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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.XVI, NO.1, WINTER 1985

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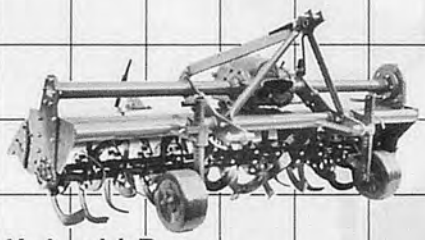

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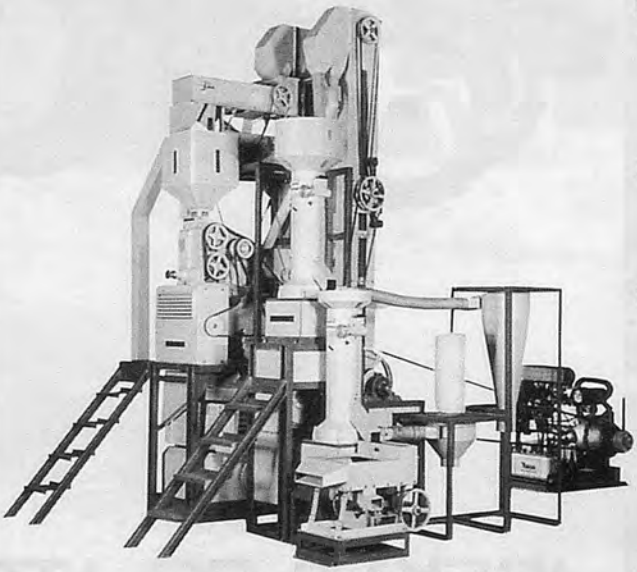

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EDITORIAL

Some lessons from Central Africa

A happy new year to all AMA readers and contributors!

Towards the end of 1984, the mass media seemed to have suddenly converged from all over the world to focus on the tragedy that struck Central Africa – children, the aged and even the strong ones dying by the thousands from hunger. Food from domestic sources was nowhere to be found. And even if donations of food, medicine and blankets came from many countries and organizations, they came rather too little, too late to save thousands more from dying.

The tragedy, like most tragedies, was not without recriminations and fault-finding. International and local politics were blamed for the calamity but the more logical analysts traced the source of the famine from man's indiscriminate abuse of the ecosystem: for instance, the cutting down of forests and the consequent disappearance of watersheds which, in turn, induced the development of deserts where economic crops cease to grow. And all this did not develop overnight. As a matter of fact, the abuse or misuse of the ecosystem took generations to do before governments realized the consequences at which time it was too late to avert a famine of the proportion that struck Central Africa.

Some lessons that serve as grim reminders are learned from the Central African tragedy and these lessons are back to basics, *i e,* the proper management of forest, water and other natural resources must rank high on government policies in order to avert similar shocking scenes of the dying humanity, particularly in Ethiopia.

And as the AMA eners its 15th year of service to the cause of farm mecahization this year, the management reiterates its pledge to continue to bridge the communication gap in this regard between developed and developing nations.

Chief Editor
Yoshisuke Kishida

January, 1985
Tokyo

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Boat-Tractor Hull Design to Minimize Drag Forces

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Abstract

Boat tractors and "Turtle" tillers illustrate the true buoyant flotation characteristics necessary for agricultural equipment designed to operate in the very soft and "bottomless" flooded soil conditions common to many tropical flood plain and delta areas used for rice production. The main problem associated with these types of units is the high drag forces generated as they move through the soil-water mixture. This article reports on research aimed at minimizing these drag forces by:

a) Using boat-design theory to minimize (i) forces generated by the hull displacing the soil-water mixture during forward motion, and (ii) forces generated by the shearing of the sticky soil-water mixture as the hull slides through this mixture.
b) Using field experiments to determine which operating condition changes contribute most to the reduction of drag forces.

It was found that a hull shape with maximum beam at the rear was most efficient and that having the cross-section circular or elliptical in shape tended to minimize drag. Drag forces were nearly twice as high at 4.0 km/h as at 0.8 km/h, but having the center of mass to the rear of the center of buoyance tended to reduce this tendency toward higher drag forces at higher speeds. As a result of the hull shape chosen, drag forces were about 20% lower than might otherwise be anticipated from standard data for sleds on soft soils. The hull shape chosen in combination with optimized operating conditions tended to reduce drag forces to as low as 27% of the hull weight supported by the soil. This value is about 60 to 70% of the values from standard data for soils of the strength of those on which tests were carried out.

Introduction

Many of the world's most fertile soils are those of the flood plains, swamps and deltas of major river systems. Rice grows particularly well when these soils are in a shallow, flooded state. The alluvial and organic soils common under these conditions tend to have little bearing capacity when continually flooded – sometimes to the extent that even draft animals such as water buffaloes cannot work. This has until recently essentially excluded farm machinery from being applicable to rice production under these conditions. However, in the last few years two designs of truly buoyant farm power units have appeared. One of these is the boat tractor **(Fig. 1)** the technical aspects of which have been described by Wang and Zhu (1980). The other is the "Turtle" tiller **(Fig. 2)** (Villaruz, 1981). For both of these units, their weight is insufficient to displace soil-water mixture in a volume equal to that of the lower part of their hulls.

For sleds operating on these very soft soils (cone penetrometer resistance from 138 to 345 kPa or 20 to

Fig. 1 Boat tractor of Chinese design. For wet field operation the rear tires are removed and paddle wheels substituted.

Fig. 2 Turtle tiller chassis from the Philippines. The driven rotors are at the front of the unit to provide propulsion and to help liquefy the soil water mixture on which the hull will slide.

50 lb/in^2) standard data (U.S. Army, 1954) show that drag forces range from 23 to 68% of the vehicle weight for nonsticky soils and from 60 to 92% of vehicle weight for very sticky soils. This high level of motion resistance not only makes vehicle operation under these conditions very inefficient but also tends to immobilize the vehicle when low soil strength prevents the generation of regular tractive forces by paddle wheels or rotary tillers.

The objectives of the work reported here were to determine if theoretically-based hull design could reduce the drag forces associated with these buoyant vehicles, and to find, by using field tests, which operating conditions might contribute to minimization of such forces.

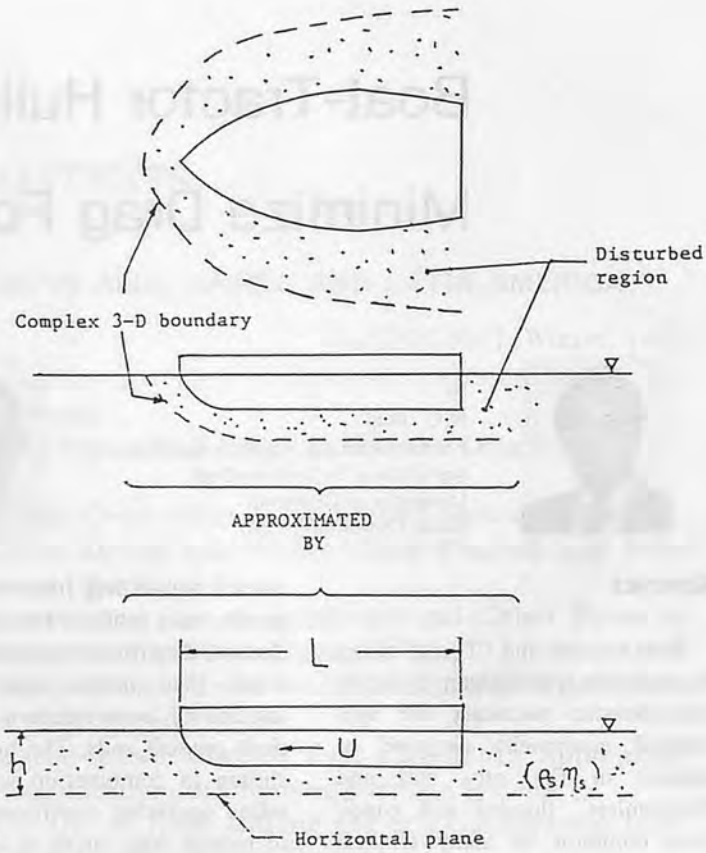

Fig. 3 Scheme of approximation for the boundaries of the disturbed and undisturbed regions as used in shallow-water theory.

Theoretical Considerations

When a structure, partially embedded in a visco-plastic material, is moved across its surface, a complex 3-dimensional boundary is formed separating the undisturbed zone, considered to be rigid, from the disturbed zone, considered to behave like a viscous fluid (**Fig. 3**). In this study, this 3-dimensional boundary was simplified to a horizontal plane surface (**Fig. 3**) to satisfy the requirement for continuity of fluid flow.

The approach used was as follows:

a) Super-critical inviscid shallow-water theory was used as a model for the effects owed to the shallow depth (sinkage) involved. The drag force prediction determined by a formula derived from that model was then minimized, resulting in an optimal distribution of the submerged cross-sectional area along the hull length.

b) The component of the drag force due to the viscosity effect of the mud was then minimized by finding shapes which would minimize the wetted area for the submerged volume distribution found in a).

Under the above assumptions Thai (1983) developed equations to show that the drag force on the hull (exclusive of viscous forces) depended on:

a) density of the soil-water mixture ρ_S (**Fig. 3**),
b) hull speed V (**Fig. 3**),
c) depth of the disturbed layer h (**Fig. 3**),
d) hull length L (**Fig. 3**) and
e) the rate of change of S(x), the submerged hull cross-sectional area, with changes in position (x) of the cross-section along the length of the hull (**Fig. 4**).

The submerged volume of the hull, V, needed to be based on the following factors:

V = (Gross weight supported by the hull)/(Soil-water mixture specific weight) = $W/\rho s \cdot g$ (1)

in order for the boat to be statically buoyant.

As a result of quantitative relationships developed mathematically, it was found that the submerged hull cross-sectional area, S(x), was a polynomial function of the second degree with respect to the position, x, along the hull length, and that the shape of the hull could be represented by a single shape factor, k, the numerical value of which was restricted to a range between 0.0 and 3.0.

$k = L\,A_t/V$

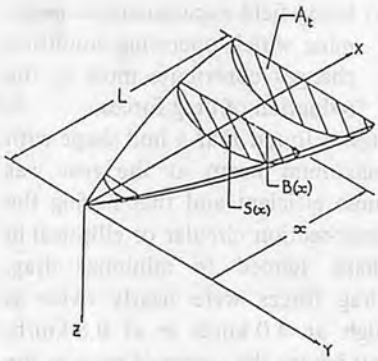

Fig. 4 Sketch defining the dimensions and variables used in the formulation of the hull shape.

