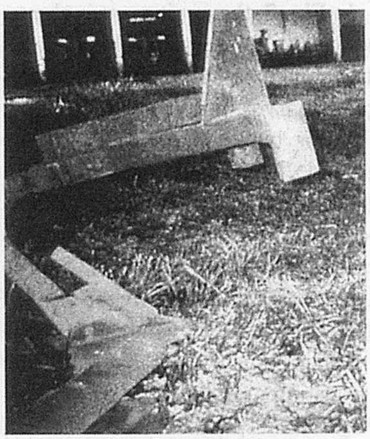


Fig. 2(a) Photograph of the two-row single-shank cassava harvesting aid with vee-shaped hoe.

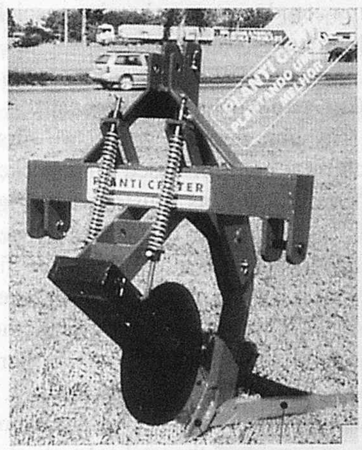


Fig. 2(b) Photograph of two-row single- shank harvesting aid from *Ikeda* Coy.

here in **Fig. 2 (b)**.

Overall Assessment of the Existing Harvesting Aids

Overall, it can be said that both implements performed well the intended function of loosening the soil around the cassava root bunches sufficiently to make it easy to pull out the bunches manually. But it is misleading to call them "cassava lifters" as everybody does, because the actual job of pulling out or lifting the cassava bunches out of the soil is done manually. The bunches were pulled out one by one, and gathered in heaps.

There were 3 or 4 heaps in a row, depending on the size of the field or the length of the row. This job of manually pulling out and gathering the bunches in heaps is very laborious and therefore, unwelcome. It should be pointed out that the intermediate operation of gathering the bunches in heaps is necessary to allow for the next manual unit operation of cutting the cassava roots from the stem peduncle. This is necessary to reduce the amount of unwanted materials taken from the field to the factory, since the trucking companies charge per trip. So the tubers have to be removed from the stems before they are loaded into the specially designed bags, each holding about 500 kg, ready for loading into trucks with a fork lift as illustrated in **Fig. 3**.

Gaps in Mechanized Cassava Harvesting Technology

Fig. 3 Loading of cassava placed into a truck from specially designed bags.

Since the performance of the existing harvesting aids are considered acceptable, the next most urgent mechanization need in cassava harvesting is to develop a machine to pull out the cassava bunches from the soil, gather them in heaps of appropriate sizes or load them directly into a cart, trailer or truck.

It was noted that planting the cassava cuttings horizontally on the flat led to the situation whereby the cassava root tubers developed along the 20 - 25 cm length of the planted cuttings, as shown in **Fig. 4**, even when only one node, usually at the apex of the cutting, produced the aerial stem/stems of the cassava plant. For better root-bunch geometry, cassava cuttings should be planted vertically or nearly vertically on the ridge (Odigboh, 1983).

We have given the above detailed account of the operation of the harvesting aids to clearly show what is the current state-of-the-art in mechanized cassava harvesting. Based on that, we came to the conclusion that the areas of most urgently needed research effort aimed at developing machines for cassava harvesting are:

i. The development of a machine or machine system to pull or collect the cassava root bunches from the soil, elevate and load them into a cart or trailer (based on the existing harvesting aids).

ii. Incorporation of a simple vibration mechanism in the design of the harvesting aids to make it possible for them to operate well in all soil types and under all soil conditions. Vibration of the hoe will also lead to the break up of soil clods into smaller particles and thereby facilitate the collection of the cassava root bunches. The vibration may be achieved with banks of compression springs arranged in such a way as to impart a sort of "passive vibration" to the cutting blades. In this regard, the vee-shaped single-shank harvesting aid may be preferable.

The research work reported here deals with only item (i) above, meanwhile.

Various Concepts of a Complete Cassava Harvester

Earlier Work

Several attempts have been made to mechanize the lifting of cassava roots out of the soil. Odigboh and Ahmed (1982) described a single-row vibratory cassava harvester prototype with a conveyor system designed to collect the uprooted cassava roots, move them backward, to dump them in small heaps along the row. Recently, a company called Interplan in Itarare of Sao Paulo State in Brazil, demonstrated a prototype cassava harvester which employs a system of vee-belts to pull the cassava root bunches out of the soil, lift them above the soil surface and then drop them back on the soil surface as illustrated in **Fig. 5**. This prototypes requires that, in slashing the stems and branches of the cassava plot which is usually done before harvesting, sufficient lengths of the cassava stems should be left to provide good grips for the belts. Several problems are likely with the prototype, the least of which is not the high probability that the stems of certain species may tend to snap or break, especially in heavy soil conditions.

Current Work - First Concept

In our current work, we first chose a concept based on a bucket type elevator, as illustrated in **Fig. 6**. The idea is that specially designed buckets, attached to a sufficiently robust chain and sprocket system, would comb through the soil already broken up by the harvesting aid, as described in 3.1 above, to pick up the cassava root bunches from the soil, elevate the bunches and then discharge them into a directly hitched trailer. The cassava root bunch lifter/elevator, as we called the equipment, was to be integrally attached to the cassava harvesting aid to form a complete cassava harvester. As such, and since it should possess the mass and robustness necessary to perform under all the usual cassava harvesting soil conditions, the resulting complete cassava harvester was to be a semi-mounted machine, (i.e., trailed but able to be raised or lowered about the transport wheels as pivot, by the tractor hydraulic lifting mechanism).

The Equipment as Constructed

An initial phase of the cassava root lifter/elevator equipment for only one row, with only three of the buckets, was actually constructed in 1999 to test out the concept.

In **Fig. 7**, the equipment is shown hitched to the tractor in the elevated (transport) position, with the digger or harvesting aid blades, C, and elevator buckets B_k lifted off the ground. **Fig. 8** is a close-up photograph of the equipment in transport position, showing the transport/elevating wheels, A, operated by the hydraulic ram, B, from the tractor hydraulic system, and the right-hand-side shank and blade of the harvesting aid identified as C. With a series of speed reduction drives, from the Cardan shaft driven at 540 rpm from the tractor pto, through a 2:1 speed reduction gear box, D_1, a second $\sqrt{5}$:1 speed reducer gear box, D_2, and a third $\sqrt{5}$:1 speed reducer gear box, D_3, the bottom sprocket of the chain and sprocket elevator system, D_4, is driven at 50 rpm.

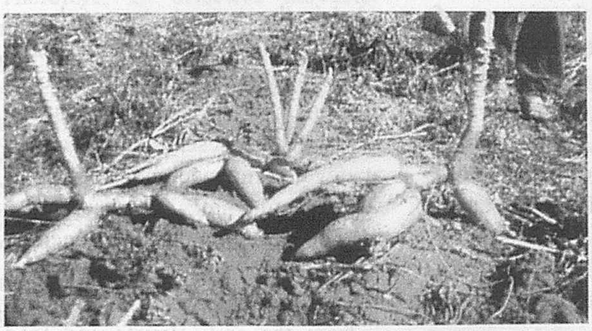


Fig. 4 Photograph of cassava tubers developed along the length of the cuttings planted horizontally on the flat.

Fig. 5 Vee-belt cassava uprooter/lifter prototype from Interplan Company in Itarere. S.P., Brazil.

Evaluation of the Equipment as Built

(a) The lifting mechanism

The evaluation of the equipment as built started with the lifting mechanism being tested both in the workshop and in the field. As illustrated in **Figs. 7** and **8**, the blades of the harvesting aid are lifted over 10 cm off the soil or ground surface to get the equipment in the transport position. Of course, in that position, the tips of the elevator buckets are lifted even higher. Pictures showing different views of the equipment when lowered into the cassava harvesting operation position are presented in **Figs. 9 - 11**. Note the position of the transport wheels, A, during the harvesting operation when the blades of the harvesting aid are completely inside the soil, with only a part of their shanks visible above the soil, as shown in **Fig. 11**. The bottom-most bucket, B_k, of the elevator is shown in **Figs. 9 - 11** in their position ready to comb through the soil to pick up the cassava roots.

(b) The elevating system

As already described pictorially, the pick-up and elevating system consists of buckets attached to a 63.3 mm (2 in) double-pitch chain, with bottom sprockets of 300- mm pitch diameter driven at 50 rpm, with the buckets spaced at 37.68 cm around the sprockets. The elevator is rotated counter clockwise and is supposed to pick up the roots, elevate and load them into a trailer at the rear. Accordingly, at the pick-up point at the bottom of the elevator, the tips of the bucket have a peripheral velocity of about 150 m/min. This adds to the tractor forward speed or the harvesting speed of 75 m/min to make the tips of the bucket move at the very high speed of 225 m/min relative to the soil at the picking point. It was found during the field test, therefore, that this extremely high velocity of the tips of the bucket relative to the soil was not suitable for the proper functioning of the picking/ elevating system for several reason:

(i) The resultant high impact of the tips of the bucket on contact with

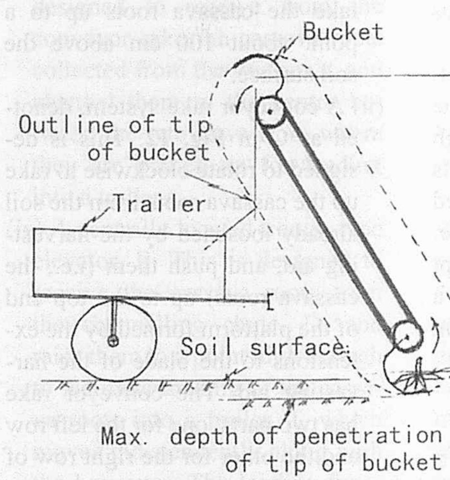


Fig. 6 A sketch illustrating the concept of the cassava lifter/elevator.

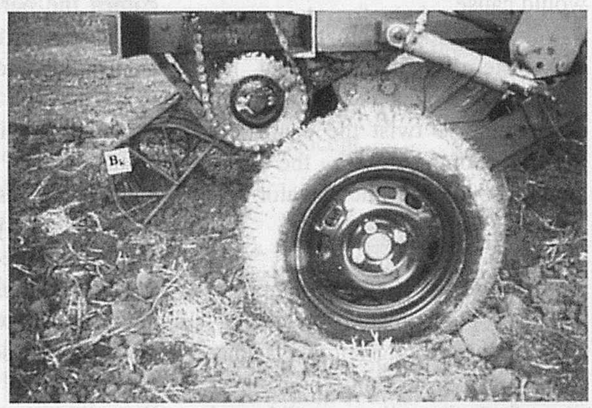
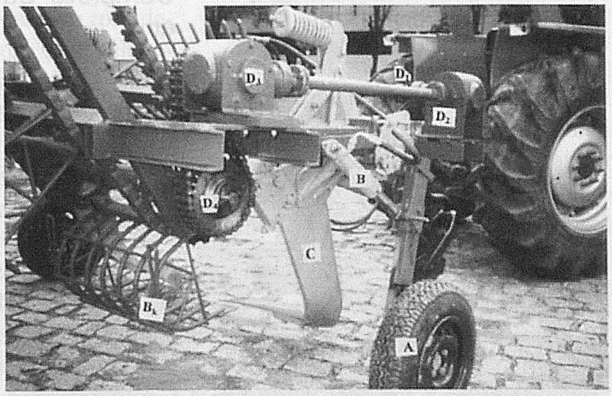


Fig. 9 Side view of cassava root lifter/elevator when lowered into harvesting operation position.

Fig. 7 The cassava root lifter/elevator raised into transport position outside the workshop. C – harvesting aid; B_k – elevator bucket.



A - transport/guage wheels; B – hydraulic ram; C – right-side shank/blade of harvesting aid; D_1 – 2:1 gear box; D_2 – 2^{nd} gear box; D_3 – 3^{rd} gear box; D_4 – bottom/driving sprocket of the chain-and-sprocket elevator system. B_k – elevator bucket.

Fig. 8 Close-up photograph of the cassava root lifter/elevator in transport mode.

the soil was too high, and so negated the intended gradual combing action.

(ii) Together with the combined weights of the buckets, the cassava root bunches and soil, the high impact forces tended to overload the links of the chain, making them kink and thereby impairing the smooth rotation of the elevator.

Another problem found with the elevator system was the tendency for soil to clog up the driving sprockets and chains, thereby tensioning the chain beyond the design limit and causing the slippage of the chain. Naturally to be associated with this problem is the fast wearing of the chain and sprockets which the attendant high friction would cause.

Yet another problem found with the system is the fact that the weight of the buckets and their contents tends to twist the chain and thereby contribute to the non-smooth rotation of the elevator system.

Analysing Identified Problems

The problem created by soil clogging of the driving sprockets may be solved by relocating them as far away from the soil as possible and using smooth pulleys in their stead at the bottom of the elevating system. The twisting of the chain caused by the weight of the buckets and their contents can be eliminated or appreciably reduced by using several strands of the chain on each side, instead of the single strand used.

Alternatively, a more robust chain, specifically designed to resist twisting and clogging, may be used. Thus, the most serious problem of this concept of the elevating system is clearly the extremely high velocity of the tips of the buckets relative to the soil at the point of picking up the cassava root bunches. But, there are several possible solutions to that problem one of which is to make the rotation of the elevator clockwise rather than counter clockwise, so that the velocity of the tips of the buckets relative to the ground becomes the peripheral speed minus the harvesting speed.

It is clear from the above discussions that the original idea of the cassava root lifter/elevator, though plausible and quite simple in its conception, has nevertheless proved difficult to practically execute. Therefore, a re-think of the concept has been undertaken resulting in a new concept which is discussed in the following sections.

A Modified Concept of a Complete Cassava Harvester

Conceptualisation

In order to appropriately address the inherent practical problems in the first concept, it was decided to separate the lifting operation from the elevating/loading operations and accomplish each with a separate mechanism. The modified or new concept of the cassava harvesting system is as follows:

(i) The two-shank two-row (*Ikeda*) harvesting aid, identified as A, with extensions denoted as B added to the blades of the harvesting aid. The extensions, consisting of flat bars which are spaced sufficiently to allow soil to fall through, form a platform which is made long enough and inclined at an angle sufficient to take the cassava roots up to a point about 100 cm above the soil surface.

(ii) A conveyor rake system, denoted as C in **Fig. 12**. This is designed to rotate clockwise to rake up the cassava roots from the soil already loosened by the harvesting aid, and push them (i.e., the cassava roots) up to the top end of the platform formed by the extensions to the blade of the harvesting aid. The conveyor rake has two parts, one for the left row and the other for the right row of cassava.

(iii) A channelling chute, D. This is

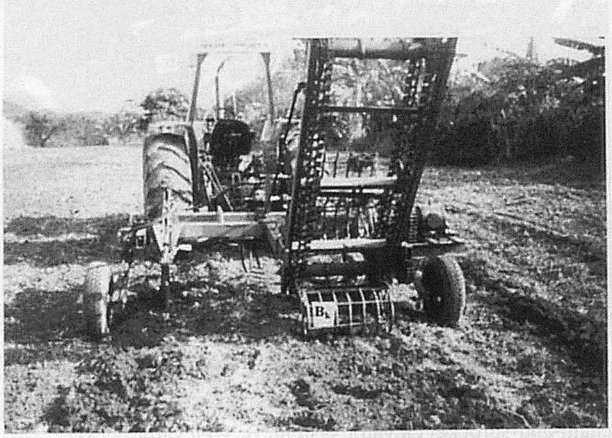


Fig. 10 A photograph showing the rear view of the lifter/elevator, with the bucket, B_k, about to comb through the soil.

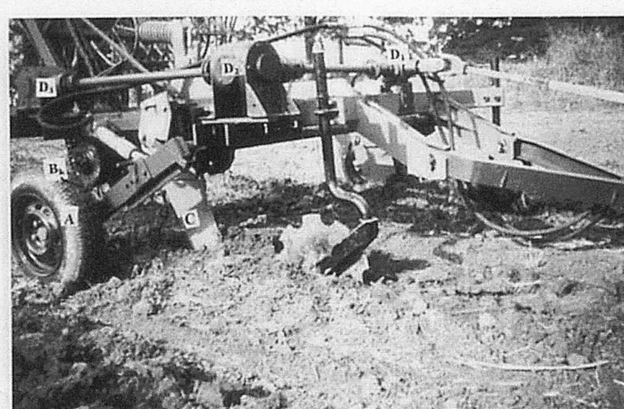
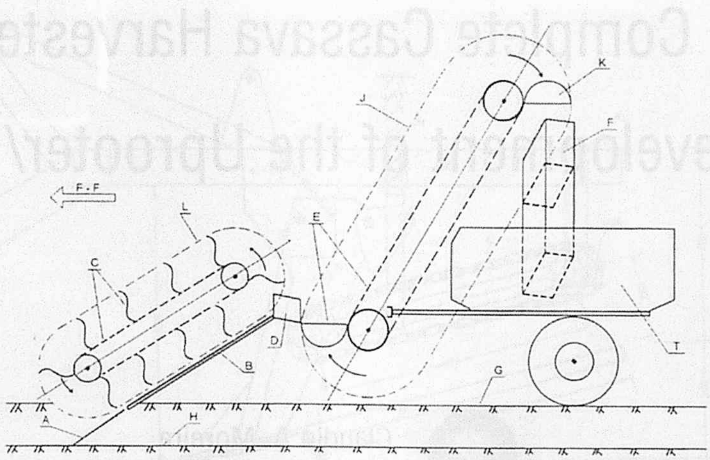


Fig. 11 Photograph showing a front/side view of the lifter/elevator prototype in working position.(Parts are as identified in Fig. 8).



A – harvesting aid; B – extensions to the blades of A; C – conveyor rake system; D – channeling chute; E – trough-type elevator; F – loading chute; F-F – direction of forward travel; G – soil surface; H – max. depth of blades A; J– outline of tips of elevator troughs; K – troughs; L – outline of raking tines; T - trailer.

Fig.12 A sketch illustrating the modified concept of the complete cassava harvester.

designed to receive from the conveyor rake the cassava roots collected from the two rows, and channel them to the centre between the two rows from where they are picked up for loading into a trailer.

(iv) A centrally located trough-type elevator, E. This is designed to receive the cassava roots from the channelling chute, D, and raise them to a point high enough to facilitate loading of the cassava roots into a trailer, T, which moves independently along with the harvester. The loading function is to be achieved using an appropriately long channel or trough shown as F, pivoted at the centre, and designed to tilt to the right or to the left, (depending on the position of the harvester relative to the already harvested plot), in order to load the roots into the accompanying trailer. Alternatively, by providing it with a swivelling arrangement or mechanism, the elevator, E, may be designed to always incline towards the harvested row to discharge the roots into the accompanying trailer. The alternative of hitching the trailer directly to the harvester may also be considered if enough tractor power is available and adequate articulation can be achieved so that the train does not become unduly cumbersome. The decision on which alternative to adopt will depend on which is found or considered easier to achieve practically.

To design parts A, B and C to work effectively together poses the greatest challenge of the modified concept. First, the harvesting aid must be able to function well in all soil types under different soil moisture regimes and reach down to the different depths of cassava root development. To ensure this will require some redesign of the *Ikeda* harvesting aid. But the current work is not addressing that problem yet. Next, the extensions B, added to the blades, A, may have to be set at a different and steeper angle than that of the blades, contrary to the illustration in **Fig. 12**. This may be necessary to maintain the rake angle of the blades of the harvesting aid as originally designed. The conveyor rake system is very crucial to the effectiveness of the modified concept. It is shown in **Fig. 12** that it rotates counter clockwise so that the velocity of the raking tines relative to the ground is the peripheral speed of the tines minus the harvesting speed, as earlier discussed above. Given the arrangement illustrated in **Fig. 12**, and since the harvesting aid is constrained to direct the soil and the cassava tubers up the inclined platform formed by the extensions, B, the conveyor rake system must ensure that the soil is sufficiently broken up to fall through the slats of B while the cassava tubers are effectively pushed, (i.e., pushed fast enough to avoid choking or clogging of the system), up the platform of B into the channelling chute D.

Closing Remarks

A good deal of work has already been done to implement the new concept described above. Part II of this special report presents work done on the development of the uprooter/elevator system of the proposed concept.

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Development of a Complete Cassava Harvester: II - Design and Development of the Uprooter/Lifter System

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Abstract

This paper is Part II of a special report on applied research work being done under the Third World Academy of Sciences (TWAS) Associate Membership Scheme. It deals with the design, development and preliminary testing of the uprooter/lifter system for cassava comprising the harvesting aid, extensions to the harvesting and a conveyor rake to lift the cassava roots up to the platform formed by the extensions. Limited tests performed so far showed that the prototype can effectively perform the intended function.

Introduction

Acknowledgement

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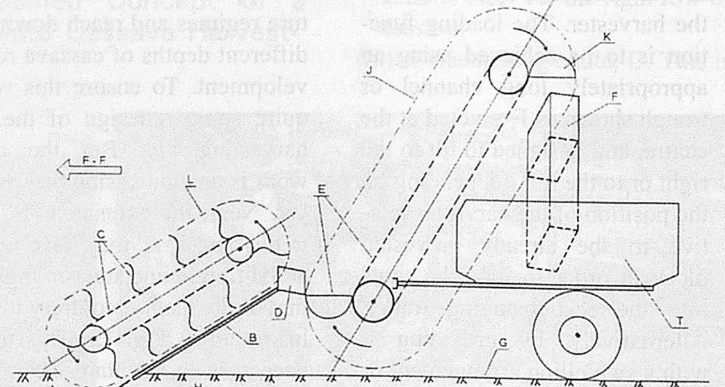
In Part I of this paper (on Conceptualisation), we described the concept of the proposed complete cassava harvester, part of an illustration of which is presented here (again) as **Fig. 1**. The uprooter/lifter system comprises three components, namely; the harvesting aid, the rear extension to the harvesting aid and the conveyor rake which are identified in **Fig. 1** as A, B and C, respectively.

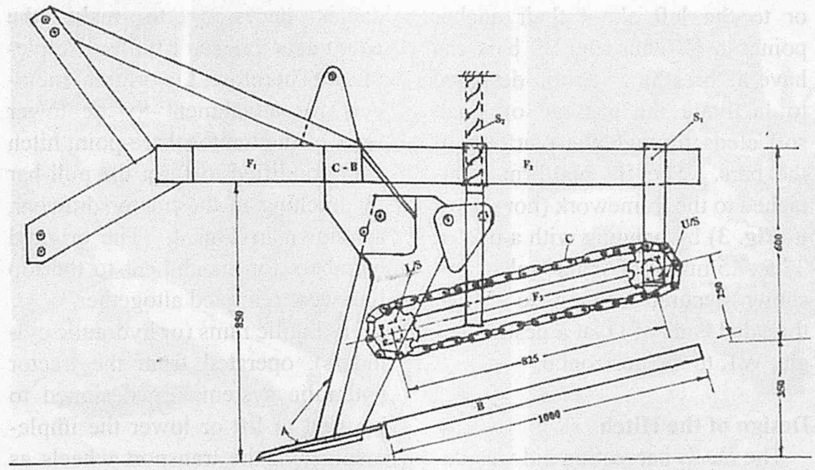
Design of the Uprooter/Lifter System

The three components A, B and C must be designed with care because, the success of this new concept of the complete cassava harvester depends on the effectiveness of the uprooter/lifter system. A sketch of the design is presented in **Fig. 2** showing the *Ikeda* harvesting aid, A, as mounted on its original frame, F_1, the extensions to the blades of A denoted as B, and then



A – harvesting aid; B – extensions to the blades of A; C – conveyor rake system; D – channeling chute; E – trough-type elevator; F – loading chute; F-F – direction of forward travel; G – soil surface; H – max. depth of blades A; J– outline of tips of elevator troughs; K – troughs; L – outline of raking tines; T - trailer.

Fig. 1 A sketch illustrating the modified concept of the complete cassava harvester.



A – Ikeda harvesting aid; B – extensions to blades of A; C – base chain of conveyor; F_1 – frame of A: F_2 – frame of B&C; F_3 – frame- work for C; L/S – lower sprockets; U/S – upper sprockets; S_1 – rigid attachment of C to F_2; S_2 – spring attachment of C to F_2; C-B – cross beam of F_1 carrying F_2.

Fig. 2 A sketch showing major components and their relative positions in the conveyor rake system.

the conveyor rake, C which is mounted on a frame of its own, F_2, and attached to F_1.

The Conveyor Rake

Based on the experience gained in testing the root lifter/elevator described earlier in Part I of this report, it was decided that the conveyor rake should rotate counter clockwise to make the raking tines move in the opposite direction to the forward travel, with a linear speed which is about 20% higher than the harvesting speed. Accordingly, the driving sprockets, with a pitch diameter of 165.91 mm, are driven from the tractor pto at a speed of 159 rpm at a harvesting speed of 4 km/h; the pto rpm of 540 is reduced to 159 rpm through a 2:1 speed reducer gear box and an appropriate chain-and-sprocket final drive.

The conveyor rake is 550 mm wide and consists of a pair of 63.3 mm (2.5 in.) double pitch base chain drives, using 165.91 mm pitch diameter pair of sprockets at 825 mm centre-to-centre distance. Mild steel plates, 5mm thick and measuring 50x50 mm, are welded to every fifth link of the chains to form flanges which are thus spaced 260 mm apart. Slats made of 50.8mm angle-iron bars are bolted to the flanges to form the base of the conveyor rake. The tines of the conveyor rake, consisting of 250mm long mild steel rods of 12.5mm diameter, are welded to the angle-iron slats and spaced about 150 mm apart. The locations of the tines on the slats are staggered from one slat to the next so that the tines in two adjacent slats taken together are spaced about 90 mm apart.

In the sketch of **Fig. 2**, the base of the conveyor rake, C, is shown mounted about 175 mm above and parallel to B which is the platform formed by the extensions to the blades of the harvesting aid, A. But, the design has provisions for varying both the slope and distance of C above B. Although both the lower and upper sprockets, denoted as L/S and U/S respectively in **Fig. 2**, are shown as toothed, only the upper ones which are the driving sprockets have teeth, while the lower driven sprockets are smooth; this is intended to reduce or eliminate the problem of soil clogging of the lower sprockets, as discussed in Part I.

As shown in **Fig. 2**, the conveyor rake is rigidly mounted to the frame, F_2, only at one pair of points, i.e., through the shaft of the driving sprockets, U/S, using a pair of flat bar attachments, S_1. The other points of attachment of the conveyor to F_2 are through a pair of compression springs, S_2, attached to a crossbar in the framework of the conveyor, F_1, at points located 600 mm from the shaft of the driving sprockets. Thus, the conveyor rake can move up and down, or passively vibrate about the shaft of the driving sprockets. These up-and-down motions of the conveyor rake are intended to accommodate large soil clods and also assist in breaking them up. The mounting of the conveyor rake is designed with provisions for moving it along the frame, F_2, so as to determine its optimum position relative to the blades of A, for the most effective raking/conveying functions.

Extensions to Blades of Harvesting Aid

A sketch giving some details of the extensions to the blades of the harvesting aid is presented in **Fig. 3** for the left-hand-side blade denoted as A. The extensions are in two parts. The first part is an extension plate, B_1, which is welded to A to give the approximate parallelogram shape denoted as a-f-e-c-d-a. The dotted line denoted as f - g will be explained later. The plate, B_1, is welded to A along the line b - c. The second part of the extension, denoted as B_2, consists of 50x12.5mm flat bars spaced 50 mm apart to cover the 550mm width of B1. Along the bottom edge of B1, and 15 mm below it, a 50x 12.5mm flat bar, denoted as C in **Fig. 3**, is bolted. On C, 19.5mm diameter holes are drilled at 50mm centres and used to anchor the bars of B2 which are provided with prongs at one end for that purpose. The anchoring is such that the angle of B2 to the horizontal, W1, can be made different or steeper than W2 which is the angle of A with the horizontal. The B2 bars are of different lengths depending on their position on B1, as shown in **Fig. 3**. The other ends of the bars have 21 mm diameter holes through which a 19.5 mm diameter shaft, D, is passed, with sleeves denoted as E placed between the bars to serve as spacers. In this way, the B2 bars form a platform on which soil and cassava roots from A are to be constrained to move. But the spacers are made slightly less than the spaces between the bars. Since the holes in the bars are also larger than the diameter of the shaft, the bars are free to rock a bit. That means that they are able to move slightly to the right or to the left about their anchor points in C. Thus, the B2 bars can have a "breathing" action designed to facilitate the passage of small soil clods through the platform of the bars. The B2 platform is attached to the framework (not shown in **Fig. 3**) by hanging with a pair of 37.5x7.5mm flat bars (also not shown) secured with nuts to the two threaded ends of D, at a desired angle, W1, to the horizontal.

Design of the Hitch

The *Ikeda* harvesting aid was designed as an integrally mounted implement, as sketched in **Fig. 2**. But with the proposed addition of the extensions, the conveyor rake system and the elevator system, it becomes necessary to make the equipment a semi-trailed implement. Therefore, the original members for attachment to the lower links of the tractor three-point hitch were modified to form the pull-bar for hitching to the tractor drawbar, as shown in **Fig. 4**. The original members for attachment to the top link were removed altogether.

Hydraulic rams (or hydraulic cylinders), operated from the tractor hydraulic system, are designed to be used to lift or lower the implement, with the transport wheels as pivots. From the experience gained in testing the cassava root lifter/elevator described in Part I, it was found necessary to increase the size, and thereby the strength, of the supports of the transport/elevating wheels.

Evaluation of the Prototype Uprooter/Lifter System

On completion of the initial phase of the construction work on the uprooter/lifter system for the left-hand-side row, it was decided to first take the equipment to the field for evaluation, before any further work.

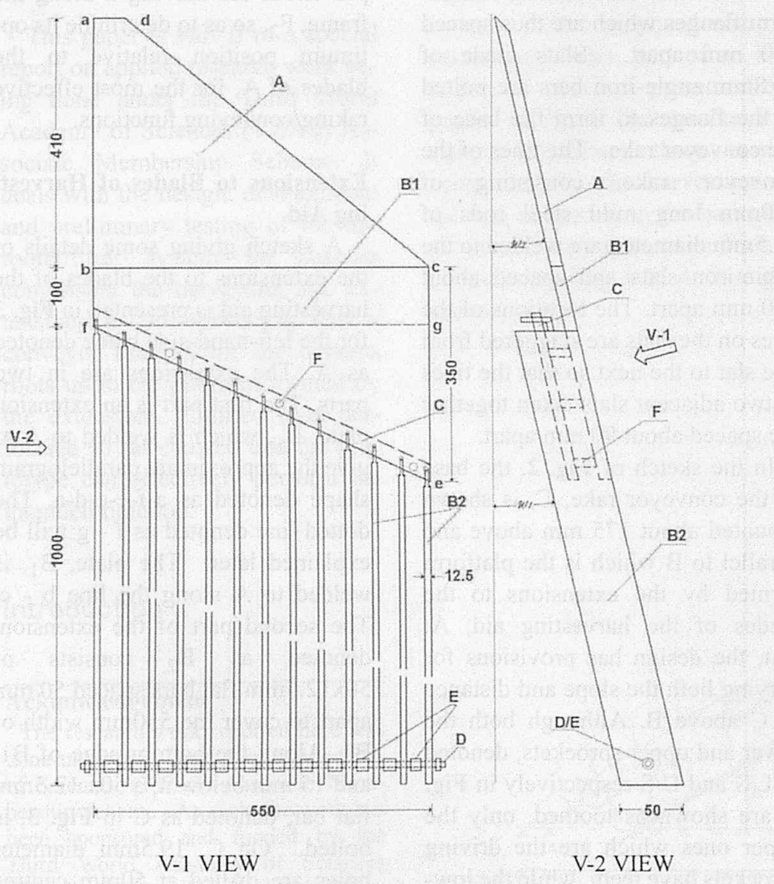
A description of the uprooter/lifter system as built, illustrating its performance in the preliminary tests is given pictorially in **Figs. 5 - 10.**

Preliminary Testing

The preliminary testing of the prototype cassava uprooter/lifter system was started on 1st June 2000. The conditions and details of the tests and the major observations are discussed in the following sections.

Lifting/Lowering of the Implement

When the implement was lifted into the transport position, the tips of the blades of the harvesting aid were only about 75 mm above the



V-1 – front view in the direction of the arrow;
V-2 side view in the direction of the arrow; A – left-hand-side blade;
B_1 – extension plate; B_2 – extension bars; C – bar bolted to B_1 to hold B_2;
D – shaft thro' B_2; E – spacers between B_2; F – spacers between B_1 and C.

Fig.3 A sketch showing some details of the extensions to the blades of *Ikeda* harvesting aid.

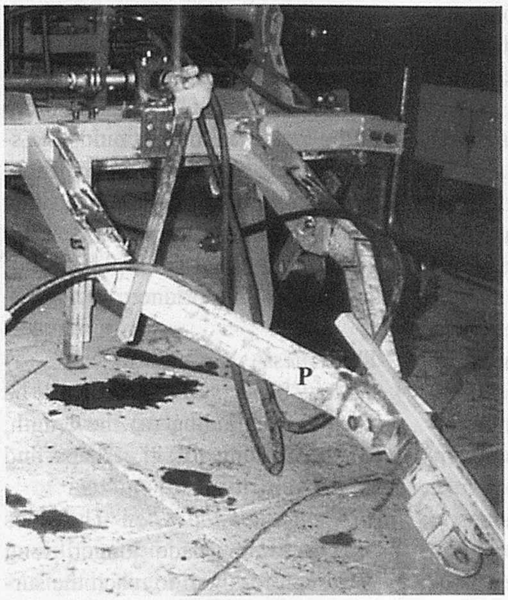


Fig. 4 Photograph showing the constructed pull-bar, P, welded to the original lower-link hitching members of the *Ikeda* harvesting aid.