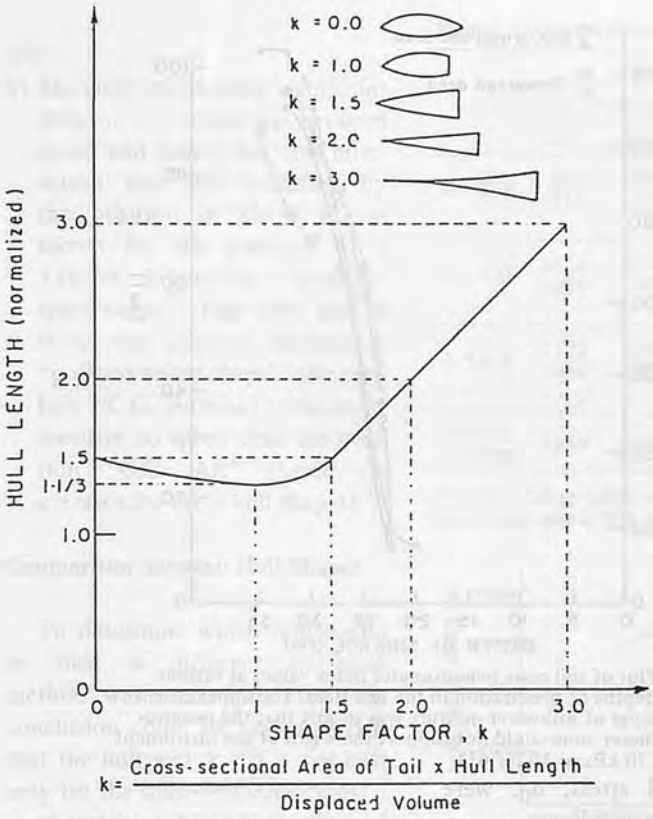

Fig. 5 Relationship between the normalized hull length, $L/(2V/z_m b_m)$, and the shape factor, $k = A_t \cdot L/V$

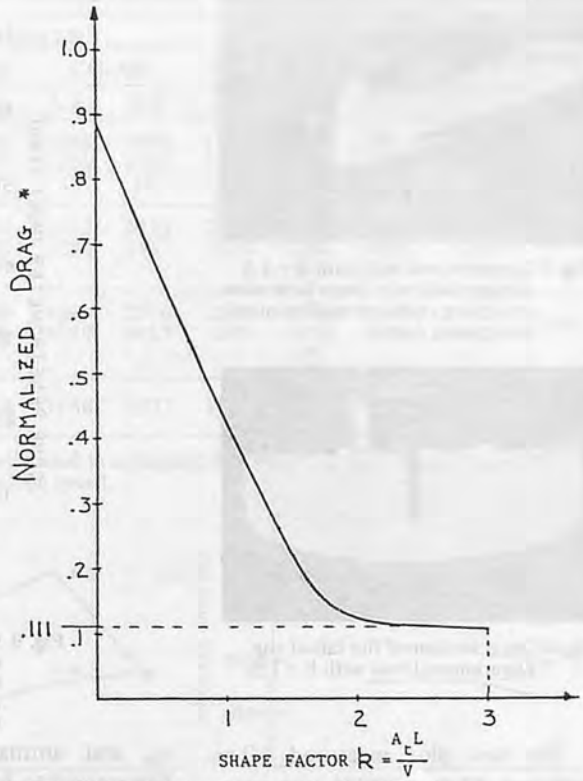

Fig. 6 Relationship between the shape factor, $k = A_t \cdot L/V$, and the normalized drag force, $R/[\text{constant} \times (z_m b_m)^3/V]$.

where A_t = the submerged cross-sectional area of the tail of the hull.

Fig. 5 illustrates shape factors ranging from 0.0 to 3.0 and how hull length would be related to k, to the maximum depth of sinkage, z_m, and the maximum half-beam of the hull, b_m, as well as to the displaced volume, V. **Fig. 6** shows that when only nonviscous drag forces are being considered that these forces are minimum when the shape factor, k, is 1.5 and above. However, upon reference to **Fig. 5** it can be seen that for shape factors, k, much above 1.5, the hull length becomes unusually great relative to the volume displaced by the hull.

Once the cross-sectional area at each point along the hull length, S(x), was described as has been done above, the minimization of the viscosity effect could be achieved by shaping that area, S(x), such that it had a minimum wetted area for the whole hull, *ie* a nimimum wetted perimeter at each location x. It is also known that for a given enclosed area a circle would have a smaller perimeter than an ellipse, however, if circular sections were used along the entire hull length, the sinkage at locations where the enclosed area was numerically great would also be large, thus creating a very deep rut after the hull passage.

Here a compromise design rule was introduced:

a) To use a circular section whenever the resulting radius was less than a fixed design maximum sinkage z_m.
b) If the resulting radius was to be greater than z_m, to use an ellipsoidal section with a minor axis equal to z_m.

Prototype Construction and Testing

Three test hulls were made to meet the following design conditions:

weight = 9806 N; mud density = 1540 kg/m^3; beam = 2 b_m = 1.50 m; max. sinkage = 0.2067 m corresponding to a ground pressure of 2.45 kPa; k = 0.0, 1 and 1.5, therefore L = 4.0 m, 3.556 m and 4.0 m, respectively.

The hulls were constructed from wood, polyurethane plastic foam and polyester-fiberglass covering. In **Fig. 7** the hull with k = 1.5 is illustrated during field test. Also illustrated in **Fig. 8** is the rear cross-section of this hull.

Polyester-fiberglass membranes were installed at selected locations[1] on each hull bottom. Deflections of these membranes when subjected to soil pressure, were transmitted to the cores of linear-variable differential transformers by brass rods moving inside 1/4" holes through the plastic foam so that surface pressures could be measured.

A strain gage bridge was used to measure the necessary pull to move the test hulls during field tests.

[1] Three pressure sensors were located at various longitudinal positions on the center line of the hull bottom, and three were located aproximately 0.26 m to the left of those on the centerline.

Fig. 7 Experimental hull with k = 1.5 during field tests (note bow wave, and the transducer used to measure towing force).

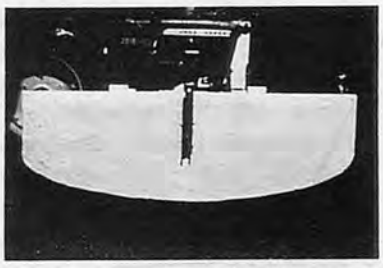

Fig. 8 Cross section of the tail of the experimental hull with k = 1.5.

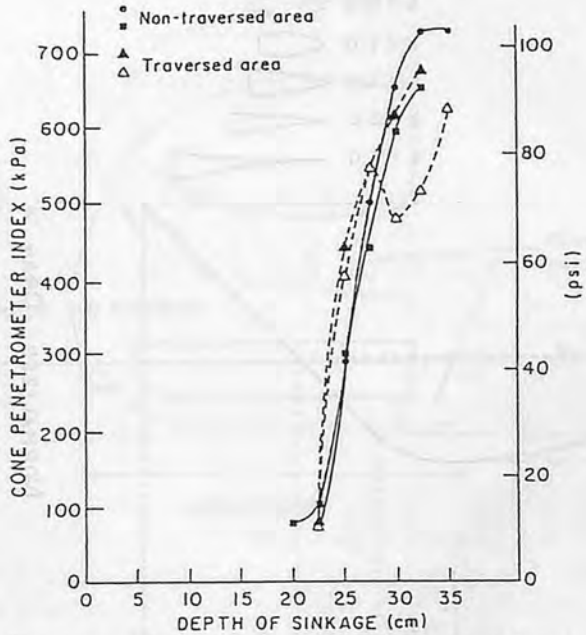

Fig. 9 Plot of soil cone penetrometer index values at various depths of penetration in the test field. The upper 22 cm layer of soil-water mixture was so soft that the penetrometer cone could not support the wight of the instrument (70 kPa or 10 lb/in^2).

The test plot measured 60 m long and 13 m wide, it was rototilled while dry to a depth of about 22 cm and kept flooded with 5-7 cm of water above the soil level.

The soil was a Yolo silty clay (46% clay, 48% silt, and 6% sand).

The soil-water mixture density was determined by collecting core samples having a fixed volume of 100 cm^3. The results were as follows:

soil-water mixture density = 1784.0 (standard deviation = 22.0) kg/cm^3; porosity = 57.4% (std. dev. = 2.4%); moisture content based on dry weight = 47.8% (std. dev. = 3.1%).

A modified "Cohron-sheargraph" was used to determine the soil shear strength data and the hull-soil interface friction properties at different normal loadings; Two annular shear-rings were used:

the grouser type ring was used to determine the shear strength of the soil-water mixture; the smooth ring, made of Masonite board coated with finish polyester resin, was used to determine the soil-hull interface properties.

The maximum soil shear strength, τ_s, and normal stress, σ_n, were determined to be as follows:

$\tau_s = 0.1\ \sigma_n + 1.620$ (kPa) (grouser ring)

$\tau_s = 0.03\ \sigma_n + 0.372$ (kPa) (smooth ring)

A cone penetrometer was also used to map the soil strength variations with depth (**Fig. 9**). The upper 22 cm layer of soil-water mixture was so soft that the penetrometer tip could not support the instrument weight (70 kPa or 10 lb/in^2).

The test hulls were pulled by a tractor via a steel cable (1/8" dia.) during field tests (**Fig. 7**). Each hull was subjected to a combination of 3 experimental factors, at 2 levels each:

weight: 5783 N and 8852 N; speed: 0.805 km/h and 4.023 km/h; center of gravity position (0.305 m aft, and 0.305 m forward of the longitudinal center of buoyancy).

Thus there were 8 possible combinations of weight, C.G. position and speed, furthermore each combination was replicated 3 times so that each hull would have 24 pull tests.

Analysis of Drag Data

The drag data points considered in numerical evaluations were those taken at the higher peak of the drag data trace close to the beginning for each test run. (**Table 1** contains the average values of drag data.)

A statistical analysis of variance was performed on the natural logarithm of the drag values. The results were as follows:

a) "weight", "speed" and "shape" were the main effects, *ie*

– the drag would increase with increasing weight;

Weight	Average Drag
5783 N	1575 N
8852 N	2442 N

Speed	Average Drag
0.805 km/h	1535 N
4.023 km/h	2482 N

– the drag would increase with increasing speed; and

– the "shape" effect will be examined in more detail in a later section.

b) The only statistically significant 2-factor interaction was between speed and shape, but this interaction was also modified by the position of the C.G., as shown by the presence of a 3-factor interaction "position-speed-shape". **Figs 10A and B** show the 3-factor interaction "position-speed-shape": the position "C.G. Forward" was more sensitive to speed than the position "C.G. Aft" (based on averages for the 3 hull shapes).

Table 1 "Average Drag ± Standard Deviation" Values for the Whole Experiment (in N)

	W = 5783 N				W = 8852 N				Overall Average
	C.G. Forward		C.G. Aft		C.G. Forward		C.G. Aft		
	L.S.	H.S.	L.S.	H.S.	L.S.	H.S.	L.S.	H.S.	
k = 0.0	966 ±118	1965 ±222	1085 ±276	2042 ±342 (*)	1459 ±107	3633 ±888	2117 ±386	2650 ±488	1990
k = 1.0	1111 ±250	2574 ±95	1412 ±288	1723 ±467	2138 ±630	5169 ±264 (*)	1920 ±485	2637 589	2336
k = 1.5	1371 ±366	1560 ±189	1068 ±118	2016 ±617	2254 ±289	1779 ±378 (*)	1557 ±89	2016 401	1703
Overall Average	1149	2033	1188	1927	1950	3527	1865	2434	

* = only 2 drag values were used in averaging; W = weight; C.G. = center of gravity; L.S. = low speed; H.S. = high speed.

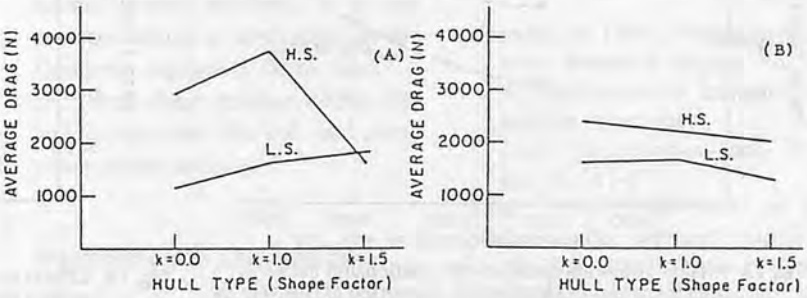

Fig. 10 Plot (A) above of the drag forces as the three hulls, all having the center of gravity forward of the center of buoyancy, shows large drag force differences between low and high speed tests, while these differences are smaller in plot (B) below in which the center of gravity was rearward of the center of buoyancy.

Comparison between Hull Shapes

To determine which hull would be best, a different statistical method was used. Only one firm conclusion could be drawn; that is that the hull with k = 1.5 was best only for the following conditions:

a) weight = 8852 N (*ie* close to design weight of 9806 N); b) center of gravity forward of center of buoyancy; c) high speed regime.

No firm conclusion could be made about the other combinations of conditions, or about the comparison between hull k = 0.0 and k = 1.0.

Drag Force Analysis with Buoyancy Taken into Account

In the previous statistical analyses, the free water level on top of the field was considered to be a random effect; alternately, the following analysis used an estimation of the buoyancy effect (due to this free water level only) and its cancellation from the hull gross weight to get the net weight supported by the soil-water mixture below (*at the start of each pull test*).

The portion of the hull volume occupied by the sheet of free water on the field surface was computed, thereby determining the resulting *static buoyancy force* acting on the hull; of course, this was only an estimation of the buoyancy effect, valid only when the hull was at rest or just starting to move. The resulting values are given in **Table 2**.

Data from **Table 2** were used to plot **Figs. 11 through 13** to illustrate the gross effects of hull shape

Table 2 Ratio of Drag Force to Hull Weight Supported by Soil

Shape Factor	Hull Weight = 5783 N				Hull Weight = 8852 N				Average
	C.G. Forward		C.G. Aft		C.G. Forward		C.G. Aft		
	Low Speed	High Speed	Low Speed	High Speed	Low Speed	High Speed	Low Speed	High Speed	
k = 0.0	0.231*	0.407	0.328	0.451	0.202	0.461	0.260	0.343	0.335
k = 1.0	0.249	0.737	0.405	0.412	0.327	0.681	0.263	0.343	0.427
k = 1.5	0.283	0.375	0.317	0.509	0.275	0.298	0.255	0.283	0.324
Average	0.254	0.506	0.350	0.457	0.268	0.480	0.259	0.323	0.362

	C.G. Forward		C.G. Aft		All Data		All Data	
	Low Speed	High Speed	Low Speed	High Speed	Low Speed	High Speed	W = 5783 N	W = 8852 N
Average over all three hull shapes	0.261	0.493	0.305	0.390	0.283	0.441	0.392	0.332
	0.377		0.348					

*Each figure represents an average from three test replicates.

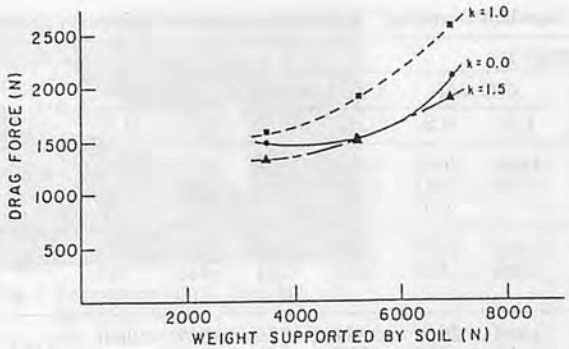

Fig. 11 Effects of hull shape on the relationship between drag force and hull weight supported exclusively by the soil.

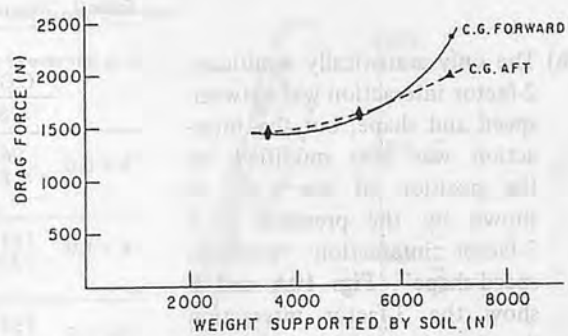

Fig. 12 Effects of center of gravity position on the relationship between drag force and hull weight supported exclusively by the soil.

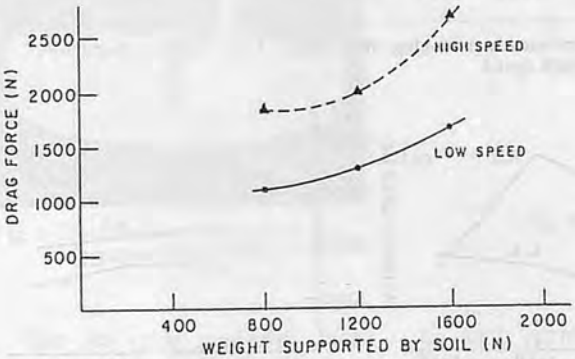

Fig. 13 Effects of towing speed on the relationship between drag force and the hull weight supported exclusively by the soil.

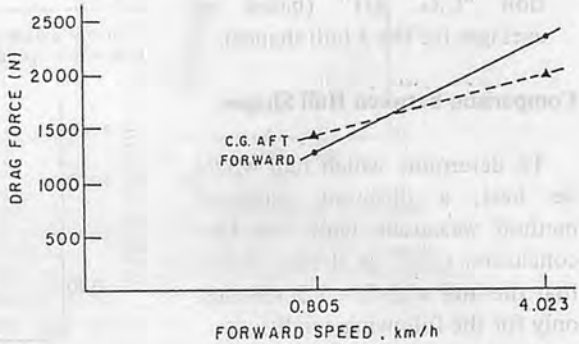

Fig. 14 Effects of the center of gravity position on the response of drag force to increases in towing speed.

(k values), speed and of center of gravity position. These data were also used in plotting **Fig. 14** to examine the interaction between speed and center of gravity position.

Analysis of Pressure Data

The primary trend observed upon anlysis of the data from the hull pressure sensors was that *an increase in drag was accompanied by a decrease in hull pressure and vice-versa.* This was especially true for all the pressure sensing stations along the keel line, while those stations further to the sides did exhibit some pressure increases.

It was, therefore, hypothesized that this outward pressure shift might be explained by the fact that, because of the imposed maximum sinkage z_m condition, each test hull pushed the soil outward more than downward when it was pulled across the field, so that higher pressures had to be present around the hull edges to do this soil-pushing work. Consequently, pressure concentration at the edges of the hull would cause the interior points of the hull to be subjected to reduced normal pressures since the gross weight supported by the hull remained constant.

Discussion of Results

If the above hypothesis was true, *i e*, drag forces were related to the presence of high normal pressure forces around the edges of the hull, then the apparent wedge angle of the front of the hull[2] would be an important factor:

a) A smaller wedge angle would correspond to a smaller streamwise component, therefore, to a smaller drag force.
   This might explain why the hull "k = 1.5" had the smallest drag of the 3 test hulls, as it had the smallest wedge angle (21.24°).
b) The difference in wedge angles between the hulls of k = 0.0 and k = 1.0 (41.12° − 36.12° = 6°) was smaller than a similar difference between the k = 1.0 and k = 1.5 hulls (36.12° − 21.24° = 14.88°) which would tend to explain why the difference between the hull "k = 0.0" and the hull "k = 1.0" was not statistically significant.
c) The results of the program design sequence adopted (Thai, 1983) reflect the fact that the optimal shape factor k was always greater or equal to 1.5, because when k ⩾ 1.5, the maximum cross-section would occur at the very stern of the hull, thus giving the smallest possible wedge angle.

Hegedus (1958) performed a series of tests towing rigid wheels in viscous mud and reported that the wheel with a *parabolic cross-section* produced a lesser motion resistance when compared to the one with a *rectangular cross-section* or the one with a *"tire-shape" cross-section.*

[2] The wedge angle may be determined by constructing a triangle on the plan projection of each hull using the front hull tip and the endpoints of the maximum beam.

The U.S. Army (1959) also reported some results of sled-towing tests in soft soils. These data for cone index values from 140 to 560 kPa gave ratios of towing force to sled weight ranging from 60 to 87% for very sticky soils and from 23 to 68%[3] for non-sticky soils. The performance of the hulls tested in this study (mean ratio value = 36%) tended to be somewhat better than might have been anticipated from the U.S. Army information and the cone index values shown in **Fig. 9** for this study.

The finding that having the center of gravity to the rear of the center of buoyancy tended to give lower drag increases with speed than with the center of gravity forward of the center of buoyancy, were similar to results found by other researchers:

a) Shah (1980) did pull tests similar to those in this study but with flat and ski-type floats. He also reported that by moving the center of gravity to the rear, lower levels of drag would be obtained.
b) Wang and Zhu (1980) also recommended that boat-tractors should have the bow lifted up while working in the field to reduce motion resistance.

The position of the center of gravity relative to the center of buoyancy also influenced the formation of the bow wave on the free surface of the water layer present in the test plot (**Fig. 7**). The center of gravity position forward of the center of buoyancy (as opposed to rearward of the center of buoyancy) gave a larger bow wave, occurring further away from the hull bow. Thus for the *same ground speed, more energy* was spent in making a bow wave *further away* from the hull, when the center of gravity was forward of the center of buoyancy than when it was aft: indeed it appeared that the wasted energy was manifested in the form of a higher drag – particularly at high speeds.

The finding that the average ratio of drag force to soil-hull normal force was lower for the high hull weight case than for the low hull weight case gives credence to the concept that in wet clay soils a certain portion of the drag is related to the area of soil-hull contact – irrespective of the normal forces involved. It is this concept which is embodied in the Coulomb equation form used to represent shear stresses within the soil or between the soil and some other sliding surface.

Summary and Conclusions

This study presents a first-order approximation in the assessment and minimization of the forces involved in moving an equipment-supporting buoyant hull across a field of viscous mud:

1. Computations indicated that the most efficient hull shape was one which used an elliptical cross-section.
2. Of the three hulls field-tested, the one with the maximum beam at the rear, *i e* with 1.5 = k = (length x submerged cross-sectional area at rear)/displaced volume), gave the lowest drag, about 32% on the average, of the soil-supported weight.
3. When the center of gravity was forward of the center of buoyancy, the drag increased more rapidly with speed increases than when the center of gravity was rearward of the center of buoyancy.
4. Drag, on the average, at 0.8 km/h was 62% of that at 4.0 km/h.
5. Drag forces, on the average, tended to increase approximately linearly with increases of weight on the hull.
6. Contact pressures between the mud and the hull center-line tended to decrease as drag forces increased. This is believed to have been due to increased pressures at the lower outside edges of the hull, pressures necessary for displacing the mud laterally under high drag-force conditions.