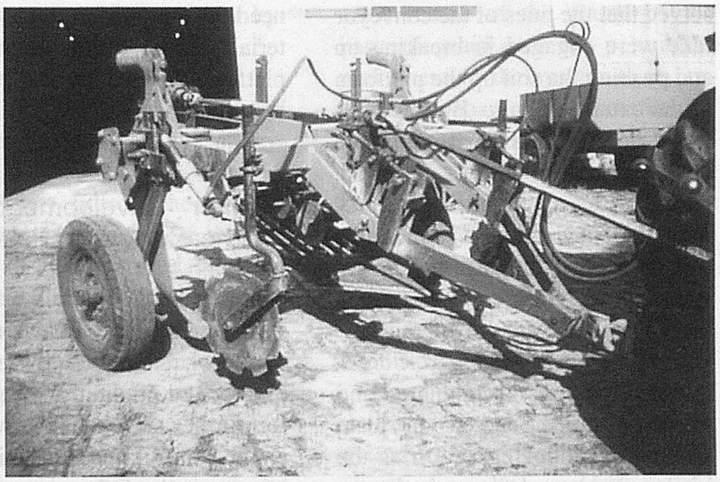


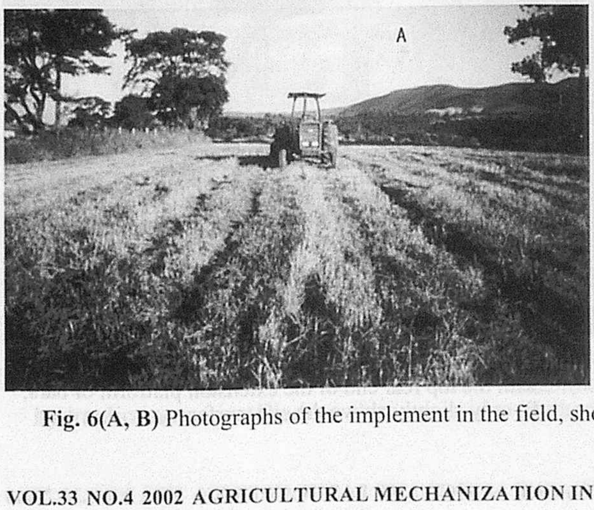
Fig. 5 Photograph of implement raised into transport position.

ground surface. That height of elevation is not sufficient for unimpeded transportation on farm roads, to and from the farms or in turning at headlands in the field. However, it was observed that the hydraulic cylinders were able to raise the transport/elevating wheels sufficiently to lower the blades of the harvesting aids to the design depths of between 250 and 350 mm below the soil surface.

Work Performance of the Implement

There was no cassava plot available in CMAA or nearby farmlands to test the work performance of the implement in a proper cassava harvesting operation. Therefore, the implement was tested in a field adjudged to have the usual characteristics of a cassava plantation ready for harvesting, with respect to soil type, grass or vegetation cover and period of fallow. The field chosen was left fallow for over nine months and may be rated as medium trashy. Since it was the dry (winter) season in Sao Paulo, Brazil, there had been no rain for about two and half months (i.e., since the middle of March); the performance tests were started in the first week of June, 2000.

Although only the constructed left-hand-side uprooter/lifter system was actually being tested, the original right-hand-side part of the harvesting aid was still in place and so facilitated a comparative evaluation of the uprooter/lifter system performance. The tests were performed using a MF 290 tractor at forward speeds between 3.5 and 5 km/h (2nd gear low to 3rd gear low). At all speeds the depth of penetration of blades of the harvesting aid was maintained at about 300 mm below the soil surface. As the implement made a pass, the right-hand-side harvesting aid left the field as though virtually undisturbed as described in Part I. But in the left row, as a result of the actions of the conveyor rake system, the soil was observed to move from the harvesting blade up the extension plate and thence on to the platform formed by the extension bars (refer to **Figs. 1** and **2**). It was ob-



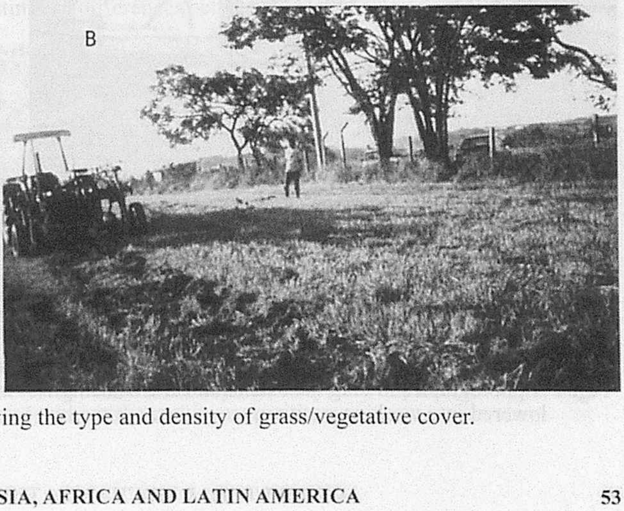


Fig. 6(A, B) Photographs of the implement in the field, showing the type and density of grass/vegetative cover.

served that the tines of the conveyor rake were engaged in breaking up and pushing the soil up the platform of the extension bars. But the tines were spaced too far apart and were not long enough to do a good job. Also, it was easy to see that the prototype conveyor rake was mounted too far behind the harvesting aid such that the tines could not reach the soils as the blades of the harvesting aid pushed them up. Consequently, the soils accumulated and piled up on the extension plate causing a bulldozing action as the implement moved forward. It was observed that the soil on the platform of the extension bars did not readily fall through the bars as intended, even when the clod sizes were small enough. This indicated that the spacing of the extension bars was not large enough. It is intended that soil clods would be broken up into small pieces which would fall through while large particles comprising (hopefully) of mainly cassava tubers and cassava root bunches would be moved up to the platform of the extension bars, to be discharged at the end of the platform, into the collection trough located there, according to the concept sketched in **Fig. 1**. In contrast, the big soil clods fell off the sides of the platform, making ridges on both sides of the row and leaving the centre of the row as a ditch or wide furrow. This indicated the need for a provision to prevent materials falling off the sides of the platform formed by the extension bars.

Further Development Work on the Conveyor Rake System

The preliminary field tests of the conveyor rake system revealed explicitly and implicitly, several areas for further development work, including the lifting mechanism, certain aspects of the conveyor rake specifications and the extensions to the blades of the harvesting aid. The recommended or planned modifications in those areas are presented in this section.

Modification of the Lifting Mechanism

To increase the height of lift of the implement, the tyres of the transport/elevating wheels were changed to larger ones, from 5.50 - 16 to 7.00 - 16. This improved the height of lift from about 75 mm to about 115 mm. But, it is still considered necessary to increase the height of lift further and so, the stroke of the hydraulic ram will be increased slightly.

Modifications in the Conveyor Rake Specifications

Certain modifications of the conveyor rake specifications were indicated by the preliminary field tests as necessary to improve its performance. No particular ranking order of the factors involved could be discerned since their effects appeared to be combined. Therefore, they are discussed hereunder, one after the other, without an implication of any order of importance.

The Tines

Many aspects of the tines will be modified, including (a) the length, (b) the spacing, (c) the shape and (d) the velocity.

(a) Length of the tines. The tines have to be made longer, long enough for them to reach the surface of the platform formed by the extension bars. It may, in fact, be desirable to make some of the tines go in between the bars below the surface of the platform. This will facilitate sifting or passage of the pulverised soil through the platform of the extension bars, as intended.

(b) Spacing of the tines. As now built, the conveyor rake has rows of tines which are spaced 250 mm apart along the length (of the conveyor). The locations of the tines in the rows are staggered in such a way that, for two adjacent rows taken together, the spacing between two tines is 90 mm. This spacing has been found to be too large to ensure adequate

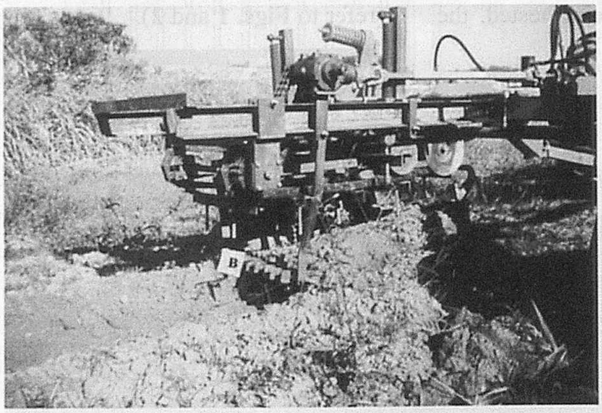


Fig. 7 A photograph showing the extension bars, B, being lowered into working position.

Fig. 8 A photograph showing a side view of the implement, with the top rear end of the extension platform of bars, B, only slightly above the soil surface.

pulverisation of soil clods into particle sizes which are small enough for their easy passage through the platform of the extension bars. Therefore, while maintaining the staggering arrangement, the spacing between two tines in adjacent rows will be reduced to 45 mm, by increasing the number of tines per row appropriately.

(c) *Shape of the tines.* As built, the tines now consist of 12.5mm diameter knurled mild steel rods. There is no apparent advantage of making the tines of knurled rods. Therefore, smooth rods will be used in the place of those already there, but the new tines will be elongated as specified in (a) above. The tines to be used to reduce the spacing between tines discussed in (b) above are to be made of 25mm angle-iron bars.

(d) *Velocity of the tines.* As earlier described, the conveyor rake is driven from the tractor pto which is constant at 540 rpm at full load. Through a series of speed reduction drives, the linear speed of the tines was designed to be only about 20% higher than the harvesting speed (as earlier explained. Although it was not easy to determine the contribution of the factor of speed of the tines to the less than satisfactory quality of raking achieved during the preliminary tests, there was some evidence that soil pulverisation was more at the lower harvesting speeds. It was also observed that at the current rpm of the driving sprockets, impacts that were apparently too high were imparted to the materials as the tines accelerated around the driven and driving sprockets. For these and other reasons, it is desirable to be able to vary or otherwise control the speed of the tines. To achieve this control, it has been planned to use a hydraulic motor installed on the tractor, with an independent hydraulic oil tank.

Optimum Location of the Conveyor Rake

From the results of the preliminary tests, it became clear that the location of the conveyor rake relative to the blades of the harvesting aid has a crucial effect on the effectiveness of the raking performance of the system. It was determined that the system must be moved forward to a point that makes it possible for the raking tines to reach and immediately engage the soils (and the cassava roots) as they are lifted up and pushed unto the extension plate. As designed, there are adequate provisions for changing the position of the conveyor rake as desired. But unfortunately, one of the cross-beams of the frame of the harvesting aid does not permit the movement of the system to an appropriate position. Therefore, a major structural modification of the frame of the harvesting aid has to be undertaken, involving the removal and repositioning of the impeding cross-beam denoted as C-B in **Fig. 2**.

Modifications on the Extensions

The extensions to the blades of the harvesting aid are in two parts, as earlier described (see **Fig. 3**), namely; a plate welded to the blades and flat bars pivoted to the plate to form the extension platform. There are three main aspects of the extension to be modified as follows:

(a) The extension plate. The main function of the extension plate is

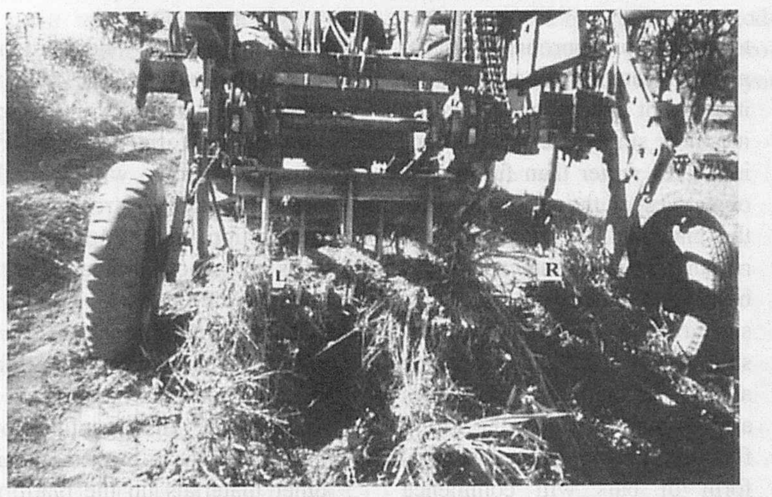


Fig. 9 A photograph showing the rear view of the implement with the harvesting aid fully in the cassava harvesting position and illustrating the differences between the left (L) and right (R) rows.

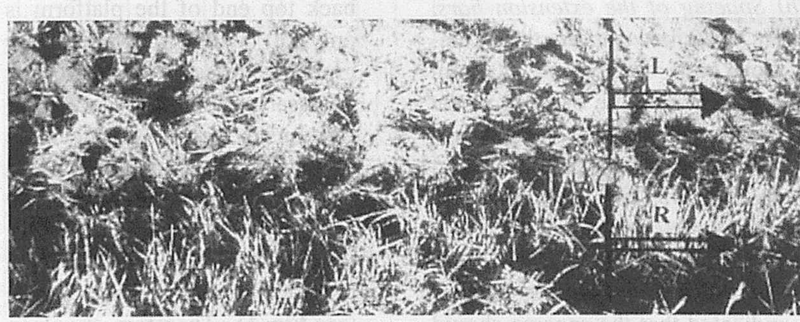
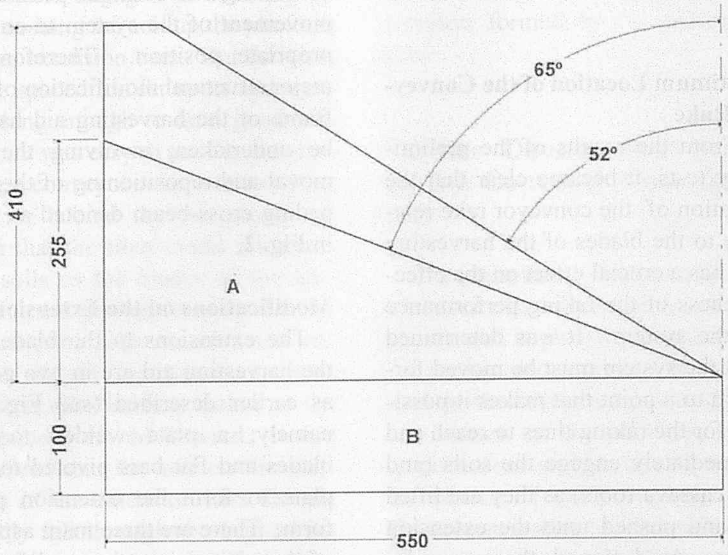


Fig. 10 A photograph showing comparative conditions of the worked rows.L – left-side row harvested with the conveyor rake system in place;R – right-side row harvested without the conveyor rake system.



A- recommended size/shape of blade; B – new size/shape of the extension plate.

Fig. 11 Sketch of recommended modifications on the blade of the *Ikeda* harvesting aid using the left-hand blade as example.

to provide an appropriate attachment for the extension bars. But it does not have to be as wide as it is now since its excess surface interferes rather than further the objectives of the extension. So the plate will be modified to a rectangular piece shown as f-g-c-b in **Fig. 3** and as B in **Fig. 11**, in such a way as to make the extension bars of equal length, starting as close to the harvesting blades as possible. That way, the sifting function of the extension platform of bars will commence sooner and more uniformly across the width of the platform.

(b) Spacing of the extension bars. As described earlier, the extension bars are spaced 50 mm apart. But on the first day of the preliminary tests, it became immediately evident that the 50mm spacing was too restricting. It was, therefore, increased to 100 mm for subsequent tests. But, the results of the subsequent tests indicated that the spacing should be increased further. So it is planned to space the flat bars 100 – 200 mm apart, and introduce 6.25mm diameter rods in between the bars at 25 mm below the surface formed by the flat bars. The rods will naturally present much less resistance or obstruction to the passage of soils and other particles than the 50mm wide flat bars.

(c) Slope of the platform of extension bars. As built, the platform of extension bars has a slope of 15o. While that gentle slope makes it easy to move soils and other materials up the platform, the maximum elevation achievable by a particle that reaches the back top end of the platform is only 50 – 75 mm above the ground surface. It is, therefore, necessary to make needed modifications to increase the elevation of materials attaining the top end of the platform to 500 mm at the least. 500mm. This is necessary to facilitate the next elevation unit operation discussed earlier (see **Fig. 1**). Therefore, the slope of the platform of extension bars will be increased to obtain the required elevation. If the necessary slope is found to be too steep, the length of the platform will be increased as necessary. The results of the preliminary tests encourages some optimism that the conveyor rake system, which includes the extensions to the blades of the harvesting aid, can be made to perform this crucial function on which the success of the new concept hinges.