[3] At the lowest cone index values given by the U.S. Army (1969) a 30% ratio for very sticky soils of 70 kPa cone index, and a 13% ratio for non-sticky soils of 100 kPa cone index were reported.

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Energy Conservation in Mechanized Agriculture in Chile

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Abstract

The effects of 5 conservation practices upon energy consumption and potential savings while performing field operations are analyzed. Results show that massive fuel savings can be obtained by means of rational tractor selection, adequate tractor-implement matching, use of the gear up-throttle down concept, proper tractor ballasting and reduced tillage systems.

Introduction

The energy perspective of Chile is moderately acceptable. This condition can be improved because the country has primary energy resources that are relatively abundant for its size and development. Among the more important resources are hydroelectricity, coal, oil, and forest residues.

However, the country depends heavily on imported oil. Of the total energy used in Chile in 1981, 40% was produced from this source at a cost of US$900 million. Five years ago this percentage was even larger (CNE, 1983).

Global energy consumption has grown from 111 330 to 192 500 barrels of oil daily and from 5.46 to 6.23 oil barrels per person per year, between 1960 and 1981. The trend of this consumption shows a continuous growth in the use of oil and natural gas and a steady decline for coal and wood (CNE, 1983).

Energy use in the agricultural and forest sectors of the economy has been estimated by Pinto *et al* (1983) to be near 2.67×10^{12} kcal per year in the primary production phase only. Fuel and nitrogen fertilizer consumption account for 38.4% and 33.0% of the total energy consumed in production and agriculture, respectively. In the exploitation of forests 57.8% of the energy used corresponds to fuel.

One of the major conclusions of the Chilean Commission of Energy in Agriculture (CNE, 1983) emphasizes the need to research and develop energy conservation systems through reduced tillage, rational tractor and machinery selection and adaptation, appropriate technology for small farmers, increasing the efficiency in the use of fertilizers, fuel and the maintenance of machines.

The objectives of this paper are: 1) to analyze five energy conservation practices to stimulate their use in mechanized agricultural operations, and 2) to quantify their effects upon the potential savings of diesel fuel at farm, regional or national levels.

Energy Conservation in Field Operations

There are several actions to be taken without large costs that help energy consevation in field operations. Most of them should be rather obvious to farmers with good judgement and common sense. Some of the more important are the elimination of waste and lossses in the transportation and handling of fuels and lubricants; to reduce evaporation and quality losses in fuel storage; to keep engines well tuned and timed; to establish adequate repair and maintenance programs; to achieve high field efficiency through adaptation of field sizes and shapes; and to carry out tillage and seeding operations at a soil moisture slightly below field capacity (Helsel and Oguntunde, 1981).

It is also very important to select and adequate working depth and speed for the tractors. White (1975) points out that energy consumption increases from 65 to 103 HP-h/ha when tractor speed increases from 4.8 to 9.6 km/h, in the case of the moldboard plow. Another fact to consider is the energy consumed by similar implements. For instance, a chisel plow demands only 4 to 6 kN/m as compared to the 14 to 16 kN/m needed by a moldboard plow (Stephens *et al*, 1981).

However, there are other practices which can produce a much larger effect upon energy conservation in field operations:

Tractor Selection

The selection of a tractor is a complex problem, including several economic and technical factors. From an energy conservation point of view it is very important to analyze the fuel efficiency (HP-h/*l*) of each tractor make and model. This parameter is normally informed in the reports provided by the various international tractor testing stations.

Koelsch (1979 a) and Rider (1979) point out that fuel efficiency has become one of the most important factors in tractor selection since it will determine the fuel expenses of a farmer for the next 10 to 15 years.

Posselius *et al* (1980), analyzed the fuel efficiency of different models of tractors sold in USA and manufactured between 1967 and 1980. Their results show that the most efficient tractor (3.90 HP-h/*l*) has a performance 60% superior to that of the least efficient (2.43 HP-h/*l*). The performance of the least efficient tractor was 26% inferior to the mean of all the models considered (3.30 HP-h/*l*).

In Chile, Lorca and Hetz (1983) found a difference of 23% between the most fuel efficient tractor (3.74 HP-h/*l*) and the least efficient (3.04 HP-h/*l*) of the tractor models with a Nebraska Tractor Test sold in that country. The performance of the least efficient tractor was 10% smaller than the mean of all the models analyzed (3.39 HP-h/*l*).

Only diesel tractors are sold in Chile and this fact explains the smaller variation in fuel efficiency as compared to that reported by Posselius *et al* (1980) who included gasoline and LP gas tractors.

To estimate the fuel savings that can be achieved in Chile through proper tractor selection is to consider two representative tractors of similar power (45.6 and 46.4 drawbar HP) and their respective fuel efficiencies (3.12 and 3.40 HP-h/*l*). Assuming a 15 year useful life with 800 h/year of work and using Equation (1) (Posselius *et al*, 1980) their respective total fuel consumption can be calculated.

l/year = [Max. Drawbar HP x Hours/year] / [Fuel efficiency (HP-h/*l*)] . . . . . (1)

The results show that the farmer who buys the more fuel efficient tractor, will save 11 620 *l* of diesel fuel equivalent to approximately US$4,648 in Chile (November, 1983).

Tractor-Implement Matching

White (1977) and Cromwell (1976) emphasized the importance of properly matching tractor horsepower and farm implement size. Implements that are too small will tempt the operator to work at unsafe speeds resulting in excessive implement wear and breakdowns. Implements that are too large for the power available will cause excessive tire slippage and wear and tractor overloading with a high incidence of breakdowns. In both cases the fuel efficiency and quality of work are reduced.

However, in farms are normally found a wide variety and range of implement sizes, which makes it very difficult to make an ideal tractor-implement matching. The objective in this case should be to establish the best match between the tractor and the majority of the heavy draft implements. For the lighter implements the gear up-throttle down concept can be used. If the farmer has more than one tractor, he should plan to use the smaller tractor with the lighter implements.

Tractor-implemant matching is especially important in PTO-operated machines which should work at the manufacturer's rated speed. According to Cromwell (1976), a tractor working at rated speed but loaded to 45% of its power will produce only 80% (70% in gasoline engines) of the work that can produce at rated load per *l* of fuel.

Equation (2), adapted from ASAE (1982), can be used to estimate the average annual diesel fuel consumption of a tractor:

l/year = 0.166 (*l*/HP-h) x Max. PTO x H/year . . . . . .(2)

Considering a 60 HP tractor, the assumptions used in "Tractor selection", and the proposition of Cromwell (1976), the fuel savings obtained with a proper tractor-implement matching can be estimated at 23 904 *l*, representing approximately US$9 562 in Chile.

Gear Up- Throttle Down Concept

Tractors should be operated near their rated capacity to obtain maximum efficiency. However, only plowing and disking demand total power from the tractor, the rest of the time the tractor works only partially loaded. In the performance of these light operations fuel savings, in the order of 15 to 30%, can be obtained by reducing engine speed to about 80% of rated speed and shifting to a higher gear to maintain the desired field speed (Koelsch, 1979 b; Shelton and Von Bargen, 1977).

The Nebraska Tractor Test includes two trials at 50% load in which the same drawbar power is obtained: one with the engine at rated speed and the other at reduced speed in a higher gear. The results, shown in **Table 1**, confirm the fuel savings predicted earlier. At reduced speed and higher gear fuel consumption was 18% smaller and fuel efficiency improved 22%.

The Nebraska Tractor Test includes also another test which determines the tractor's lugging ability, which is the capability of an engine and transmission to withstand momentary overloads by increasing pull with reduced engine speed. Results from this test can also be used to predict the behavior of the tractor when using the gear up-throttle down practice.

Table 1 Average Performance of 15 Diesel Tractors in the 35-68 Drawbar-HP Range.

Test 1: 50% pull at rated engine speed	
Drawbar power (HP)	27.90
Fuel consumption (*l*/h)	9.25
Fuel efficiency (HP-h/*l*)	2.99
Test 2: 50% pull at reduced engine speed	
Drawbar power (HP)	27.90
Fuel consumption (*l*/h)	7.60
Fuel efficiency (HP-h/*l*)	3.65

The use of higher gear and reduced engine speed is recommended for loads requiring no more than 65% of the tractor's rated power. The most important fact to remember is not to overload or lug the engine. Confirmation of proper engine loading can be obtained by opening rapidly the throttle to which the engine should respond with a ready pick up of speed. Visible black smoke may be an indication of an overloaded diesel engine.

There are, however, two limitations to this practice related to engine speed reduction: 1) PTO speed is correspondingly reduced, and 2) reaction time of the tractor hydraulic system is slower.

Tractor Ballasting

Fig. 1 shows that the amount of wheel slippage needed to obtain the maximum available drawbar power varies from 10% in a firm soil to 15% in a sandy soil. Too little slippage overloads and stresses the transmission and drive train of the tractor; too much slippage causes excessive tire wear and fuel waste. In both cases the available drawbar power is smaller (Koelsch and Daum, 1978).

Slippage can be determined using Equation (3). If wheel slippage is 5% or smaller, weight should be eliminated and when slippage is 20% or larger, weight should be added.

Slip (%) = (1 – Distance travelled loaded / Distance travelled unloaded) x 100 . . . . . .(3)

Wight control upon the drive wheels of tractors and the development of an optimum slippage greatly improves their tractive efficiency (TE), resulting in large fuel savings. Taylor (1981) analyzed this problem in USA and estimated that the average TE of tires in that country was 46%. He concluded that about 300 million *l* of fuel could be saved yearly if the TE could be improved to 47%.

Considering 30 000 tractors, with an average of 55 PTO horsepower working 800 h/year, and using Taylor's methodology the Chilean situation can be summarized in Table 2.

Table 2 shows that improving the TE by 1%, from 40 to 41%, fuel savings of 3.95 million *l*, equivalent to US$1.58 million could be achieved. It should be pointed out that as the TE improves the potential for fuel savings decreases, hence the importance of improving the TE in countries where it is rather poor.

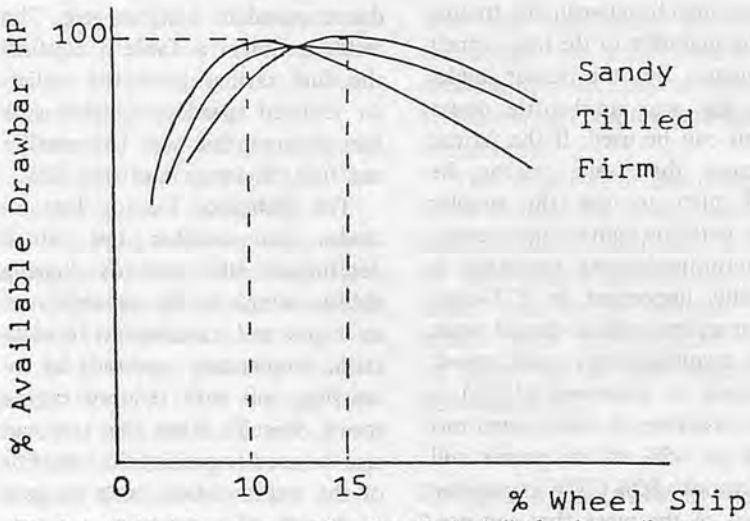

Fig. 1 Available horsepower as a function of wheel slip for three soil types.

Reduced Tillage Systems

Many authors agree that reduced tillage systems make possible energy savings of up to 66% of the fuel used in crop establishment (Wittmuss *et al*, 1975).

Twenty years of research in tillage systems at the Agricultural Engineering Department of the University of Concepción in southern Chile (Anselmo, 1975; Ibañez, 1980) and by others elsewhere in the country (Rojas and Soza, 1982) show the many advantages and energy conservation potential of these practices.

Research results confirm that: a) reduced tillage systems do not alter yields significantly (except for maize after wheat); b) they drasti-

Table 2 Annual Diesel Fuel Consumption and Potential Savings at Various Levels of TE for 30 000 Tractors in Chile.

Tractive efficiency %	Total fuel consumption ($l \times 10^6$)	Decrease in fuel consumption for 1% increase in TE (litres x 10^6)
100	64.80	–
99	65.45	0.65
90	72.00	0.79
66 a)	98.18	1.46
50	129.60	2.54
47	137.87	2.87
46 b)	140.87	3.00
45	144.00	3.15
40 c)	162.00	3.95
39	166.15	4.15
30	216.00	6.97

Remark: a) Estimated average TE for tracks (USA); b) Estimated average TE for tires (USA); c) Estimated average TE for tires (Chile).

cally reduce fuel consumption, production costs, soil compaction and erosion; c) they improve the moisture regime and increase the intensity of use of the soil.

There are, however, two major drawbacks with these systems, especially in their extreme expression of zero tillage: a) they demand a more intensive use of herbicides and pesticides, b) they demand excellent farm management and qualified farm machinery operators.

Anselmo (1975), evaluated more than 10 years of research in the province of Ñuble. He concluded that the replacement of the conventional system by reduced tillage systems in that province would generate savings sufficient to acquire 500 tractors per year (more than US$8 million).

Ibañez (1980) analyzed fuel consumption and potential savings in the 75 000 ha of wheat grown yearly in the province of Ñuble. He concluded that nearly 3 million *l* of fuel could be saved annually by using the plow-plant system (Table 3).

Ibañez (1980) compared the conventional system which uses 6 field operations with three reduced tillage systems: RT 3 (3 field operations); RT 2 (2 field operations); RT 1 (1 field operation). Conventional = plowing; 3 diskings; seeding; packing. RT 3 = plowing; disking; seeding + packer. RT 2 = plow + packer + plank; disking + seeder. RT 1 = plow + packer + seeder.

At the national level, Rojas and Soza (1982) estimate that fuel savings could exceed 100 million *l* per year, if all the area with annual crops and artificial pastures was treated with the zero tillage system (Table 4).

Conclusions and Recommendations

1. Chilean agriculture appears highly dependent upon petroleum energy and other non-renewable resources. Fuel consumption stands at 38.4% and 57.8% of total energy consumed in the agricultural and forest sectors, respectively.

2. Rational tractor selection, using information about their fuel efficiency (HP-h/*l*) provided by tractor testing stations, can save large quantities of diesel fuel (11 469 *l*/ 12 000 h) in tractors of power representative of the Chilean conditions (46 drawbar HP).

3. Matching tractor power to farm implement size can generate diesel fuel savings of up to 20%, which for a 60 PTO horsepower tractor represents 23 904 *l* during its useful life.

4. The use of the gear up-throttle down concept, for loads up to 65% the rated horsepower of the tractor, can generate fuel savings of 15 to 30% and improve diesel fuel efficiency by 20%.

5. The development of an optimum amount of slip (10 to 15%), through adequate ballasting, can effectively improve the tractive efficiency (TE) of tractors and other self-propelled machines. If the TE of the 30 000 Chilean tractors was improved by 1%, from 40 to 41%, diesel fuel savings of 3.95 million *l*/year would be generated.

6. The adoption of reduced tillage systems can generate massive fuel savings in Chile. It has been estimated that reducing to 2 the field operations in the 75 000 ha planted yearly to wheat in the province of Ñuble alone would save more than 2 million *l* of diesel fuel per year. Moreover, if only 1 disking pass was eliminated on the 1.8 million ha of annual crops and artificial pastures, fuel savings would exceed 21 million *l*/year.

7. Considering the depletion of the non-renewable energy resources it becomes very important and necessary to adopt production systems based upon renewable energy resources. Therefore, researchers should develop alternative energy sources to replace fossil fuels and appropriate technologies based on animal traction for small farmers.

Table 3 Diesel Fuel Consumption and Potential Savings of 4 Tillage Systems in 75 000 ha of Wheat in the Province of Ñuble, Chile, May 1980.

Tillage System	Fuel Consumption		Fuel Savings
	Per ha (*l*)	Total ($l \times 10^6$)	($l \times 10^6$)
Conventional	66	4.95	–
RT 3	46	3.47	1.48
RT 2	38	2.85	2.10
RT 1	28	2.10	2.85

Source: Ibañez, 1980.

Table 4 Diesel Fuel Savings in Chile by the Elimination of Tillage Operations in 1.8 million ha of Annual Crops and Artificial Pastures. Unit: m^3/year

Percent Area	Eliminating 1 plowing	Eliminating 1 disking	Eliminating 1 plowing and 1 disking	Using zero tillage
10	3 600	2 160	7 920	10 080
20	7 200	4 320	15 840	20 160
30	10 800	6 480	23 760	30 240
40	14 400	8 640	31 680	40 320
50	18 000	10 800	39 600	50 400
60	21 600	12 960	47 520	60 480
70	25 200	15 120	55 440	70 560
80	28 800	17 280	63 360	80 640
90	32 400	19 440	71 280	90 720
100	36 000	21 600	79 200	100 800

Source: Rojas and Soza, 1982.

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Cocoa Drying and Storage Using Charcoal and Solar Heated Rocks

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Abstract

A cocoa dryer cum-storage using as much local material as possible has been designed. The dryer uses charcoal and the sun for its heating requirements for drying and storage.

Results of drying and storage experiments conducted with the equipment showed that cocoa has a critical moisture content of 50% and drying times from 46 to 10% moisture content were 22.5, 13.0 and 7.0 h for drying temperatures of 50°C, 75°C and 100°C, respectively, at 65% relative humidity and 45 m^3/min air flow rate. The moisture content, M variation with time, t was found to follow a logarithmic curve of the form $M = Ct^a$, where C and a are constants. Temperature rise of up to 100°C was possible with the rock bed heat storage part of the equipment and storage of up to 5 months was possible with the system.

Introduction

Bourne (4) defines post-harvest as the point at which grain, separated from the plant stalks or root, is bundled for field drying or placed in a container in which it is moved or held, or both. With this background definition, Baryeh (2) quotes post-harvest losses of cocoa and most West African root crops as 16% and 27%, respectively, while Mphuru (6) quotes an average of 20% for most grains. These figures are alarming.

In September 1975, the growing international awareness of the need for reducing post-harvest food losses culminated in a resolution of the Seventh Special Session of the United Nations General Assembly stating that "The further reduction of post-harvest food losses in developing countries should be undertaken as a matter of priority with a view to reaching at least 50% reduction by 1985" (5). The African Regional Centre for Technology too in its objectives, calls for a 50% reduction in post-harvest losses by 1985 (2). There is, therefore, an obvious need to properly dry and store farm products in developing countries to reduce post-harvest losses.

Post-harvest losses for cocoa occur primarily as a result of insect and rodent attack, micro-organism activities and moulding. Some losses occur during depoding, fermentation, handling and transportation but to a lesser degree. This study focuses on the reduction of post-harvest cocoa losses through the techniques of establishing an atmosphere to inhibit insect, rodent and micro-organism activities and mould growth. The method utilizes bio and solar energies.

Drying Equipment

A sketch of the dryer cum-storage equipment is shown in **Fig. 1**. It consists of a charcoal-fired plenum, a drying bin and a rock bed heat storage with or without a fan and engine unit.

The plenum which is bounded by red semi-argilous mud blocks is composed of six 58 cm diameter drums running parallel to each other. Each drum is 5 m long and is fabricated by welding four drums together at the ends. (The drums are used as containers of petroleum products and paint for export to developing countries. When the contents are used the drums can be purchased cheaply for the dryer construction.) Two sliding metallic trays are provided in each drum: one at the base and the other at the middle. The trays are made from scrap metal. This arrangement is illustrated in **Fig. 2**. The upper tray which supports charcoal for burning is perforated to facilitate ash release onto the lower one which is emptied regularly. Fifteen-centimeter air inlet holes are provided in the wall between the drums.

The dryer-cum-storage bin is constructed with heat treated, red, semi-argilous blocks to reduce the dryer cost. It measures 10 m by 5 m in section by 4 m high with the length running East-West. It is

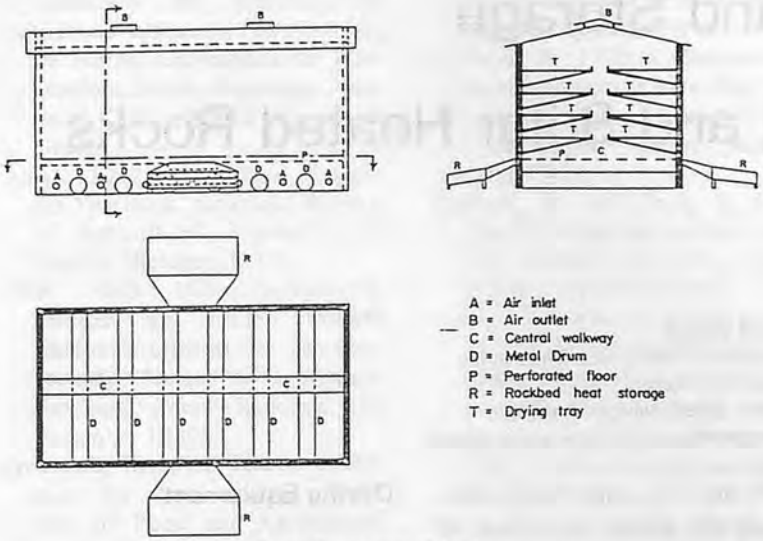

Fig. 1 Dryer-cum-storage

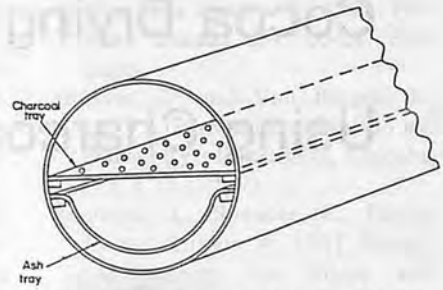

Fig. 2 Plenum drum, charcoal and ash trays.