(d) Side guards for the platform of extension bar. As implied in (c) above, the most crucial function of the extension bars is to facilitate the elevation of the cassava roots and root bunches to a point sufficiently high above the ground to position them for easy pick-up by the elevator/loader system. So the tendency for the materials to fall off the sides of the platform of extension bars before reaching the top end, as reported above, must be prevented. Therefore, side guards, made up of flat bars or mild steel plates, have to be provided to disallow particles as large as cassava tubers from exiting by the sides of the platform. The guards should start from the extension plate to channel all materials from the blades of the harvesting aid onto the platform of extension bars. But the design of the guards must be such as not to impede the normal functioning of the harvesting aid or in any way obstruct the flow of materials up the platform of extension bars.

Miscellaneous Considerations

There are several other aspects of the proposed complete cassava harvester that require some further development work to improve performance, including some elements of the harvesting aid and the extension platform.

(a) The angle of the blades of the harvesting aid to direction of forward travel. The blades of the harvesting aid make an angle of

about 52o to the direction of forward travel. It was observed that this angle results in a much deeper penetration of the blades at the (right and left) sides of the rows than at the centres of the rows where the cassava roots are. It is desirable to increase this angle, which is the same thing as reducing the angle made by the blades with the horizontal as shown in **Fig. 11**, in order to reduce the big difference in the depth of penetration across the rows. This will lead to a reduction in the amount of soil dug up per metre length of row and therefore the amount of soil that the conveyor rake system will be required to handle. Furthermore, as indicated in **Fig. 11**, increasing the angle to about 65o reduces the length of the blades as well as their size which, in any case, does not seem to make any discernible contribution to the digging function of the blades. In fact, the reduction in the size/area of the shares will be beneficial in bringing the blades proper closer to the conveyor rake, with the attendant improvement in the raking/conveying functions.

(b) Alternative design for the extension platform. Considering the crucial importance of the conveyor rake system to the proposed new concept for the complete cassava harvester, an alternative design for the extension platform is being contemplated. The proposed design consists of cylinders of discs on a common axial shaft. The discs of 125mm diameter are to be spaced 50 mm apart on a 25-mm diameter common axial shaft. The cylinders are mounted at 100mm centre-to-centre distance of the shafts, such that the discs of adjacent cylinders overlap to form the extension platform illustrated in the sketch of **Fig. 12**. Although not to be positively driven, the cylinders are to be mounted on special sealed bearings to make them rotate readily as the soils and cassava tubers/bunches are pushed up across them. The width and length of the platform are the same as for the platform of bars. It is expected that this alternative design will be more effective in removing or sifting soils from the dug-up cassava roots because, the platform formed by the cylinders of discs does not consist of one plane but numerous planes, in fact, with hills and valleys that can actively aid the soil sifting operation. The mounting of each cylinder (or set of cylinders) can be independent of one another to achieve a desired inclination of the platform without unduly impeding the movement of particles up the platform by the tines of the conveyor rake. One can think of several variations to enhance the sifting/conveying effectiveness, such as the use of different diameter discs or notched discs or eccentrically mounted discs, etc. But, the cost of production, in terms of expenditure of both time and materials, is likely to be much higher than for the platform of bars.

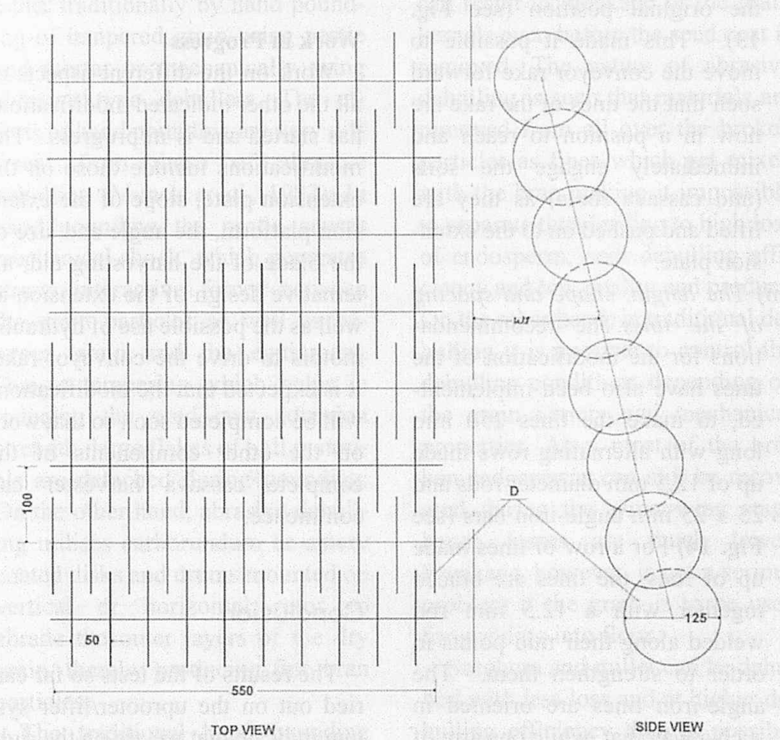


Fig. 12 Sketch of an alternative design of the extension platform, consisting of cylinders of discs, D, on a common axial shaft. D – Discs; W_l – adjustable angle of platform.

Implementation of Recommendations

Work Done So Far

Work on the implementation of the recommended modifications started soon after the preliminary tests was carried on along with further tests, and is still going on. The modifications already made or in the process of being made include the following:

(i) *Structural modification of the frame of the harvesting aid.* Some of the recommended modifications depend on the appropriate location of the conveyor

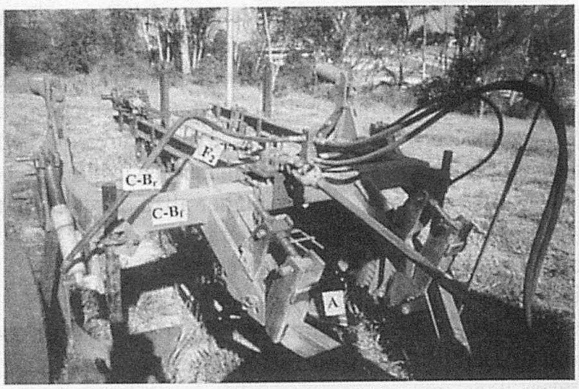


Fig. 13 A photograph of the modified frame of the *Ikeda* harvesting aid, showing the rear cross-beam, $C\text{-}B_r$, moved closer to the front cross-beam, $C\text{-}B_f$, and the frame of the conveyor. rake, F_2 moved forward closer to the blades of the harvesting aid, A.

Fig. 14 A photograph of elongated tines, showing rows of round rod tines, T_r, alternating with rows of angle-iron tines, T_a, spaced 45mm apart and reaching to 25mm above the platform formed by the extension bars, B_2, hung with a pair of bars, F_b, from the frame, F_2, of the conveyor rake.

rake relative to the blades of the harvesting aid. That in turn calls for the structural modification of the frame of the harvesting aid. Therefore, that was the first major recommended modification attended to. It involved the removal of the cross beam denoted as C-B in **Fig. 2** and repositioning it at a point 270 mm ahead of the original position (see **Fig. 13**). This made it possible to move the conveyor rake forward such that the tines of the rake are now in a position to reach and immediately engage the soils (and cassava roots) as they are lifted and pushed on to the extension plate.

(ii) *The length, shape and spacing of the tines.* The recommendations for the modification of the tines have also been implemented, to make the tines 250 mm long with alternating rows made up of 12.5 mm diameter rods and 25 x 25 mm angle-iron bars (see **Fig. 14**) For a row of tines made up of rods, the tines are braced together with a 12.5 mm rod welded along their mid points in order to strengthen them. The angle-iron tines are oriented in such a way that, while one arm of the angle is positioned as a blade to cut up the soil clods, the other arm of the angle presents a 25 mm x 250 mm surface to help rake the soils (and cassava roots) up the extension platform of bars. As recommended, the spacing between tines in adjacent rows taken together has now been made about 45 mm only. The tines reach down to about 25mm above the platform of the extension bars.

Work in Progress

Work on the different aspects of all the other indicated modifications has started and is in progress. The modifications include those on the extension plate, slope of the extension platform, the angle and size of the blade of the harvesting aid, alternative design of the extension as well as the possible use of hydraulic motors to drive the conveyor rake. It is expected that the modifications will be completed soon so that work on the other components of the complete cassava harvester can commence.

Conclusion

The results of the tests so far carried out on the uprooter/lifter system indicate that we are on the right track with regards to the proposed new concept for the development of a complete cassava harvester. But there is still a great deal of interesting work left to be undertaken to achieve the objectives. We consider the project very important for all the cassava producing countries of Asia, Africa and Latin America. Therefore, we shall continue to communicate progress made on the project through AMA. This special report has been given in some details to encourage or to elicit suggestions and critcal views on the project from AMA readers. ■■

Design and Development of a Prototype Dehuller for Tempered Sorghum and Millet

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Abstract

A prototype dehuller for dehulling tempered grain was developed incorporating a dehulling surface not affected by moisture or clogging problems associated with current mechanical dehullers. The use of short tempering duration and ensuring that all the temper moisture was absorbed into the grain before the grain was introduced into the dehuller eliminated the clogging problem. The prototype was able to achieve higher dehulling efficiency and recovery levels compared to conventional abrasive dehullers. The quality of the produced grain was also much higher as indicated by low kernel breakage and superior colour of the flour obtained from grain dehulled in this prototype compared to a conventional abrasive dehuller. This showed that it is possible to increase the yield and dehulling efficiency of sorghum and millet substantially by the use of appropriate dehulling equipment in combination with simple pre-treatment procedures.

Introduction

Sorghum and millet form an important part of the diet in many areas of the semi-arid regions of Asia and Africa. These two grains account for up to 70% of the daily dietary protein and energy intake in these areas (Hulse *et al.*, 1980). Dehulling (the removal of the seed coat from the grain kernel) represent a key step in the final processing of these grains for human consumption due to the presence of high fibre content, pigments and anti-nutritional factors on the seed coat. Efficient dehulling of these grains is a major problem hindering their wider use as human food.

The dehulling process for sorghum and millet is accomplished either traditionally by hand pounding of tempered grain using pestle and mortar or mechanically using abrasive type dehullers. The effects of hand pounding are very different from those of abrasive dehulling (Munck *et al.*, 1982). In hand pounding the pestle causes mechanical shock, which generates strong interactive forces between the grain particles as well as between grain and the equipment. Due to tempering which helps in reducing the seed coat adhesion strength, large flakes of hull materials are detached during pounding. On the other hand, abrasive dehulling utilises carborundum or emery coated disks and drums mounted on vertical or horizontal rotor to abrade the outer layers of the dry grain, thereby producing fine bran particles.

The traditional hand pounding method is a slow and laborious process hence the urgent need to develop mechanical processing methods that could reduce the hardship and drudgery involved in this process. Abrasive dehulling is much faster and less tedious, but it causes excessive losses of endosperm in the bran fraction through kernel breakage. This is especially serious in the case of soft grain varieties mainly due to the fact that for sorghum and millet, the seed coat is tightly attached to the endosperm and to remove it by abrasion a large compressive force is required. This can result in breakage of the grain kernels even before the seed coat is removed. The nature of abrasive dehulling is such that materials are removed from all over the broken particles as fines which get mixed with the bran making it impossible to separate thus leading to high loss of endosperm, poor dehulling efficiency and low quality end product. On the other hand, in traditional dehulling it is possible to control the dehulling conditions depending on the grain variety and mechanical properties. Also, most of the broken endosperms can still be recovered during the winnowing stage hence losses are much lower. Breakage, however, is not a serious problem if the grain is to be used for grinding into flour.

Sorghum and millet can be dehulled with less loss and at higher dehulling efficiency than is possible with current mechanical dehullers if proper pre-treatment procedures and dehulling equipment could be developed. Simple pre-treatments such as tempering have been used for centuries and with great success in the traditional dehulling system to facilitate the removal of the seed coat from the endosperm. Incorporation of some of pre-treatments commonly used in traditional dehulling system in mechanical dehulling system could, therefore, make it possible to use only a fraction of the force required to remove the seed coat from the dry untreated grain. This could lead to less breakage of grain during the dehulling process and hence lower losses; also faster and complete seed coat removal from the endosperm could be achieved leading to improved dehulling efficiency and saving on the energy cost.

So far, however, it has not been possible to successfully incorporate these simple pre-treatment principles in mechanical dehulling systems mainly due to the following reasons:

(1) Combination of moisture and fine bran produced during the abrasive dehulling process tends to clog or block the sieve systems commonly used in these dehullers, depressing both capacity and efficiency.

(2) The abrasive effect of the dehulling disks or stones used in these machines diminishes with addition of water. Deposition of a layer of fine wet bran on the surface of the disks as dehulling progresses also lead to low dehulling capacity and efficiency.

(3) Many of the grinding stones and disks used in these dehullers are made by pressing stone materials together using adhesive materials which are dissolved by water, therefore presence of moisture damages the disks.

Attempts have been made to develop dehullers for tempered sorghum grain but with little success so far. Weineckle *et al.* (1965) developed an experimental unit for peeling and degerming tempered sorghum grain. Their dehuller consisted of a 6-in diameter stainless steel compact wire brush rotating within a 7-inch diameter perforated cylinder. The grain was introduced into the cylinder and remained there until it was small enough to pass through the perforations on the cylinder wall together with the hull and the germ. Dehulling was accomplished by the brushing action on the grain, which took place between the brush and the screen. The hull and the germ were later separated from the dehulled grain by aspiration and floatation in a sodium nitrate solution, respectively. The grain was tempered to moisture content of 18-19% prior to dehulling. The problem with such a dehuller design was that the fine moist bran produced during the dehulling process, could accumulate within the compact wire brush causing clogging. Also with time, the wet bran can lead to blockage of the perforations on the cylinder screen reducing both throughput and dehulling efficiency. Freeman *et al.* (1969) described a method for peeling sorghum grain for starch manufacture by wet milling techniques. However, the reduction in starch yield associated with their method prevented the acceptance of the process on a commercial basis (Shoup *et al.*, 1970).

The objective of this paper was to design and build a prototype dehuller for dehulling of tempered grain, which could overcome the problems encountered by the previous designs, or current mechanical dehullers. Successful development of an efficient small-scale dehuller for tempered grain will eliminate much of the daily drudgery that is currently associated with traditional processing of sorghum and millet and also will increase the use and acceptability of sorghum and millet products. Tempering technology is well established throughout the sorghum and millet producing areas, therefore, the introduction of such dehullers will be complimenting the indigenous technology and hence will have a higher chance of being adopted compared to other types of dehullers so far introduced in these areas.

Design Considerations

Apart from low dehulling efficiency and yield, other problems facing the introduction of mechanical dehullers in the rural areas include: the high cost of the dehullers, lack of locally available spare parts and the requirement of trained technicians for servicing these dehullers. In order to develop a sustainable and efficient dehuller suitable for both rural and urban areas in the developing countries, these problems must also be considered. Therefore, the following design considerations were taken into account during the design stage of the prototype dehuller.

The dehuller should be able to dehull tempered grain effectively without the clogging problems experienced by current mechanical dehullers or previous designs. To achieve this requirement a dehuller with a different kind of dehulling surface, which is not affected by water or moist grain was required.

The dehuller should be simple in design and construction, easy to operate and maintain without necessarily requiring highly trained personnel. It should also be reasonably cheap but durable and spare parts should be locally available and at affordable price.

It should be possible to modify the dehuller in the future such that it can be manually operated by hand cranking or foot pedal using cheap locally available materials and parts

Construction of the Prototype Dehuller

The constructional drawings of

the dehuller are shown in **Figs. 1** to **4**. The main part of the dehuller consists of the dehuller drum, which is made from a 5-mm thick, 200 mm long and 100 mm inside diameter mild steel cylinder. Fixed to the inner surface of the drum is a new type of a dehulling surface, which is made from a 3 mm thick stainless steel sheet rolled into a cylinder and has 1.5 - 2.0 mm protrusions on its inner surface. These protrusions act as a rough abrasive surface to the grain kernels in contact with the drum surface when the dehuller is in operation, they also help to increase the inter-locking within the grain mass for the grain layers near the drum surface, thus increasing the dehulling efficiency. To develop these protrusions a round wooden block was fitted inside the cylinder and the cylinder was punched from the outside using a punch at a regular spacing. To ensure regular spacing of the protrusions a grid paper (2.5 × 2.5 mm) was glued to the outer surface of the cylinder and the protrusion were made following the grid pattern. The centre-to-centre spacing between rows and columns of the protrusions was 2.5 mm. This dehulling surface is moisture proof, durable and is easy to remove and replace in case the protrusions are worn out.