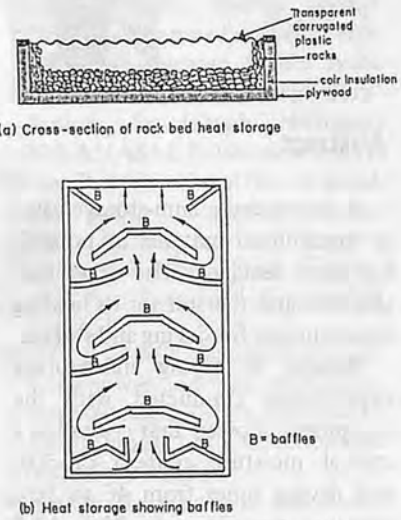

Fig. 3 Rock bed heat storage (not to scale).

smoothened on the inside to make the walls reflect heat into the bin rather than absorbing heat. A perforated floor separates the bin from the plenum. The dryer has a central 50 cm wide walk way. The false floor and walk way are strengthened with I-section bars. The bin is provided with a small access door and four pairs of drying wooden trays. Each tray measures 10 m by 2.25 m and there are two such trays separated 50 cm on each of four horizontal levels. The bin is roofed with clay tiles and two openings are provided for air outlet.

The rock bed heat storage comprises two 3 m by 1.5 m by 30 cm plywood boxes, blackened rocks, corrugated plastic sheet cover and wooden baffles. The sides and bottom of the box are made of two plywood sheets 3 cm apart with 21.3 kg of coir sandwiched between them. According to recent studies by Baryeh (3) this coir packing density gives optimum heat insulation. The average rock size is 3.5 cm. Rose and Rizk (7) found that edge effects on flow and temperature are reduced to negligibility if the ratio of container diameter or width to particle diameter is greater than 20. The storage is mounted at an angle of 20° to the horizontal to facilitate warm air draft in the system. The inlet of the heat storage is coincident with the rock bed section and the outlet above the top of the rocks for the same reason. They are provided with sliding wooden gates. A cross-section of the rock bed and the baffle positions are illustrated in Fig. 3.

Three versions of the dryer cum-storage system are possible. These are:

(1) Dryer cum-storage system without fans;
(2) Dryer cum-storage system with electric or gasoline powered fan; and
(3) Dryer cum-storage system with wind-driven fans located at the air exit in the roof.

The cost of the dryer is U.S. $1 500 (including labour cost) and it is expected to last at least 15 years if the rock bed plastic cover is renewed at 18-month to 2-year intervals.

Operation

In operation fill the drying trays about 5 cm deep with cocoa beans if forced air is not used and about 10 cm deep if forced air is used. Close the inlet and outlet of the rock bed and open the plenum air inlet holes. Put some charcoal on the charcoal tray and light it. Rake the cocoa beans with a wooden rake two or three times during initial drying to prevent beans from sticking together. Leave the system until cocoa dries to the desired moisture content.

Load the drying trays deeper during storage. Close the plenum air inlets and open the rock bed inlet and outlet. Aerate beans with air warmed by blowing through the rock bed. Alternately, let warm air move through the cocoa beans by natural convection and buoyancy. (Aeration may be done during the day or at night or both).

Test Performed

The moisture content of Amazonian Forastero variety of *Theobroma cacao* L. is commonly between 40% and 50% (wb) after

fermentation. About 4.0 kg of cocoa were wetted to more than 50% moisture content and were oven dried at 80°C and 70% relative humidity in a preliminary investigation.

A series of drying tests were performed with and without a fan. In one series, cocoa bean moisture content was measured as drying proceeded for drying temperatures of 100°C, 75°C and 50°C at a relative humidity and air flow rate of 65% and 45 m^3/min, respectively. The temperature profile in the drying trays were also monitored for a drying air temperature of 100°C. In another series, a pair of drying trays was filled with cocoa. The pressure drop across the cocoa depth was measured when the moisture content was 15% and 25%. The rock bed temperature profile was also measured during charging and discharging. Finally, the cocoa beans dried to a moisture content of 10% was divided into three parts. One part was stored in an open pan, another part in a jute bag and tied and the largest part in the dryer-storage equipment. The equipment was aerated every three or four days through the rock bed heat storage. The cocoa was inspected every three or four days. The average ambient relative humidity was 85%.

Temperatures were measured with copper-constantan thermocouples, air flow with an orifice and manometer, relative humidity with a sling hygrometer, pressure drop with an inclined manometer and moisture content by the oven method. Relative humidity was controlled with sodium chloride and silica gel. Charcoal of calorific value 200 MWh/m^3 was prepared from *Funtumia elastica* stem and branches.

Results and Comments

Results of the preliminary investigation (shown in **Fig. 4**) indicates that cocoa exhibits a critical moisture content of about 50% (wb). This means that for moisture contents in excess of 50%, the internal resistance of moisture transport is much less than the external resistance to water vapour removal from the cocoa bean surface resulting in a constant drying rate. When the moisture content falls below 50% the drying rate falls curvilinearly with time. This behaviour is also exhibited by potatoes, sugar beets (8) and cassava (1) at high moisture contents.

Fig. 5 shows the drying curves for the cases where fans are used and where fans are not used for drying air temperature and relative humidity of 75% and 65%, respectively. The air flow was maintained at 45 m^3/min. The results indicate that drying with a fan or blower from 46% to 12% moisture content under the above conditions takes 10 h less than drying without a blower. After 30 h of drying, the cocoa dried without a blower had 5% more moisture than the one dried with a blower. This is due to the extra high moisture extraction characteristics of the fan blown air. When a wind-operated fan is used, the drying curve is not smooth as its direction depends on the strength and frequency of the wind: steep when the wind is strong and shallow when the wind is still.

The moisture content variation with time for drying air temperatures of 50°C, 75°C and 100°C is shown in **Fig. 6** for a relative humidity of 65% and an air flow of 45 m^3/min. The Figure shows that the higher the drying air temperature, the faster the drying. Drying is fast during the first 5 h then it slows down. This is due to the fact that excess moisture is more easily detached from the produce at high moisture content. As the moisture in the cocoa diminishes, it takes a

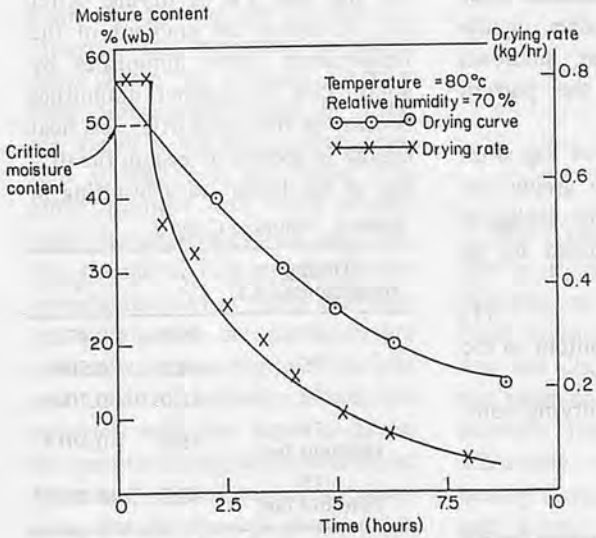

Fig. 4 Drying curve and rate showing critical moisture content.

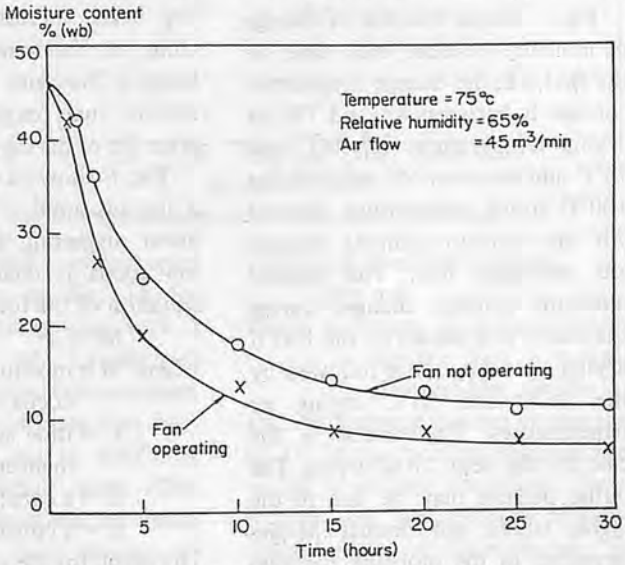

Fig. 5 Drying curves with and without fan operation.

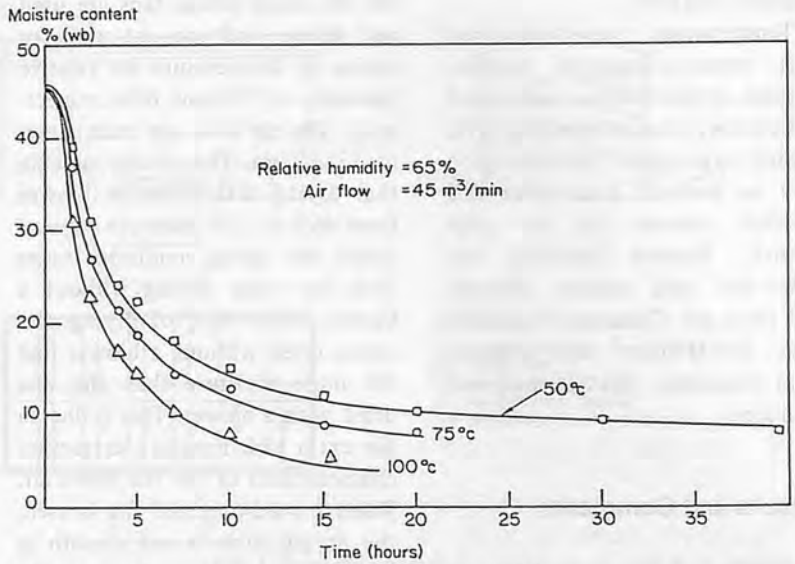

Fig. 6 Drying curve for different drying air temperatures.

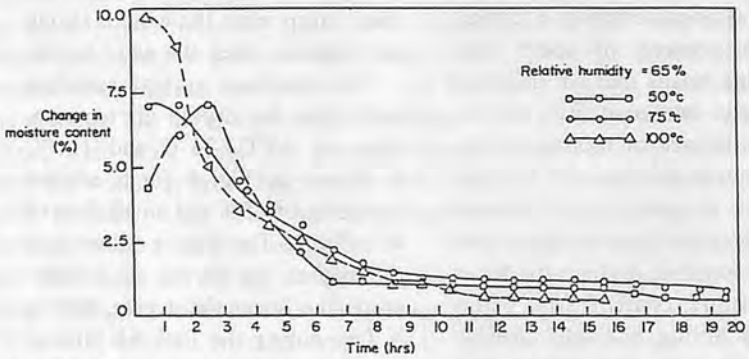

Fig. 7 Change in moisture content with time.

longer time to break the bond between the moisture particles and the cocoa beans.

Fig. 7 shows the rate of change in moisture content with time. In the first 4 h, the change in moisture content is between 4% and 7% for drying temperatures of 50°C and 75°C and between 4% and 10% for 100°C drying temperature. Beyond 7 h the moisture content changes are generally low. The highest moisture content changes during the first 2 h is shown by the 100°C drying air temperature followed by the 75°C and 50°C drying air temperatures. The reverse is the case for the next 2 h of drying. The initial pattern may be due to the higher kinetic and thermal energies imparted to the moisture particles by the high drying air temperature. As the moisture is released and reduced the energy needed to release the remaining moisture from the beans increases because they cling to the inner pores of the beans. This and other unknown factors may explain the pattern after 8 h of drying.

Fig. 8 shows a plot of Fig. 6 on a log-log graph. These graphs are linear suggesting that the drying of the cocoa is characterized by an equation of the form:

$$M = Ct^{a} \qquad (1)$$

Where M = moisture content in the cocoa

t = time since drying commenced

C = a constant

a = a constant.

The graph for the case where the air movement is by convection does not plot as a perfect straight line on log-log graph. This appears as broken lines in Fig. 8. It is, however, linear from 2½ h of drying onwards. From 0 to 2½ h of drying the curve is shallow and may be approximated to a straight line. Hence this curve may also be approximately described by equation 1. From the graphs, the values of C and a may be evaluated. These are shown in Table 1.

Fig. 9 is the temperature variation of the dryer as recorded in the middle of the trays. The temperature rise progresses gradually with time from one tray to the next. Thirty minutes after commencement of drying the temperature within the bottom tray is 49°C while the top tray hovers just above 40°C with the two intermediate trays at temperatures between 40 and 49°C. The bottom tray being closer to the heat source than the other trays receives more heat than the others resulting in its achievement of higher temperatures. As the heat passes through this tray some of the heat energy is expended in extracting moisture from the cocoa and some is absorbed by the cocoa itself and the material of the tray. Thus the heat that gets to the next tray is at a lower energy level. This pattern is maintained for the first 3 h of drying. After 3 h of drying the gradient of the temperature curve diminishes by about 55%. The gradient diminishes because as the cocoa dries, less heat energy is needed to sustain the drying of the lower trays resulting in

Table 1 Values of C and a

Drying temperature (°C)	C	a
50	45.5	−0.471
75	44.5	−0.569
100	42.0	−0.704
75 (without fan)	55.0	−0.491*
75 (without fan)	45.5	−0.263**

*Accurate for $t \geq 2.5$.
**Accurate for $t \leq 2.5$.

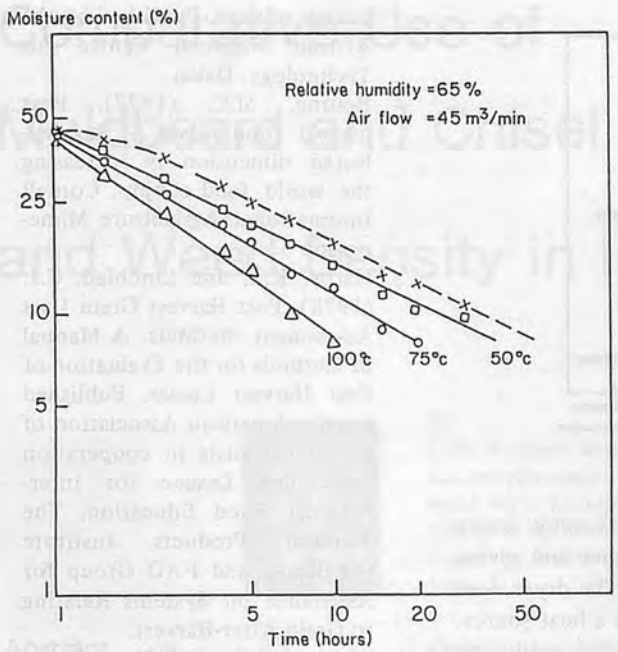

Fig. 8 A log-log plot of the drying curves.

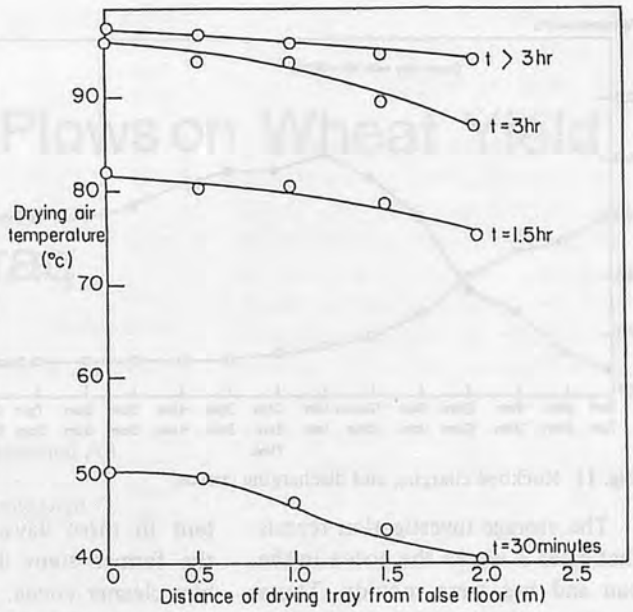

Fig. 9 Drying air temperature vs drying tray position. (Air-flow = 45 m³/min, RH = 65%)

more heat energy passing the lower trays to the upper trays. It is clear from **Fig. 9** that after 3 h of drying this phenomenon results in a reduction in the temperature difference between the top and bottom trays from 9.5°C to 3°C. Theoretically this difference is supposed to be zero after a long period of time when the system is in a thermodynamic equilibrium and under steady state.

The air flow rate variation with the pressure drop within the cocoa is shown in **Fig. 10**. It is clear from **Fig. 10** that the air flow increases with increasing pressure drop within the product. Pressure drop and corresponding air flows are higher when the moisture content is high and vice versa. The curve position will likely change with the air temperature and relative humidity. This may be further investigated. Other items that may be investigated are the moisture content variation with air flow rate and relative humidity, and the variation with the depth of cocoa for various drying temperatures, air flows and relative humidities. Operating the fan through photovoltaic cells is also worth investigating.

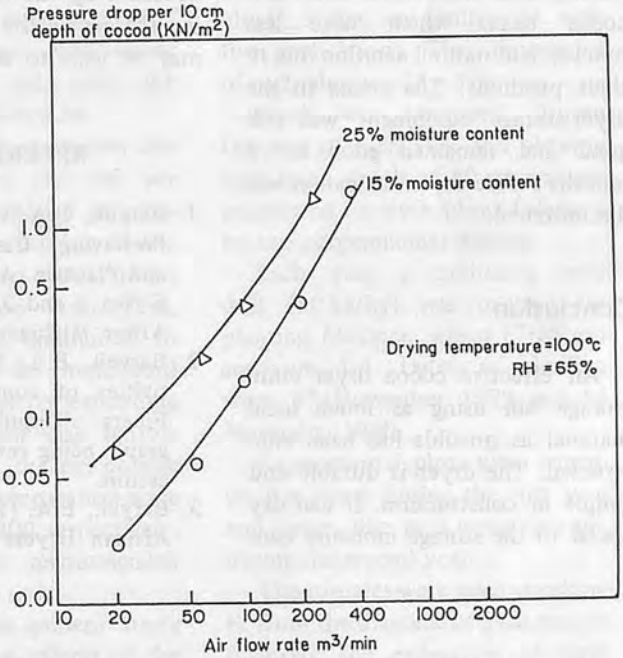

Fig. 10 Pressure drop across cocoa vs air flow rate.

The rock bed temperature profile is shown in **Fig. 11** for charging on a sunny day with a total insulation of 5.2 kWh/m²/day and discharging after sundown the same day. It is clear that temperature rise of up to 100°C is achievable on sunny days. This usually occurs between 12 noon and 2 pm. The heat energy, H stored in the rock bed may be calculated from the equation:

$$H = mst$$

where m = mass of rock; s = rock specific heat; t = temperature rise of rocks.

During discharge it takes an average of 8 h for the rock bed temperature to fall to ambient condition. These account for the effective storage characteristics of the equipment as discussed in the next paragraph.

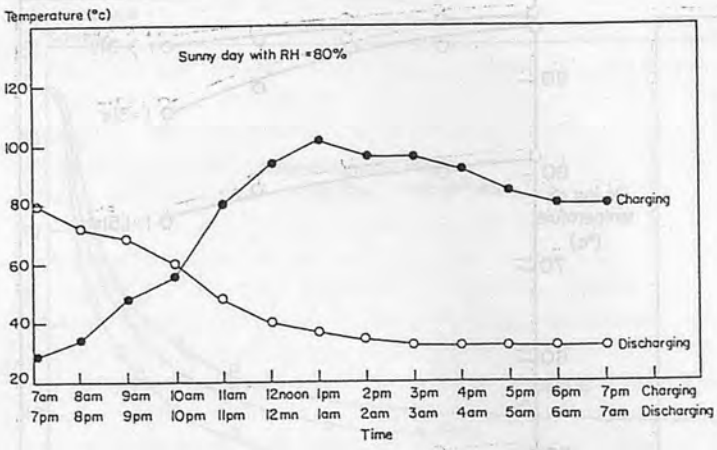

Fig. 11 Rockbed charging and discharging curves.

The storage investigation reveals that after 3 weeks the cocoa in the pan and bag were mouldy. Those on the surface in the pan and in contact with the bag were less mouldy than the others. These few cocoa beans which were less mouldy had natural aeration due to their positions. The cocoa in the dryer-storage equipment was still good and remained good for 5 months before the investigation was discontinued.

Conclusion

An effective cocoa dryer cum-storage bin using as much local material as possible has been constructed. The dryer is durable and simple in construction. It can dry cocoa to the storage moisture content in three days thereby saving the farmer some time and giving him cleaner cocoa. The dryer does not use fossil fuel as a heat source. The energy used can easily be obtained by the farmer. After drying the cocoa, the same equipment may be used to store the product.

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Comparative Use of Moldboard and Chisel Plows on Wheat Yield and Weed Density in Iraq

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Abstract

The suitability of various types of plows to Iraqi soils is a highly-debated issue. Some claim that the moldboard plow reduces productivity and suggest to use the chisel plow instead, while others still favor the former.

A field experiment was conducted at the Ameria Experiment Station, College of Agriculture, University of Baghdad, for two consecutive years where two types of plows (moldboard and chisel) were used in the preparation of seedbed for wheat while keeping all other parameters constant.

The statistical analysis of data reveals no effect for the type of plow on the yield of wheat and density of weed population.

Introduction

The introduction of mechanical power into Iraq was made throughout the past 40 years. Since the introduction of mechanical tillage practices sometimes fail as a successful input, the usage of various types of plows must be evaluated, and assessment attempts so far have been concentrated on expectations and theory.

Russel (1957) enumerated both the advantages and disadvantages of using the moldboard plow under Iraqi conditions and gave the chisel plow as an alternative.

Alkhafaf (1980) compared the size of soil lumps and the per donum costs of seedbed preparation resulting from the use of the moldboard and chisel plows; lumps with diameters less than 5 cm, which is favorable, amounted to 49% when using the moldboard and disk harrow. The corresponding value for chisel and disk harrow was 60%. Whereas, the per donum costs of seed-bed preparation were I.D. 1.000 and 0.900 respectively. Consequently, he recommended the latter practice.

The aim of the present study was to compare the effects of the moldboard and chisel plows on yield of wheat and the density of weeds under Iraqi irrigated conditions.

Materials and Methods

This experiment was conducted on clay loam soil at the Ameria Experiment Station, College of Agriculture, University of Baghdad for two consecutive years (1979-1981). A randomized complete block design was employed with five replications. The dimensions of each plot was 15 x 100 m.

Land was prepared during October of each year and plowing to a fixed depth of 20 cm was appropriated for both plows followed by one perpendicular disking.