The drum is fixed to the supporting frame and a drive shaft 20 mm in diameter ran through the axis of the drum carrying two mild steel impellers bolted on each side of the shaft (**Figs. 2** and **4**). The drive shaft is mounted on horizontal bearings and fixed to a pulley driven through a v-belt by a 0.3 kW electric motor coupled to a variable speed drive unit (**Fig. 1**). The task of the impellers is to move the grain around inside the drum thus creating the relative movement of grain against grain and against the dehuller surface, leading to grain-grain and grain-wall friction, which

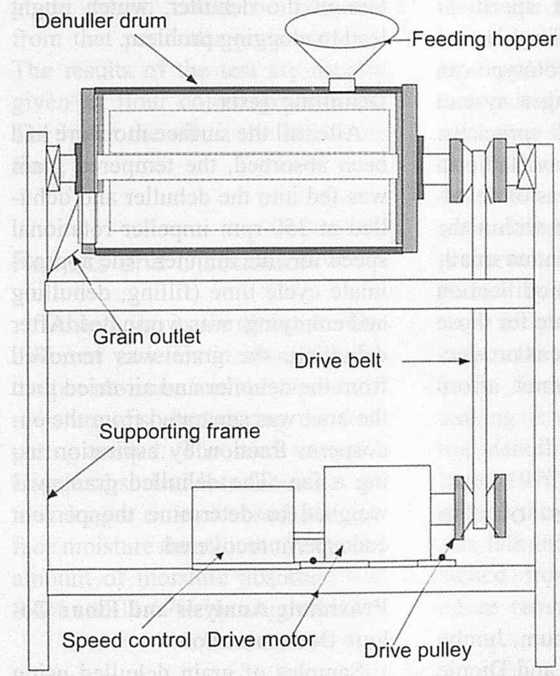

Fig. 1 Front view of the final prototype design.

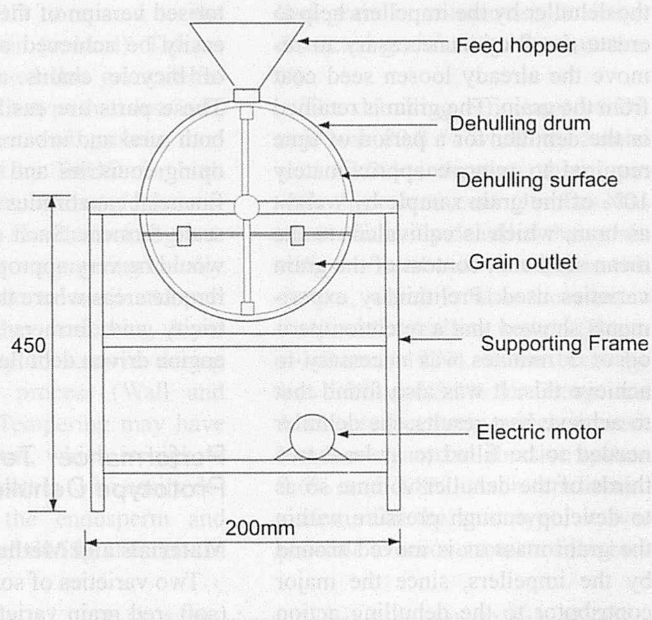

Fig. 3 Side view of the prototype dehuller.

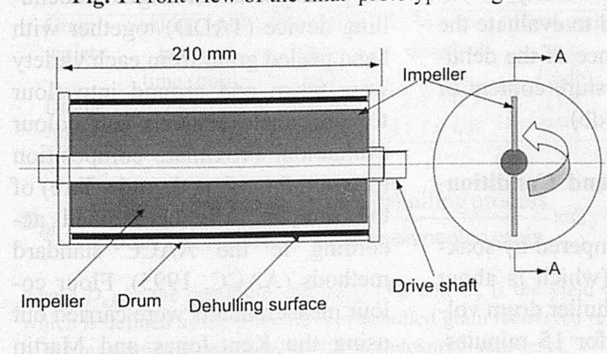

Fig. 2 Cross-section of the dehulling drum and impeller.

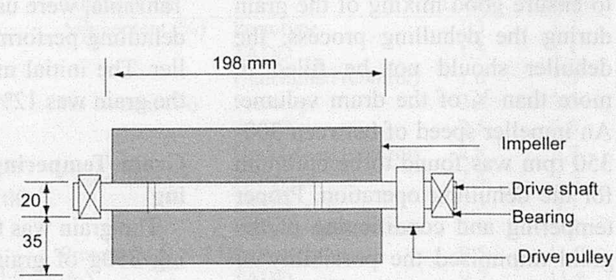

Fig. 4 The impeller assembly.

is the main dehulling force in this prototype. For loading and unloading grain in the dehuller, an inlet hopper is provided on top of the drum and an outlet at the rear end drum cover.

Dehulling Mechanism of the Prototype Dehuller

The dehulling process (i.e., the removal of the seed coat from the endosperm) is accomplished mainly through abrasion between grain and grain and between grain and the rough dehuller drum surface. The jostling and rubbing of individual grain particles against each other and against the dehuller surface as the grain is moved around inside the dehuller by the impellers help to create the friction necessary to remove the already loosen seed coat from the grain. The grain is retained in the dehuller for a period of time required to remove approximately 10% of the grain sample by weight as bran, which is equivalent to the mean seed coat content of the grain varieties used. Preliminary experiments showed that a retention period of 5 minutes was necessary to achieve this. It was also found that to achieve best results, the dehuller needed to be filled to at least two thirds of the dehuller volume so as to develop enough pressure within the grain mass as is moved around by the impellers, since the major contributor to the dehulling action is the grain to grain friction. Also, to ensure good mixing of the grain during the dehulling process, the dehuller should not be filled to more than ¾ of the drum volume. An impeller speed of between 300-350 rpm was found to be optimum for the dehulling operation. Proper tempering and conditioning of the grain minimised the possibility of material sticking to the sides of the dehuller. Also, during the dehulling process a lot of heat is produced due to friction between the grain particles and the dehuller surface, this also helps to reduce the moisture content of the grain mass and thus further reducing the chance of materials sticking to the sides of the dehuller.

Most of the parts used in the construction of the prototype are cheap and easily available in most developing countries. The construction of the prototype is also very simple and could be easily carried out even in small village workshops without necessarily requiring highly trained technicians. A secondary objective of this work was the possibility of future modification of the prototype so that it can be manually operated using either pedal power or handle cranking. A rotational speed of 300-350 rpm selected for this motorised version of the prototype can easily be achieved using a system of bicycle chains and sprockets. These parts are easily available in both rural and urban areas of developing countries and are within the financial capabilities of most small-scale farmers. Such a modification would be very appropriate for those remote areas where there is no electricity and farmers cannot afford engine driven dehullers.

Performance Tests of the Prototype Dehuller

Materials and Methods

Two varieties of sorghum, Jumbo (soft, red grain variety) and Dionje (hard, white grain variety) from Tanzania, were used to evaluate the dehulling performance of the dehuller. The initial moisture content of the grain was 12% (db).

Grain Tempering and Conditioning

The grain was tempered by soaking 350g of grain (which is about two-thirds of the dehuller drum volume) in tap water for 15 minutes. Soaking was followed by a rest period to allow the surface moisture to be absorbed into the grain, during this period the grain was kept in a closed container and mixed occasionally. No attempt was made to hold a constant time for the surface moisture absorption between the different grain varieties used, rather an effort was made to ensure that all surface moisture was absorbed before the grain was introduced into the dehuller. The surface moisture absorption was considered complete when no moisture was left on the palm when a handful of grain was lightly squeezed. It is very important to make sure that all surface moisture is absorbed before the grain is fed into the dehuller to avoid introducing too much moisture in the dehuller, which might lead to clogging problem.

Dehulling Tests

After all the surface moisture had been absorbed, the tempered grain was fed into the dehuller and dehulled at 350-rpm impeller rotational speed for five minutes. The approximate cycle time (filling, dehulling and emptying) was 6 minutes. After dehulling, the grain was removed from the dehuller and air-dried then the bran was separated from the endosperm fraction by aspiration using a fan. The dehulled grain was weighed to determine the percent endosperm recovered.

Proximate Analysis and Flour Colour Determination

Samples of grain dehulled using the prototype and a tangential dehulling device (TADD) together with hand peeled grain from each variety were taken and ground into flour for proximate analysis and colour evaluation. Proximate composition (protein, fat, ash and crude fibre) of the samples was determined according to the AACC standard methods (AACC, 1995). Flour colour measurements were carried out using the Kent-Jones and Martin colour grader. This colour grader determines the whiteness and brightness of a milled flour sample by measuring the reflectance of flour-water slurry. The flour colour depends on the inherent whiteness of the grain endosperm, and the amount of bran contamination present in the sample. The objective here was to compare the two dehulling systems (the prototype and TADD) to find which one was able to remove most of the bran and hence colour from the flour sample, especially from the coloured sorghum variety. The hand peeled sample was used as a standard for comparisons as how close the two dehullers approached an ideal dehulling system (assuming that the hand peeled sample was the best grade which could be obtained from that particular grain variety). The results of the test are usually given as flour colour grade units. The lower the value, the whiter the flour.

Results and Discussion

Table 1 shows the time taken by different varieties in absorbing the temper moisture and the amount of moisture absorbed during the tempering period. The hard variety - Dionje absorbed less moisture and took longer time to absorb the surface moisture than Jumbo. The total amount of moisture absorbed was 8.4% and 11.67% by weight for Dionje and Jumbo, respectively, (at 20℃ and 70% RH). This amount of moisture raised the moisture content of the grain from 12% (db) to 21.4 and 25.1% (db) for Dionje and Jumbo, respectively.

The yield of dehulled grain after 5 minutes retention in the dehuller was 92% and 91.2% for Dionje and Jumbo, respectively. **Table 2** shows the proximate composition of milled fractions of grain dehulled using the prototype together with grain dehulled using the conventional abrasive dehulling method (TADD) and undehulled grain which in this case acted as a control.

There was a reduction in ash, fat and crude fibre content for the dehulled grain from both the prototype and TADD compared to the undehulled grain (control). The results also showed that grain dehulled by the prototype had less ash, fat, crude fibre and protein than grain dehulled by TADD for both grain varieties. This could be explained by the fact that adding water to the grain or tempering usually causes the germ to swell and pull away from the cementing layer making it easy to remove during the dehulling process (Wall and Ross, 1970). Tempering may have caused the germ, which is high in ash, fats and protein to be easily detached from the endosperm and hence removed during the dehulling process in the prototype whereas in dry dehulling process in the TADD the germ was retained on the endosperm. The lower fat content, however, is an advantage because it ensures longer shelf life and stability for the dehulled products. The lower crude fibre content of the dehulled grain from the prototype (2.4 % compared to 3.3% for Dionje and 3.5% compared to 4.1% for Jumbo) indicated that the prototype was more efficient than the TADD in removing the seed coat (which is high in fibre) from the grain kernel during the dehulling process.

The dehulling efficiency of the prototype for the two varieties of sorghum was determined from the crude fibre reduction in the dehulled grain in comparison to hand-dissected grain using the **equation** (1).

The dehulling efficiency of Dionje was 89.8 % while for Jumbo was 93.2% indicating that grain with thick seed coat (Jumbo) was more efficiently dehulled than grain with thin seed coat (Dionje) in this system, which is also the case in traditional dehulling system (Kapasi-kakama, 1977). Grain breakage was 1.2% and 2.3% for Dionje and Jumbo, respectively, which is much lower compared to abrasive system 2.6% and 3.8%. As in traditional system, for the prototype, it was possible to recover most of the bro-

Table 1. Relationship between Grain Hardness and Absorbed Moisture

Grain variety	Soaking/tempering time (min)	Absorption time (min)	% Moisture absorbed (w/w)	Final grain m.c (%db)
Dionje	15	45	8.4 ± 0.7	21.4
Jumbo	15	30	11.7 ± 0.8	25.1

$$D_{eff} = \frac{\text{crude fibre reduction by the dehulling process}}{\text{crude fibre reduction in the hand peeled grain}} \times C_y \times 100$$

where D_{eff} is the dehulling efficiency (%) and C_y is the yield factor which is defined as the proportion of dehulled grain recovered relative to the maximum expected yield (100% endosperm recovery).

Equation (1)

Table 2. Proximate Composition of the Dehulled Grain

Proximate Composition	Dehulling method	Grain variety	
		Dionje	Jumbo
Ash content (%)	Prototype	1.3	1.2
	TADD	1.5	1.5
	Undehulled (control)	1.6	1.5
Fat content (%)	Prototype	2.3	3.3
	TADD	2.5	3.5
	Undehulled (control)	2.8	3.7
Crude fibre (%)	Prototype	2.4	3.5
	TADD	3.3	4.1
	Undehulled (control)	3.9	5.8
Protein (N 6 × 25)(%)	Prototype	9.5	11.7
	TADD	9.7	11.8
	Undehulled (control)	9.1	11.6
Colour Grade	Prototype	11.6	13.4
	TADD	11.7	16.6
	Hand peeled	6.7	12.5

ken particles during the aspiration stage and hence leading to reduced actual loss of endosperm.

Comparison of the results obtain with the prototype dehuller with results from untreated grain dehulled in TADD showed that, the prototype was able to achieve an improvement in dehulling efficiency of approximately 36.9% for Dionje and 30.3% for Jumbo. This indicated that there was a substantial improvement of the dehulling efficiency by dehulling tempered grain using the prototype compared to dehulling untreated grain in conventional tangential abrasive dehullers such as TADD. The recovery levels from the prototype dehuller were also substantially higher compared to conventional abrasive dehuller. This was mainly due to the fact that, less fines were produced during the dehulling process in the prototype than in TADD hence there was less loss of endosperm in the bran fraction. Lower breakage indicated that higher quality dehulled grain could be obtained using this system.

Flour colour grades were used to quantitatively compare the efficiency of the two systems in reducing colour in the dehulled grain. Colour reduction is an important factor in consumer acceptability of products produced from sorghum, especially from coloured sorghum varieties. The results indicated that the prototype was more efficient in terms of colour reduction compared to TADD for both varieties. This was especially evident for Jumbo; the coloured sorghum variety in which the colour grade of the flour from grain dehulled in the prototype was 13.4 compared to the colour grade of 16.6 for grain dehulled in TADD. The hand peeled grain flour grade was 12.5, which, therefore, indicated that the prototype was very efficient in colour removal from the dehulled grain. For Dionje there was only a slight improvement in flour colour from the prototype (11.6) compared to (11.7) from TADD.

Summary and Conclusions

A prototype dehuller for pre-treated sorghum and millet combining basic principles from both traditional and mechanical dehulling systems was developed. A dehulling surface resistance to moisture damage was incorporated into the dehuller making possible the dehulling of moist grain without the clogging problem or damage usually associated with moist grain in conventional abrasive dehullers. The performance of the prototype was evaluated using two varieties of sorghum. The results indicated that it was possible to obtain high recovery levels and higher dehulling efficiency using this prototype dehuller than conventional abrasive dehullers. A yield of 92% for Dionje and 91.2% for Jumbo was obtained at a dehulling efficiency of 89.8 and 93.2% for Dionje and Jumbo, respectively.

Comparison of the results obtained from this prototype with results obtained from untreated grain dehulled in conventional abrasive dehuller (TADD), indicated that an average of 36.9% and 30.3% improvement in dehulling efficiency was achieved for Dionje and Jumbo, respectively. Therefore, on the basis of relative efficiencies in terms of colour removal, crude fibre reduction, kernel breakage and recovery levels achieved, the prototype was more efficient than conventional abrasive dehulling systems. Other considerations such as maintenance requirement and simplicity also favour the prototype over the present abrasive systems for village scale dehuller. This shows that substantial improvement in dehulling efficieny and quality of dehulled grain can be achieved by incorporating simple and cheap traditional pre-treatments in the mechanical dehulling system. This calls for the need to develop mechanical dehullers capable of processing pre-treated grain and the need to include more of pre-treatments used in traditional dehulling system in the mechanical dehulling system.

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Design and Development of a Universal Dryer

by

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Abstract

A passive universal dryer was designed and tested in Port Harcourt, Nigeria with the aim of providing an acceptable low to intermediate drying technology for the humid region. This paper presents the design considerations, equipment components and test results for the dryer. The equipment performed satisfactorily with the various fuels used and the variety of products tested. The dryer reduced the moisture content of fresh maize to the safe storage level of 12% (wb) within 12 hours resulting in 98% viability of dried maize. Yam chips required the same time to loose 29.62% of moisture, bringing it to the safe storage moisture level of 14.21%. Cassava chips required 20 hours of drying to attain the safe moisture level while sliced ginger required 18 hours. A 98% viability was recorded in maize dried with the universal dryer. The sensory evaluation of dried product shows a more acceptable, neat and spore less food materials when compared with the sun-dried ones. By controlling the temperature and environmental air condition of the drying chamber, it was possible to retain a good proportion of the natural taste, odor, flavor and color of the dried product. It was also demonstrated that the dryer could use four different sources of energy: kerosene stove, wood, solar energy and electrical heater, to operate economically and efficiently.

Introduction

The reduction or elimination of post-harvest losses by drying farm products/food materials has always been an important consideration of the food equation in Nigeria and perhaps elsewhere. Sun drying of food material to storage moisture level is a predominant practice in Nigeria, especially in the northern parts of the country where the mean insolation is high and relative humidity low. In the humid south, sun drying of food materials is complementary to wood fuel drying because of high humidity, frequent rains (especially between May and October) and low level of solar radiation. But these traditional methods of drying food materials have no temperature controls; they expose the foodstuff to dust, infestation by insects, mold spores and bacteria.

A number of locally developed dryers exist; but almost all of them, like the traditional methods, do not have temperature control, and thus are prone to local scorching resulting in poor (or uneven) heat distribution in the drying chamber. Even the few local dryers which have some measure of temperature control and thus are relatively efficient, were developed for specific food materials such as maize, rice, fish and meat and are not available in the market. In some cases, no deliberate effort was made from the outset to involve users and agents (Birewar, 1996). And still, most of the imported dryers in the market are more expensive than Nigerian farmers can afford with relatively high cost-benefit ratio.

However, a general problem with all the dryers mentioned above is that they are fuel specific. They were either designed to use kerosene, gas, wood, diesel or petrol, but not any combination of these fuels implying that when the fuel of a particular dryer is out of stock or becomes very expensive, the dryer is abandoned even by organizations. Consequently, the post-harvest loss of food materials is on the increase the more the effort to increase production becomes more successful. It was reported that about 75% of all grains produced in the Rivers State of Nigeria alone in 1985 were to spoiled because of total dependence on sun drying in a humid State with the highest amount of rainfall in the country (S-T-L Report, 1996).

Thus the idea of a dryer that can be adapted to use all of the fuel sources mentioned with ease and which can be used to dry various farm products was conceived in 1994 at the Department of Agricultural Engineering, Rivers State University of Science and Technology, Port Harcourt, Nigeria. The universal dryer, which resulted from this idea with its inherent flexibility in fuel use and product type, presents a comparative advantage over other dryers because flexibility in the use of equipment enhances the sustainability of use. Besides, the universal dryer lends itself to all levels of technology (i.e., low to high) making it possible to adapt the level of technology (costs and simplicity) to any target group of users. Therefore, the objectives of this work were to design a simple but cost-effective dryer which is easily adaptable to different fuel and product types, and to construct and test the dryer with the participation of farmers, extension personnel and agencies with a view to enhancing the diffusion of the technology to users.

Materials and Method

The universal dryer under consideration was constructed with locally available materials, based on the desired engineering qualities and cost. Materials used in the fabrication process are given in **Table 1.**

Equipment Description

The principal parts of the dryer are the rectangular combustion chamber base with chimney (for flue exhaust) and the aeration pipes, mild steel heat exchanger with air pots and connecting pipes, solar collector and the drying chamber (**Fig. 1**, **2** and **3**). The combustion chamber is walled and floored with burnt bricks cemented together and through which three 100-mm diameter flue exhaust pipes protrude upwards each of the two end walls. Six, 50-mm diameter short galvanized pipes made through the lower wall of the combustion chamber, connect the chamber to the environment for the aeration of the combustion process. A door is provided for fuel (kerosene stoves, wood or electric heating system) loading and unloading. Separating the drying chamber from the combustion chamber is the mild steel plate heat exchanger equipped with mild steel air pot from where 4, 100 mm pipes radiate, opening out to the environment at the upper walls of the combustion chamber. The walls of the drying chamber are lagged with wood shavings covered in the inside with corrugated iron sheet and on the outside with plywood. The dryer top cover is the same as well as the wall cover except that 21.25-mm diameter pipe holes are made through it to vent the high humidity air from the dryer by natural convection.

The solar collector is made up of a single 1m^2 glass cover, an absorber plate of corrugated iron sheet laid with lamp black and an air heating chamber opens out from the atmosphere beneath the absorber into the drying chamber but lagged with wood shavings.

Design Theory and Considerations

The dryer chamber, heat sources and connecting ducts were designed based on standard heat transfer and thermodynamic principles. The thickness of lagging for the drying chamber and the solar collector were estimated using the equation 1:

$$Q = UA\,\Delta T \quad \ldots\ldots\ldots\ldots (1)$$

where

U = Overall heat transfer coefficient

A = Area through which heat is transferred

ΔT = Difference between drying chamber temperature and the ambient

Q = Heat flow through the thickness of wall.

The overall heat transfer coefficient is defined by the **equation 2.**

The dryer efficiency was estimated from the **formula.**

The fuel supplied for the drying process was the quantity of fuel

Table 1. Materials of Construction of the Dryer

Material	Quantity
Plywood, 6 mm	3
Hard wood (0.025 x 0.03 x 3.66) m^2	2
Nails, 12mm, 500mm	1 kg each
Elmer glue	1 tin
Steel pipes, 50 mm diameter	1 length
Hinges, 75 mm	3 pairs
Staples	2 pairs
Fire bricks	150 blocks
Metal Plate, 3 mm (mild steel)	1
Gal Pipes, 25mm, 100 mm diam.	1
Angle iron, 25 mm	2
Bolts/Nuts, 6 mm	8
Elbow Joints, 25 mm	2
Electrodes	1 pkt
Wire gauge	½ roll
Cement, Bags	2
Sand dust or wood shavings	1 bag

$$U^{-1} = \left(\frac{1}{h_{s1}} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \frac{x_3}{k_3} + \frac{1}{h_{s2}}\right) \quad \ldots\ldots\ldots\ldots (2)$$

where h_{s1}, h_{s2} = Surface coefficients on either side of the composite wall,

x_1, x_2, x_3 = Thickness of plywood, wood shaving and corrugated iron sheet respectively.

Equation 2

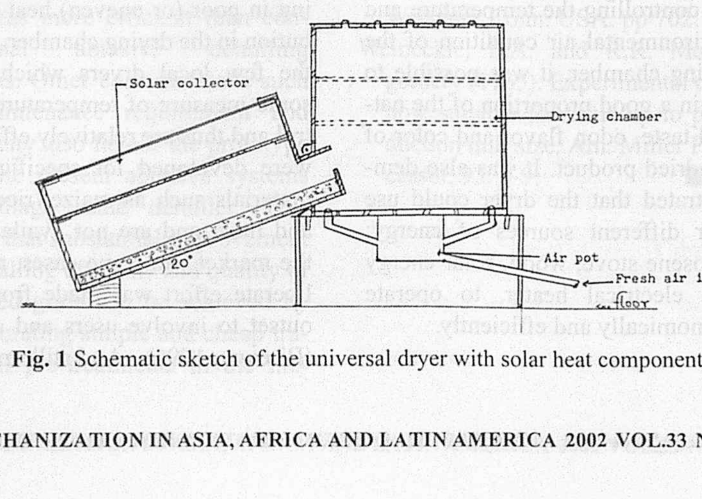

Fig. 1 Schematic sketch of the universal dryer with solar heat component.

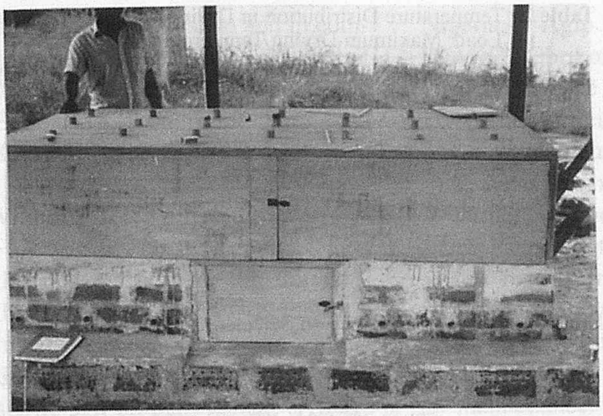

Fig. 2a The universal dryer. Note the six air-inlet holes at the base of the heating chamber and the 21 vapour outlet holes on top of the drying chamber.

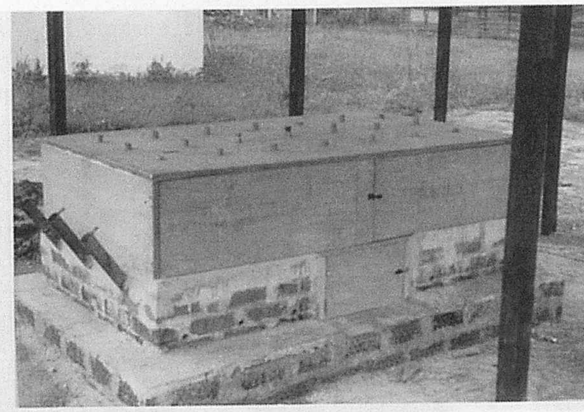

Fig. 2b The universal dryer. Note the three left exhaust pipes from the heating chamber. The air pot is enclosed.

burnt off during the process of drying a given quantity of food material. That quantity of fuel multiplied by the higher heating value of fuel gives the total heat energy supplied to the drying process to reduce the moisture in food materials from the initial to the final level. The fuel actually used in the drying process is the equivalent fuel that will give off enough heat to dry out the quantity of water that was removed from product. Thus, heat energy actually used in the drying process was:

$$Q_u = m_w S \Delta T + m_w L = m_w (S \Delta T + L) \quad \text{...} (3)$$

where

Q_u = Energy used

m_w = Mass of water

S = Specific heat of water

ΔT = Difference between drying temperature and initial product temperature

L = Latent heat of water at atmospheric conditions.

The efficiency of electric heating was calculated using a similar procedure as Zibokere (1994) in which power consumed by the heater during the drying process becomes the energy supplied, while heat energy actually used is the same as before.

In the case of solar heated drying, the heat energy supplied to dryer was estimated using insolation data for the Port Harcourt area. From Akor and Ideriah (1995) total incident irradiance at the absorber level was estimated to be 5.2kW hr/m^2, and the meteorological data for September 1996, gave an average of 75 sunshine hours. Thus the average insolation per hour would be 0.743 kW hr/m^2. The exposed surface area of the absorber is 0.922 m^2 with 0.95 as absorbtance factor. Hence the incident energy (E) on the absorber ready for transfer by natural convection to the drying chamber of the dryer was approximated from:

$$E_i = \alpha I_c A_c \tau \eta_c \quad \text{......................} (4)$$

where

η_c = Collector heating efficiency

α = Absorbtance factor

τ = Transmittance of the cover plate

I_c = Average insolation per hour

A_c = Absorber surface area exposed to insolation

The energy used to dry off water from the product from an initial moisture content to a final level was estimated as before; i.e., overall thermal efficiency (η_{Th}) on solar fuel would be:

$$\eta_{Th} = \frac{Q_u}{E_i} \quad \text{............} (5)$$

The main consideration in the design of the combustion chamber was the need to provide a heating space that is easily adaptable to the use of kerosene stove, wood and electric heater. A door and pipings were used to provide for fuel loading and unloading supplies of oxygen for combustion and the venting of flue gas.

Even heating in the drying chamber was the main consideration in the design of the chamber. Vanes were used to distribute heat among the racks. The passive dryer can easily be converted to an active one by providing the active element (fan) in a chimney hood cover to the top cover of the chamber.

Result and Discussion

Performance Test

Tests were conducted to appraise the performance of the dryer. The parameters of interest in the test were temperature distribution in the drying chamber, rates of drying, dryer fuel efficiencies, economics and viability of dried products.

Temperature Measurements of Different Fuels:

The heat yield available for drying produce at the drying chamber was assessed using two medium sized kerosene stoves of fuel capacity 1.5 litres each. All the twenty-

$$\eta_{TL} = \frac{\text{Fuel actually used}}{\text{Fuel supplied}} = \frac{\text{Heat actually used in drying up the water}}{\text{Heat supplied by fuel}}$$

Formula

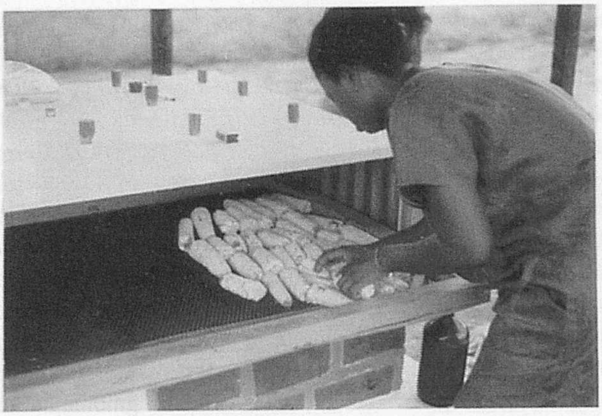

Fig. 3 An operatress setting wet maize on-cob for drying in the universal dryer.

Table 2. Temperature Distribution in Drying Chamber on No-Load Maximum Drying Temperatures(℃)

No. of Holes Open	Bottom	Midway	Top	Mean Chamber Temp.
0	84*	82	79	82
5	84	82	78	81
10	82	81	76	80
15	81	80	74	78
18	76	74	70	73
21	71	68	60	66

*Average of three mercury -in-glass thermometers.

Table 3. Drying Performance on Selected Commodities Using Kerosene Fuel

Commodity	Initial mc. % wb	Final mc.% wb	Time taken (hr)	Mean chamber temp.°C	Drying rate (kg/hr)
Maize on cobs	38.56	12.88	12	68	0.12
Yam chips	43.83	14.21	12	70	0.10
Cassava chips	59.49	13.86	20	67	0.09
Slice ginger roots	57.03	15.62	18	70	0.14

Table 5. Sensory Scores for Products Dried with the Universal Dryer

Products	Color	Aroma	Texture	Flavor	Acceptability
Yam chips	4	4	4	4	4
Cassava chips	4	4	4	4	4
Ginger	4	4	4	4	4

where 1 = not acceptable
2 = fair with objectionable color
3 = good, objectionable characters not quite pronounced
4 = very good

Table 4. Dryer Performance Using Other Fuel Types on Maize

Parameters	Solar	Wood Charcoal	Electricity
Initial mc, (%wb)	40.59	40.59	40.59
Final mc, (%wb)	13.11	12.06	12.68
Time taken, (hr)	21.00	10.00	12.00
Mean drying temp, °C	53.00*	83.00	80.00
Drying rate, kg/hr	0.07	0.15	0.13
Fuel efficiency, %	57.70	51.60	78.40

*At mid-day September 20, 1996, 27°C ambient temperature.

one vapor holes were plugged initially before introducing the fired kerosene stoves suitably adjusted to give a smokeless blue flame. After about 10 minutes of heating, the chamber attained a steady drying temperature recorded for the 3 locations in the drying chamber (bottom, midway, top) and for varying number of vapor holes shut (**Table 2**). This arrangement is one way to regulate the temperature of the drying chamber. Another way is to adjust the heating rate of the kerosene stove. However, the simultaneous use of both methods provides means of effective heat control. Similar assessment procedure was demonstrated on the wood, electric heating and solar energy.

Dryer Performance

Four different produce - fresh maize on cobs, yam chips, cassava chips, and sliced ginger roots were used to investigate the performance of the dryer. All four chosen fuels were used severally to heat three batches of 5 kg of each produce. The different resident times for drying from initial moisture content to a safe final level are as shown in **Tables 3** and **4**. Drying efficiency was found to be commodity-dependent but the overall thermal efficiency was computed to be 53.3% using kerosene fuel. **Table 4** shows the overall thermal efficiency of the dryer using the other fuels.

Tables 2, 3 and **4** show the relevant performance parameters measured or computed from measured data for the universal dryer, using the various fuel sources and drying different food materials. **Table 2** shows that the mean steady state drying chamber temperature is highest (82°C) when no hole is opened. This is the baking mood of the dryer because the food material is cooking in the drying heat as moisture is not allowed to escape. As more holes are opened, the mean chamber temperature decreases until all 21 holes are opened when the chamber records the lowest mean temperature of 66°C. This is the mean drying temperature of the chamber. With all 21 holes unplugged, the temperature difference between the bottom and top trays is maximum (11°C), because of the high temperature gradient caused by convective growth. However, the temperature of the chamber depends on the amount of heat supplied.

Table 3 gives the results of using the universal dryer to dry maize on cob, yam chips, cassava chips and sliced ginger roots. The data shows that sliced ginger has the highest drying rate of 0.14kg/hr followed by maize (0.12 kg/hr). This is expected since ginger is spongier than all the others. Yam and cassava chips have the lowest drying rate of 0.10 and 0.09 kg/hr, respectively. **Table 4** shows that the fuel efficiency of the dryer using solar, wood and electricity on maize were 57.70%, 51.60% and 78.40%, respectively. This represents an improvement, considering the fact that this is a passive system and in comparison with examples of overall thermal efficiencies as given by Earle (1983) on drum dryer (35-80%).

Viability Test on Dried Maize

A viability test was conducted on the maize dried by the universal dryer. One thousand kernels of maize selected at random among the dried maize were planted in sterile soil on petri dishes. After 6 days, the percentage germination was calculated as 98%. This shows that the dryer is suitable for drying seeds that will be planted in the ensuing season. Unlike some local dryers which destroy the embryo of the maize, (Cornes, 1960), the universal dryer has control for temperature of drying which enables the operator to choose appropriate temperatures for food material depending on the desired end use.

Sensory Evaluation of Produce Dried in the Universal Dryer

Dried yam and cassava chips were separately milled into flour using the hammer mill. A panel of five participants was constituted to assess the color, aroma, texture, flavor and general acceptability of the resulting flour. These were compared to similar products dried under the sun (sun drying) and open fire drying. **Table 5** shows that the acceptability of the various products was satisfactory - good in color, aroma, flavor and texture. A mycological study on the products dried with the universal dryer also showed that the products were neat and free from fungal spores.

The dried ginger retained its natural light yellow color and aroma.

Depending on the materials selected for the construction of the universal dryer, system costs ranged from ₦10 - ₦ 25 for a ton capacity. Three universal dryers have already been sold to the Nigerian Stored Products Research Institute (NISPRI), Port Harcourt, Nigeria; Agip Oil Company (NAOC), Obrikom and a lecturer in the food science department of the University of Science and Technology, Port Harcourt. Orders for two more have just been received from a farmer co-operative society at Cross Rivers State, Calaber.

The reports from these systems in the field show that the dryer is easily operated by the farmers and does not require so much attention in maintenance. Within the last 3 years, the NISPRI system only required the replacement of the combustion chamber door. With intensive usage, it is expected that the heat exchange may require replacement after five years.

Conclusion

The universal dryer is an improvement over the local dryers. Because of the in-built flexibility in the use of fuel and the types of products dried, the system lends itself to easy manipulation in particular areas of use. In other words, the same system can be designed as low, medium or high technology equipment by the addition of components that increase the precise control of drying, tonnage and efficiency.

In the entire four systems, user farmers and extension personnel were fully involved at all levels of the development of the system. Field results show that the acceptability for the equipment is high. The performance characteristics of the universal dryer also show that the objectives of the project were fully realized. A passive dryer, comparatively cheap that does the drying job within acceptable time for various food materials has resulted from the project. The products of the dryer are acceptable as shown by the sensory test. Viability test also shows that the dryer can be used to dry products to be used as planting materials for the ensuing farming season.

Above all the operation of the dryer is safe, reliable and the equipment has a relatively high thermal efficiency when compared with standard systems. Improvement in the performance of the dryer can be further achieved by including components (various pipes and precise controls) that enhance improved uniformity in temperature distribution and reduced heat loss.

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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.

054

An Instrumental Technique for Measuring Soil Failure Patterns Caused by Tillage Tools. **C. Divaker Durairaj** , Associate Professor, Dept. of Farm Machinery & Power, College of Agricultural Engineering, Tamil Nadu Agricultural University, Coimbatore 641003 INDIA. **M. Balasubramanian,** Professor of the same university.

This paper discusses the instrumentation and software concerning the micro-processor-based technique which was developed to detect the three dimensional soil failure fronts caused by tillage tools. Simple soil-failure sensors were embedded in the soil-tool front of the tillage tool and scanned by a micro-processor system. Exclusive electronic hardware was developed to connect the sensors to the processor and necessary software logic to effect the scanning. The relative movement of failed soil with respect to the tool was sensed under dynamic conditions. The soil failure front was computed accurately. The data acquired on the failure front measurements of bent leg tools showed that the c.v was in the range of 5.7 to 7.3% for the treatment speed of 0.56 m s-1 and 5.3 to 11.1% for 1.1 m s-1, proving the accuracy and utility of the developed technique.The analog soil-tool models could reduce the experimental cost of developing newer tillage tools. But the shape of the tool's soil failure front should be predetermined to conceive such models. This demands for accurate measurement of the failure front of the tool under question. Siemens et al., 1965; and Elijah and Weber, 1971, used high speed movies to study the failure front of simple inclined tools in a glass walled soil bin. In these works, the tillage tool traveled right next to the glass walled side of the soil bin and the measurements were hence purely two dimensional. But most of the tillage tools have complex failure fronts, which are unsymmetrical in three dimensions and no technique was available to detect the complete three dimensional soil failure front under dynamic conditions. So a technique was developed (Durairaj and Balasubramanian, 1997) which used a microprocessor system, to scan strategically placed soil failure sensors, in order to detect the failure front under dynamic soil cutting. This paper presents the instrumentation and methodology used in the study. The intelligent logic which allowed scanning the sensors at millisecond intervals, is also presented in detail.

058

Development and Evaluation of Power Tiller-operated Lawn Mower. **K. Kathirvel,** Associate Professor, College of Agrl. Eng, TNAU, Coimbatore, INDIA. **T. V. Job,** Professor of the same, **R. Manian,** Professor of the same.

Lawn mowing by manual labour is a time and labour-consuming intensive operation. A cylindrical lawn mower as an attachment to power tiller was developed for the lawn and garden maintenance works. The dimension of the lawn mower was 750 mm wide and 235 mm diameter cylinder fitted with 12 of helical steel blades on its periphery. The edges of the blades were sharpened. A horizontal blade with a concave groove was provided beneath the cylinder. The power was transmitted from the clutch pulley of the power tiller to the cylinder through a reduction gear box. A tail wheel and 2-sided rollers were provided for controlling the height of cut. The hitch assembly was mounted on a frame. The hitch assembly and the side support rods that were fixed to the handle of the power tiller enabled the unit to attach it with the power tiller. The clearance between the cylinder and the horizontal blade could be adjusted for different varieties of grass to be cut. During the operation in the field, the grass was cut and when it passed through the clearance; the cut grass was blown off and collected in the collection tray which was provided in front portion of the rotating cylinder. The collection tray could be emptied by opening the side doors (or) bottom door. The salient features of the power tiller-operated lawn mower were: (1) simple to operate and easy to handle; (2) suitable for maintenance of lawns; (3) results in 49.9 per cent and 64.1 per cent saving in cost and time respectively when compared to hand operated mowers; (4) highest cutting efficiency of is 96.7 per cent is achieved and (5) increases the versatility of power tiller in horticultural farming.

063

Computation of Actual Size and Evaluating the Performance of a Single Cylinder, Four-stroke Petrol Engine. **Ali Akbar Channar,** Associate Professor, Dept. of Farm Power & Machinary, Faculty of Agriculture Engineering, Sindh Agriculture University Tando Jam, Sindh, PAKISTAN. **A. A. Mirani,** Asst. Shift Engineer (Mechanical), Sindh Abadgar's Sugar Mill, Tando Mohammad Khan, Sindh, PAKISTAN. **Syed Gulzar Ali Shah,** Associate Professor, Dept. of Energy and Environment, Faculty of Agriculture Engineering, Sindh Agriculture University Tando Jam, Sindh, PAKISTAN. **M. S. Memon,** Student of M.E Agri: Engg., Lab: Technician., Dept. of Farm Power & Machinery of the same university.

A research study on the evaluation of performance of a single cylinder, four-stroke Otto engine was conducted at the Laboratory of the Farm Power and Machinery, Sindh Agriculture University, Tando Jam. The actual size of the engine parameters, e.g., bore, stroke, swept volume, clearance volume, compression ratio, and r.p.m. were measured, computed and recorded. Based on the actual size of the engine parameters, the indicated horse power (ihp), brake horse power (bhp) and friction horse power (fhp) were determined and were: 1.54, 1.29 and 0.25, respectively. The mechanical efficiency and thermal efficiency were also calculated which were 83% and 20.3%, respectively.

The fuel consumption per hour was assessed and determined and was 0.8 lit/hr while the fuel consumption per distance traveled so determined was 60 kilometer/liter

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Shear Strength and Tractability of Some Agricultural Soils Related to Moisture Content and Compactive Efforts. **K. O. Adekalu,** Department of Agricultural Engineering, Obafemi Awolowo University, Ile-Ife, NIGERIA. **J. A. Osunbitan,** same university. **D. A. Okunade,** same university.

The bulk density and shear strength of Iwo, Egbeda and Ondo soil series in Southwestern Nigeria were measured at different compaction efforts and moisture contents. Results indicate that bulk density and shear strength increased considerably with an increase in compactive effort. The maximum values of bulk density were reached at predetermined optimum moisture content levels for compacting the soils while the strength decreased continuously with increasing moisture content. Supper-imposing the two curves of bulk density versus moisture and shear strength versus moisture content gave the best compromise moisture content levels for working on the soils.

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Evaluating the Quantity and Quality of Groundwater for Irrigation in the Basement Complex. **H. O. Fapohunda,** Department of Agricultural Engineering, Faculty of Technology, Obafemi Awolowo University, Ile-Ife, NIGERIA. **J. A. Osunbitan,** same university. E-mail: josunbit@oauife.edu.ng.

The objective of this study was to evaluate the ground water yield and quality in relation to the irrigation requirements of common field crops grown on a small-scale basis in Ile - Ife, Nigeria. The quantitative and qualitative analyses of well water samples were carried out in order to determine their suitabilities for irrigation.

The groundwater yield in the basement complex areas on the average is 70.05m^3/day. However, the yield of 98.24 m^3/day was achieved in a well in this area. From the yield capacity of the well, the average crop area irrigable was 0.49 hectares. From the qualitative analysis, water from most of the wells is within the low electrical conductance (EC) limit of 0 - 250 μ mhos / cm but some wells have ECs of up to 750 μ mhos / cm.

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Effect of Wheat Bran on Cracker Quality. **Md. Anwarul Haque,** Scientific Officer, Bangladesh Rice Research Institute, Gazipur, BANGLADESH. **Md. Shams-Ud-Din,** Professor, Bangladesh Agricultural University, Mymensingh, BANGLADESH. **Anwarul Haque,** Research Officer, Food and Postharvest Technology Group, Cranfield University, Silsoe, Bedford MK45 4DT, UK. E-mail: a.haque@cranfield.ac.uk.

A commercial sample of wheat bran was extracted with non-alkaline aqueous extraction process. The extracted residue was dried in a cabinet drier. Crackers were prepared with extracted or unextracted bran at 2, 4, 6, 8, 10, 12, 16 and 20% substitution levels of flour and evaluated for various quality parameters. Ground bran samples from extracted and unextracted fractions were included for comparison. A control cracker with no substitution was also included. A critical flour replacement level of 6% by wheat bran produced crackers close to the control in all the parameters studied. The sensory properties were evaluated on the cracker containing 6% replacement level for colour, flavour, texture and overall acceptability by a panel of 19 judges. Aqueous extracted wheat bran yielded better quality crackers than using parent bran itself thus providing a viable alternative to alkaline extraction. ■■

BOOK REVIEW

Using the Biological Literature: a Practical Guide Third Edition, Revised and Expanded (USA)

by Diane Schmidt, Elisabeth B. Davis and Pamela F. Jacobs

This book grew out of a series of handouts prepared for students using the Biology Library at the University of Illinois at Urbana-Champaign. Its purpose is to acquaint students new to the literature of biology with important primary and secondary resources of the field. Aimed toward undergraduate and graduate biology students, it is also appropriate for anyone interested in searching the biological literature and keeping up with its bibliography.

This guide to the literature of the biological sciences presents a comprehensive list of important sources that may be found in large research libraries, with an emphasis on current materials in the English language. Retrospective reference works have been selected for historical perspective and to provide access to the taxonomic literature. All the main fields of the biological sciences are covered; applied areas such as medicine, clinical psychology, veterinary medicine, agriculture, horticulture, nutrition, and the teaching of biology are not included.

The entries are grouped by subject area, into chapters, which are subdivided by form of material. Entries are annotated only once according to their primary focus, although some are cross-referenced elsewhere. Every textbook listed is recommended, although not all of them are annotated. A certain knowledge of scientific literature is assumed, and there is minimal explanation of the definitions, uses, or importance of primary and secondary literature. A very brief discussion of searching strategies and indexing policies is included in Chapter 2, but it is assumed that more detailed information on how to search for information in the biological sciences is available elsewhere. Periodical editorial policy and subject scope have been included with journal annotations as an aid to the student looking for publication possibilities. Unless otherwise cited, quotations in the body of an annotation are taken from prefatory material of the item under consideration. Finally, annotations in this edition have been expanded to compare the use of similar resources.

The second edition of Using the Biological Literature was published just as the development of Web browsers such as Mosaic and the subsequent explosion of Web-accessible resources changed information-seeking behavior. The third edition features greatly expanded coverage of Web information, although most standard, authoritative resources are still to be found in the print format. Electronic journals have also become much more common since the second edition was published, and a discussion of their complicated subscription and access methods is included in Chapter 1. An associated Web page at www.library.uiuc.edu/bix/biologicalliterature/ has been created, with links to all the major resources discussed in this edition.

This book could not have been written without assistance. We would like to acknowledge the Research and Publication Committee of the University of Illinois at Urbana-Champaign Library, which provided support for the completion of this research. We would also like to thank Susan K. Kendall for her assistance in' editing the manuscript and suggesting titles to be added. In addition, we would like to express our appreciation for the cooperation of the other life sciences librarians and staff at the University of Illinois. In particular, the assistance of the Biology Library staff and graduate assistants has been invaluable. And finally, this book could not have been written without the excellent collections of the University of Illinois Library.

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Guide to Writing Empirical Papers, Theses, and Dissertations (USA)

by G. David Garson

The inspiration for this book was both the foundation of a new doctoral program in my department, and also my memories of what little guidance I received when writing my dissertation at a famed Ivy League institution. While every paper, thesis, and dissertation is different, it is my hope that this volume will be helpful to writers starting on the path to publication. Other books have been written on this subject, but I have sought to make this one of particular relevance to those engaged in empirical research, in which the writing process is inextricably bound to research design and statistical methodology.

This volume is intended to enrich students' comprehension of the structure and execution of the written research project. Toward this end, each chapter contains an overview, a checklist of writing considerations, and bibliographic guidance to further understanding of the topic. Special attention has been given to computer-based research tools, not just in statistical matters, but in brainstorming one's topic, locating data and information, managing a bibliography, and all the other elements of the research process.

An attempt has been made in this book to treat the entire quantitative research process in its writing aspects, including brainstorming, framing an analytic question, developing a comprehensive outline, and providing a roadmap for the reader. Electronic search resources and bibliographic software get particular attention as a prelude to meta-analysis of prior research and development of the literature review. The student is urged to think in terms of modeling as well as operationalizing variables. Selection of research designs and appropriate statistical methodology are treated, as are the basics of writing fundamentals, validity, and data visualization. The work concludes with emphasis on research ethics and issues associated with drawing inferences and making generalizations. Dealing with one's thesis or dissertation committee is not forgotten, and final chapters make explicit the special characteristics of quantitative research writing in the humanities and in the natural sciences. Last, but not least, funding sources for dissertation research are inventoried, with Web links and other contact information.

I wish to thank all those who have helped with the preparation of this book, especially my students and Paige Force, production editor at Marcel Dekker, Inc. Errors and omissions, of course, are my own and should this volume prove of some use and see another edition. I would thank dear readers who are kind enough to send their reactions and suggestions. In the meantime, additional information on quantitative research is found at my website, http://www2.chass.ncsu.edu/garson/PA765/.

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Food Plant Sanitation

(USA)

by Y. H. Hui, Bernard L. Bruinsma, J. Richard Gorham, Wai-Kit Nip, Phillip S. Tong and Phil Ventresca

As food professionals, we have noticed the monumental increase in awareness of food safety in the past decade. Professionally, this awareness manifests itself in many ways, with educational materials (print, Internet, videos, etc.) heading the list. Reference books on food safety are especially useful.

This book has three important goals: (1) to present the fundamental principles of food plant sanitation and their applications in the food industry; (2) to provide professionals with basic, hands-on information for the day-to-day operations in a food processing plant, (3) to review some of the industry's most recent developments.

To achieve these goals, the book covers nine major areas: federal and state regulations and guidelines, major biological and nonbiological contaminants, cleaning a food plant, sanitation and worker safety, housekeeping, product quality, commodity processing, retail food sanitation, and enforcement.

The book covers both basic sanitation practices and the latest information on the Hazard Analysis Critical Control Point (HACCP) program. However, HACCP is discussed as a peripheral consideration. Before one considers HACCP, one must make sure that each food processing plant has put in place an acceptable sanitation program in principle and in practice: Have the incoming raw materials been checked? Is there water (or debris) on the floor of the operations room? Does every worker wear a hairnet when handling food products or ingredients? Is the cold storage room maintained at the required temperature? Are there rat and bird droppings in the plant? There are these questions and more to consider.

This book differs from other food sanitation books in that its presentation is a compilation of multiple perspectives from more than 30 government, academia, and industry food safety experts. They cover more than 40 topics in food plant sanitation and HACCP and present the latest developments in retail food processing and sanitation. Last, but not least, the book provides examples of the enforcement activities of the U.S. Food and Drug Administration (FDA) in relation to food plant sanitation. The discussion is accompanied by a reproduction of the FDA's Handbook of Food Defect Action Levels in the appendix.

In sum, the approach for this book is unique and makes it an essential reference for the food safety and quality professional.

The editorial team thanks all the contributors for sharing their experience in their fields of expertise. They are the people who made this book possible. We hope you enjoy and benefit from the fruits of their labor.

We know how hard it is to develop the content of a book. However; we believe that the production of a professional book of this nature is even more difficult. We thank the production team at Marcel Dekker, Inc., and express our appreciation to Ms. Theresa Stockton, coordinator of the entire project.

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http://www.dekker.com

Encyclopedia of Soil Science

(USA)

by Rattan Lal

Six important challenges facing humanity at the start of the 21st century are: (l) a world population of 6.l billion that is increasing at the rate of 1.3% per year, with most of the increase occurring in developing countries where natural resources are already under great stress; (2) a food-insecure population of 790 million, mostly in sub-Saharan Africa and South Asia; (3) severe and extreme forms of soil degradation affecting more than 300 million hectares (Mha) of agricultural land, continuing unabated in developing countries where the resource-poor farmers cannot afford to invest in soil restoration; (4) an anthropogenic increase in atmospheric concentration of greenhouse gases such as CO2, with current levels at 370 ppm and increasing at the rate of 0.5% per year; CH4 currently at l.74 ppm and increasing at the rate of 0.75% per year; N2O at 311 ppb and increasing 0.25% per year; and the atmospheric C pool now at 770 Pg and increasing at the global per capita rate of 1.1 Mg per year; (5) a projected 40% decrease in the global per capita arable land over the next 50 years; (6) the threat of a decreasing, renewable fresh-water supply, dropping to scarcity levels in many countries.

The solution to all of these challenges lies in developing management strategies based on an understanding of the nature, properties, and dynamics of the life-support processes of the most basic of all natural resources Åc the soil. This thin upper surface of Earth's crust supports life in numerous ways-moderating the purification of water, detoxification of pollutants, restoration and resilience of ecosystems, and cycling of basic elements such carbon, nitrogen, phosphorus, and sulfur. These life-supporting functions of soil are accurately summed up in an old Chinese proverb that states "Man Åc despite his artistic pretensions and many accomplishments Åc owes his existence to a six-inch layer of topsoil and the fact that it rains."

Traditionally, soil was regarded as a medium for plant growth, a repository of gene pool, an engineering foundation, an industrial raw material, and an archive of planetary history. However, meet the challenges of the post-modern era of the 21st century, world soils must also (l) maximize long-term productivity; (2) moderate moisture storage and distribution; (3) proxy for interpretation of past global changes and cultural heritage; and (4) minimize environmental pollution by functioning as a repository for waste disposal, an ameliorator of water quality through bioremediation, a sink for atmospheric carbon and other greenhouse gases, a component of biogeochemical cycles and other ecological processes, and as a medium for immersing and loading infrastructure. To enhance soil's capacity to perform these functions, it is important to understand factors and processes affecting soil quality under growing and conflicting modes of land uses (among them agricultural, forestry, urban, industrial, military, aesthetic, and cultural uses).

It is necessary that state-of-the-knowledge information about these complex attributes of soil and its multi-faceted functions of interest to humans is readily available to the scientific community, policy makers, and the public at large in an easily accessible compendium such as this encyclopedia.

The Encyclopedia of Soil Science has been complied by over 400 experts in their fields to meet this need. This first edition, to be updated periodically, addresses 40 thematic topics. Each of these topics was coordinated by a topic editor and includes discussions of related subjects prepared by soil scientists from around the world. The topics cover all branches of soil science including pedology, mineralogy, physics, soil mechanics, hydrology, chemistry, biology, ecology and management, and restoration of problem or degraded soils, and address numerous challenges including soil structure, tillage methods and mulch farming, irrigation, drainage and water table management, fertilizer and nutrient management, erosion control, and management of soil organic matter. Entries are alphabetically arranged, and a subject index is included for easy access.

Preparation of this state-of-the-knowledge compendium on soil science has been made possible by the hard work, vision, and commitment of hundreds of soil scientists from around the world who have contributed as members of the advisory board, as topic editors, or as authors. I thank all of them for their outstanding efforts to prepare this volume in record time. I am especially thankful to all the topic editors for identifying expert authors, for coordinating the writing with minimal duplication, and for carefully reviewing manuscripts to ensure high quality. I also thank all of the authors for their outstanding efforts in documenting and present-ing, in a timely fashion, the scientific information supporting the current understanding of their field of specialization. Their efforts in the preparation of this volume provide up-to-date information on the nature, properties, functions, and dynamics of soil.

Thanks are also due to the staff of Marcel Dekker, Inc. for their efforts in making this information available to the world community. It has been a great pleasure working with Ms. Ellen Lichtenstein and Ms. Sapna Maloor. Their professionalism, commitment to excellence, and dedication to the mission is much appreciated. I also thank Ms. Brenda Swank of the School of Natural Resources of the Ohio State University for her efforts in handling the now of manuscripts in the review process. These efforts have produced this volume on soil science that contains information useful to meeting the challenges of the 21st century and beyond.

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Biological and Bioenvironmental Heat and Mass Transfer

(USA)

by Ashim K. Datta

It is very important to give the undergraduate engineer a fundamental education in the context of his/her likely application areas. Transport of energy and mass is fundamental to many biological and environmental processes (see pages xi to xx). Areas, from food processing to thermal design of buildings to biomedical devices to pollution control and global warming, require knowledge of how energy and mass can be transported through materials. These wide-ranging applications have become part of emerging curricula in biological engineering, and societies such as the Institute of Biological Engineering and the American Society of Agricultural Engineers have recognized the need for a course (and a text) that presents fundamentals while integrating the diverse subject matter.

The basic transport mechanisms of many of these processes are diffusion (or diffusion-like, such as capillary and dispersion) and bulk now. Additionally, there is radiative heat transfer. It is crucial for the student to see these concepts as comprehensive and unified subject matter (much like fluid mechanics); they are the building blocks for life-long learning in many of their interest areas. Such fundamentals-based approach will replace the more empirical and ad-hoc teaching that sometimes exists.

Although the concept of teaching transport processes as a unified subject has existed for over forty years in some engineering disciplines, only in recent years have we seen adequate quantitative studies to make such teaching possible in biological and bioenvironmental processes. This book attempts to bring together under one umbrella the unique content, contexts and parameter regimes of biologically related processes and to emphasize principles and not just mathematical analysis. Content, such as bio-heat transfer, thermoregulation, freezing, global warming, capillary now, and dispersion, are some of the topics not typically included in the undergraduate-level teaching of transport phenomena. Context, such as plants, animals, water, soil, and air is important at this level, because without this information students have an unnecessarily hard time relating to red physical processes. Context also helps students learn about the physical processes themselves in a quantitative way. For example, studying convective transfer of water vapor over a leaf' includes a quantitative introduction to transpiration. (The present text was created by distilling the content of hundreds of research papers and textbooks on similar biological and environmental applications.) The parameter regimes of biological processes are also different from those of typical mechanical and chemical processes. For example, biological processes often involve a source term of heat generation or oxygen consumption. Presence of the source or sink term changes the nature of the solution and is emphasized in this text.

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NEWS

Prof. Bill Stout Awarded "VDI-MEG"

Germany

The German National Agricultural Engineering Society "VDI-MEG" awarded Bill Stout at the large annual meeting on 10-11 Oct 2002 in Halle with the Max-Eyth-Medal at the Ribbon. The official formula of the award is as follows:
"in appreciation of his great contribution to the technical development of harvest machines and in the field of renewable energies helping to improve the world food situation and to protect the environment, connected with his commitment in international agricultural societies".

Dr. Bill Stout,
Professor
Texas A&M University, USA

World Conference and Tradeshow to Spread Swedish Know-how

June 2004
Jonkoping, Sweden

Press info (2002-10-31)

The Swedish Bioenergy Association (Svebio) intends to host an international conference and tradeshow at Elmia in Jonkoping, Sweden. Set for June 2004, the delegates are to learn about the latest technology and know-how developments in the bioenergy sector.

World conference and tradeshow to spread Swedish know-how

The Swedish Bioenergy Association (Svebio) intends to host an international conference and tradeshow at Elmia in Jonkoping, Sweden. Set for June 2004, the delegates are to learn about the latest technology and know-how developments in the bioenergy sector.

- One fifth of the total energy consumption in Sweden is derived from bio fuels. This gives us a cutting edge position in terms of know-how and experience says, Lars-Erik Larsson at Svebio.

What makes Sweden stand out is the fact that bioenergy is produced on an industrial scale. Large users of bioenergy are the forest industries and district heating plants.

- In Sweden there is a unique bank of competence covering several key areas involving bioenergy. For instance energy conversation, district heating, combined heat and power (CHP), machinery and equipment engineering, bio fuel production to name a few, says Lars-Erik Larsson.

Now the time has come to make this know-how available internationally. For instance, other EU countries, Japan and the USA are all looking to increase the usage of own domestic renewable energy resources, of which bioenergy is the most prominent. For both environmental and economical reasons.

Bio fuels have already replaced large volumes of Sweden's earlier coal and oil consumption. In fact the bio fuel share is expected to increase as a result of coal and oils negative environmental impact, especially in the climate issues, explains Lars-Erik Larsson.

The Swedish experiences are of international interest. That is why Svebio has decided to organise the first world conference on bioenergy in Jonkoping at the beginning of June 2004. Lars-Erik Larsson motivates the choice of venue by saying:

- In and around Jonkoping is everything that the conference delegates will need to see. Many of the leading manufacturers in the industry are situated in the region along with modern district heating plants and proximity to the forests where bio fuels are extracted.

Svebio is an association of companies, organisations and individuals, whose purpose is to work towards an increased usage of bioenergy. It was founded in 1980 in the middle of the previous bioenergy surge which came about after the second oil crisis.

- Our objective is to create a recurrent international bioenergy conference and tradeshow, which, given time, will have the same international status as the forestry tradeshow Elmia Wood has, says Torbjorn Johnsen, manager for Elmia's business area forest and timber.

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IAMFE/RUSSIA 2004
The 12th International Conference and Exhibition on Mechanization of Field Experiments

5-9 July 2004
St.Petersburg/Pushkin, Russia

Outline of the Exhibition and Field Demonstrations

The Exhibition will be open on Tuesday and Wednesday for the participants of the conference. Groups or individuals wishing to visit only the exhibition are asked to contact the AAFEI Conference Secretariat for further information. The exhibition will have indoor and outdoor sections. The conference poster session is also available at the exhibition area. Representatives of countries or regions (not commercial companies) are also invited to set up and operate National Stands at the indoor exhibition. These stands will not be charged any exhibition fees.

The purpose of the Field Demonstrations is to give the exhibition visitors the possibility to see or operate themselves field equipment or instruments. Grass land as well as bare land will be available for demonstrating and testing plot equipment for forage harvesting, planting, fertilizing, spraying, root crop mechanization, soil sampling etc..

Professional visits and tourist program before, during and after the conference

On Friday, 9 July, we plan a special program of professional visits in the St.Petersburg/Pushkin area. Tourist programmes for delegates and accompanying persons will be arranged the weekends before and after the conference as well as some arrangements during the conference week. A detailed program will be prepared and will be included in the 2nd announcement of IAMFE/RUSSIA 2004.

St. Petersburg is the second largest city in Russia with approx. 5 million people and the fourth largest city in Europe. It is also a main agriculture centre in Russia with universities in agriculture, forestry and veterinary medicine as well with a rang of so-called All-Russian (national) applied agriculture research institutes. St. Petersburg is celebrating its 300 anniversary in 2003. Pushkin town, close to the international airport just south of St.Petersburg belong to the richer parts of St.Petersburg and is one important agriculture research area. Here is the St. Petersburg State Agrarian University (SPSAU) located. SPSAU celebrates its 100 anniversary in the year 2004.

Accommodation and transport

Through the conference secretariat you will be able to reserve accommodation in several hotels in Pushkin. We may also assist in reserving hotels in St. Petersburg city. Our main recommendation will be to reserve and pre-pay rooms at a new Western standard 3-star hotel right in the centre of Pushkin town. With pre-payment together with the conference registration we will be able to offer you good room prices. Morning/evening shuttle buses between the hotels in Pushkin and the conference location will be available. A daily bus/taxi from Pushkin to St. Petersburg city will be available towards a low travel cost (for accompanying persons). .

Booking forms. Payment

Please refer to forms at the end of this document. Upon receiving your preliminary reservations, we will send you a confirmation number as well as payment and cancellations details. Please note that there will be no charges (and any payments are fully refundable) when cancellations are made before 31 March 2004.

Persons needing additional financial support in order to participate in the conference may send an application to the conference secretariat at AAFEI in Pushkin. The application should contain a very short CV and a specification of costs that would need to be covered. We have limited possibilities to give support and thus we will have to make priorities. In general, only persons from countries with a difficult financial situation can be supported. Members will get priority before others.

Proceeding of the National Symposium on Cotton Mechanization

India

National Symposium on Cotton Mechanization was held on 23-24 March 2002 at CIAE Bhopal India. During the two days deliveration various aspects related to improvement in Cotton production was discussed. The Chief guest of the function emphasised on the economic aspect of production of cotton. It is also mentioned that due to exccesive level of chemical contaminations foreign Cotton is mostly preferred in textile industries in India.

96 page proceedings contains 12 technical papers on various aspects of machinery for cotton cultivation i.e. status of cotton mechanization, including cotton delinting, various types of cotton drills and studies of plant uprooting, indigeneous cotton cutivation machinery being used in India, plant protection equipment, machinery for cotton harvesting, cotton processing and safety aspects were well discussed in the meeting. Size 27.5 × 21.0 cm, color prastic coated.

Live field demonstration of large number of machines for cotton cultivation was carried for the benefits of the cotton growers and cotton scientists.

For more details contact:
Director, CIAE
e-mail: director@ciae.mp.nic.in

■■

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S Phong-supasamit

C Rojanasaroj

V M Salokhe

G Singh

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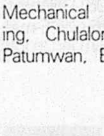
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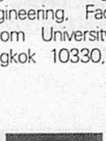
M Martinov

INSTRUCTIONS TO AMA CONTRIBUTORS

The Editorial Staff of the AMA requests contributors of articles for publication to observe the following editorial policy and guidelines in order to improve communication and to facilitate the editorial process :

Criteria for Article Selection

Priority in the selection of articles for publication is given to those that -

a. are written in the English language ;
b. are relevant: to the promotion of agricultural mechanization, particularly for the developing countries ;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission ;
d. deal with practical and adoptable innovations by, small farmers with a minimum of complicated formulas, theories and schematic diagrams ;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article ;
f. are printed, double-spaced, under 3,000 words (approximately equivalent to 6 pages of AMA-size paper) ; and those that
g. art: supported by authentic sources, reference or bibliography.
h. written on floppy disc.

Rejected/Accepted Articles

a. As a rule, articles that are not chosen for AMA publication are not returned unless the writer(s) asks for their return and are covered with adequate postage stamps. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
b. When an article is accepted but requires revision/modification, the details will be indicated in the return reply from the AMA Chief Editor in which case such revision/modification must be completed and returned to AMA within three months from the date of receipt from the Editorial Staff.
c. "The AMA does not pay for articles published. However, the writers are given collectively 5 free copies (one copy air-mailed and 4 copies sent by surface/sea mail) of the AMA issue wherein their articles are published. In addition, a single writer is given 25 offprints of the article and plural writers are given 35 offprints (also sent by surface/sea mail)"
d. Complimentary copies: Following the publishing, three successive issue are sent to the author(s) .

Procedure

a. Articles for publication (original and one-copy) must be sent to AMA through the Co-operating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article may be sent directly to the AMA Chief Editor in Tokyo.
b. Contributors of articles for the AMA for the first time are required to attach a passport size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
c. The article must bear the writer(s) name, title/designation, office/organization, nationality and complete mailing address.

Format/Style Guidance

a. Article must be sent on 3.5 inch floppy disk with MS DOS format (e.g. Word Perfect, Word for DOS, Word for Windows... **Absolutely necessary TEXT FORMAT**) along with two printed copy(A4).
b. The data for graphs and the black & white photographs must be enclosed with the article.
c. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features :
   i) brief and appropriate title ;
   ii) the writer(s) name, designation/title, office/organization ; and mailing address ;
   iii) an abstract following ii) above ;
   iv) body proper (text/discussion) ;
   v) conclusion/recommendation ; and a
   vi) bibliography
d. The printed copy must be numbered (Arabic numeral) successively at the top center whereas the disc copy pages should not be number.Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e.g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Figure 1. View of the Farm Buildings".
e. **The data for the graph must also be included.(e.g. EXCEL for Windows)**
f. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare(t/ha) and smaller units in kilogram or gram(kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies in US dollars and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.

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