Each year a calibrated seed drill (80 kg/ha) was utilized for planting Maxipak wheat (*Triticum aestiyum* L.). Dates of planting were 27 November 1979 and 24 November 1980.

Experimental plots were irrigated five times during the first year and twice, due to a wetter season, during the second year.

The samples were taken randomly from the diagonal of each plot to facilitate the estimation of yield components. The heads were threshed by hand to calculate the total weight of the samples which was converted into kg/ha. Data were analyzed statistically, using the t-test (Hayes and others, 1955).

Results and Discussion

Data on wheat and weed yield

(kg/ha) obtained for the two treatments (moldboard and chisel) are given in **Tables 1 and 2** respectively.

Although the mean of the wheat yield was higher when using moldboard treatment and the weeds are more abundant in the chisel treatment, statistical analysis of data on weight of wheat and weed seeds in the two treatments showed that differences were not statistically significant as shown in **Table 3**.

As the results show there is no significant difference in both treatments, hence it is recommended to use the chisel plow instead of moldboard plow for seedbed preparation in irrigated area in central Iraq for the following reasons:

1. The moldboard plow buries all vegetative material that may be on the soil. This material should be kept at the surface in Iraq to counteract the tendency of soil structure to collapse.
2. The moldboard plow buries the seeds of the annual wild legumes, hence interferes with their germination, and these legumes may eventually disappear. Iraqi soil needs them to help maintain its available nitrogen supply.
3. When the soil is dry, the moldboard plow tears up the soil in large, hard lumps. So they need some sort of additional tillage to reduce the sizes of these lumps. This additional tillage causes more soil compaction, destroying soil structure and increasing soil erosion.
4. The draft or power requirement of the moldboard plow is higher than that of the chisel plow, thus attributing to increased cost of seedbed preparation.

Table 1 Wheat Yield (kg/ha) for Moldboard (M) and Chisel (C) Plow Treatments*

Replicates	First Year				Second Year			
	(M)	(C)	(M-C)	$(M-C)^2$	(M)	(C)	(M-C)	$(M-C)^2$
1	4120	3960	160	25600	11948	10801	1147	1315609
2	6250	5105	1145	1311025	10646	9048	1598	2553604
3	6475	6450	25	625	9929	8533	1396	1948816
4	5850	5180	670	448900	10518	6931	3587	12866569
5	3670	3635	35	1225	4908	4908	3992	15936064
Total			2035	1787375			11720	34620062
Mean difference			407				2344	

*Each value is a mean of 10 samples

Table 2 Weed Seed Yield (kg/ha) for Moldboard (M) and Chisel (C) Plow Treatments.*

Replicates	First Year				Second Year			
	(M)	(C)	(M-C)	$(M-C)^2$	(M)	(C)	(M-C)	$(M-C)^2$
1	1065	1660	595	354025	1137	1171	34	1156
2	665	665	0	0	1663	1708	45	2025
3	700	790	90	8100	1141	2255	1114	1240996
4	875	1010	135	18225	1406	1551	145	21025
5	875	1150	275	75625	1430	1555	125	15625
Total			1095	455975			1463	1280827
Mean difference			219				292.6	

*Each value is a mean of 10 samples

Table 3 Comparison of Differences

Source of variation	Wheat		Weed	
	first year	second year	first year	second year
Standard error of a difference	489.68	1336.88	232.47	461.72
Standard error of the mean difference	218.99	597.89	103.97	206.49
Degree of freedom	4	4	4	4
t-value	1.86	1.75	2.11	1.42

*t-values for 4 degrees of freedom at: 0.05 = 2.78 and 0.01 = 4.60.

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Improved Disc Harrow with Solid Shaft and Casehardened Bush Bearings

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Introduction

A disc harrow is used to pulverize the top soil, level the ground to some extent, destroy the weeds and mix the trash with top soil. When operated before ploughing, it helps in breaking the soil surface and mixing the surface residues with the top soil. If operated after ploughing, it breaks the clods and closes air space in between the turned furrows.

Disc harrows can be classified as single-action or double-action based on their working principles. Double-action disc harrows can be further classified as tandem or offset type disc harrow. All these disc harrows have more or less one common feature. They have a number of discs mounted either on a tubular pipe, solid shaft or an arbour bolt and kept in proper relationship to one another by means of spacers known as spools. The arbour bolt is secured to a frame with two or more supports with bearings. The variation in design is mainly due to the type of shafting which supports the discs and the type of bearing used. The most common arrangements are

1) Bearings mounted on spools (spacers) between disc blades.
2) Enclosed tubular or oil bath type.
3) End mounted bearings.

Spool-mounted bearings may be of self-aligning anti-friction type or may be plain bush bearings. Bush bearings may be made of chilled cast iron or other wear resistant materials. In end mounted system, sealed anti-friction bearings are placed in self aligning housings. Tubular oil bath type design consists of a pipe in which the discs are mounted. Bearings may be of either plain or anti-friction type. They are supported inside the pipe or tubing and connected to the frame by means of axles.

Selection of the proper bearing system in a harrow is important from the point of view of harrow durability. This is because the bearings are subjected to forces of considerable magnitude. Also, the bearings are operated under dusty conditions hence proper sealing of the bearings is important in order to ensure its long life. However, little work has been done to evaluate the durability of different designs of harrows and their actual availability in the farm during use.

Bainer *et al* (1963) reported that bearings made of oil-impregnated wood were common in the past. The end thrust was taken through matching collars and grooves. However, since these bearings ran in contact with dust, their wear was rapid. Anti-friction bearings were more expensive, however, better sealing would have resulted into a reduction of lubrication problem and longer life. This was true both in spool-mounted and end-mounted arrangements. For the tubular oil bath type, the bearings in oil bath had less wear because the friction load of the bearings under these conditions was a small part of draft and there was little justification for added cost of anti-friction bearings in tubular arrangement. Turner *et al* (1948) had reported that chilled cast iron was also used for bearings which, however, were not very durable. He reported that durable bearings were made of white iron with double thrust flanges. The flanges carry the

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weight of the harrow and reduce side play.

In the experimental farm of the Indian Veterinary Institute (IVRI), Izatnagar, fodder farming is done throughout the year and hence it is necessary to carry out tillage operations all the year round. The durability of a harrow is important in such a farming system. A tubular oil bath harrow was widely used in the farm due to its low cost, simplicity of design, availability of parts, etc (**Fig. 1**). However, this harrow had frequent breakdowns and as a result it was necessary to keep a few extra harrows always in reserve. Also, in order to carry out the repairs, it was necessary to disassemble the entire harrow gang which was cumbersome and time-consuming. Hence, in order to introduce a more durable harrow, the following work was done:

1) Performance evaluation of a tubular oil bath harrow both for its durability and its field performance. In field performance tests, both the quantity of soil manipulated and the quality of field operation were considered.

2) Development of an improved harrow with a view to increasing its durability and provide easy access to critical parts for necessary repair and maintenance.

3) Performance evaluation of the improved harrow and its comparative study with tubular oil bath type harrow.

Development of Solid Shaft Casehardened Bush Bearing Harrow

A solid shaft harrow with casehardened bush assembly was developed (**Fig. 2**) to minimise the breakdowns and increase the life of the harrows. Modifications were made on the harrow designed by a local firm. The harrow was almost similar in the size of discs, spools and frame to the tubular oil bath harrow used for the study. However, changes were made in the shafting and bearing system of the harrow. A solid axle of 65 mm diameter was used for the mounting of spools and discs in place of a pipe. The shaft has a cross-section of 33 mm diameter at both ends to accommodate a casehardened bush assembly. The details of the assembly are shown in **Fig. 3**. A side view of the harrow is shown in **Fig. 4**.

The spools and the discs of the harrow were secured by two checknuts at one end and by a flange at the other. The ends of the shaft were tapered in such a way that they could accommodate a case carburized bush with a tapered bore. The outer bush was fabricated such that it fitted into a steel hub. The collar of inner bush rested against the outer bush. The inner bush collar had a recess to fit a seal which prevented entry of foreign particles into the assembly. The inner bush also had a longitudinal recess for passage of grease. The ends of the shaft were threaded and locknuts were fitted with split pins to check the bush from coming out.

While in operation, the inner bush and the axle rotated as a single unit against the outer bush. The outer bush was fitted in a hub made

Fig. 1 Tubular oil bath harrow.

Fig. 2 Solid shaft casehardened bush bearing harrow.

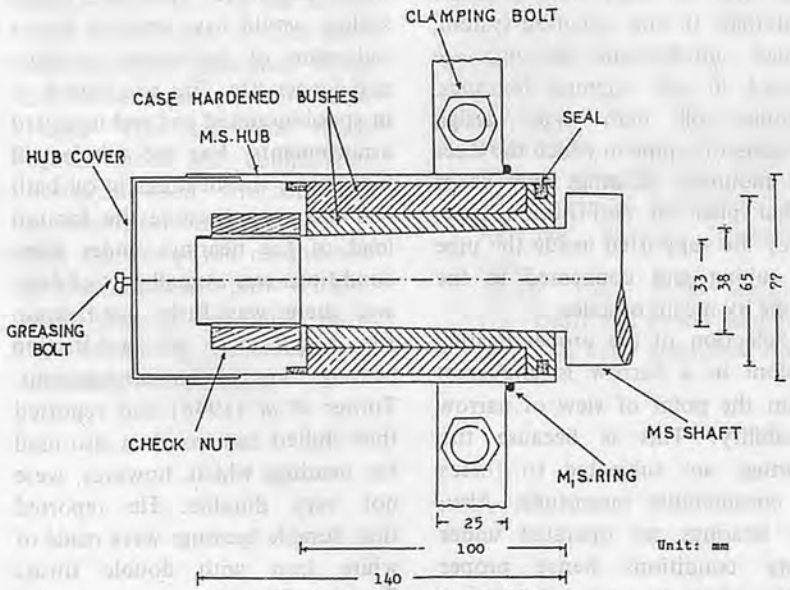

Fig. 3 Casehardened bush assembly.

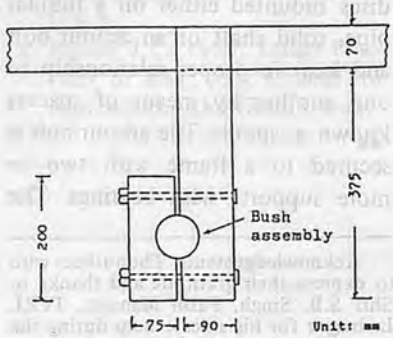

Fig. 4 Side-view of harrow showing attachment of bush assembly to frame.

of mild steel. This hub was clamped with the help of two plates of 25 mm thickness and one of them was welded to the frame of the harrow. Provisions were also made to prevent the hub from coming out of the shaft by providing a semi-circular mild steel rod as shown in Fig. 3. Suitable arrangements were also made for necessary lubrication of the harrow. A cap was fitted in the outer end of each hub.

During the field operation the thrust was taken up by the collar of the inner bush which rotated against the outer bush. The wear between the surfaces was less as they were case carburized. The play between the thrust resisting surface could be removed by pushing the hub inward after loosening the clamping bolts. This avoided any longitudinal play in the harrow gang.

Greasing of the moving parts of the harrow was very easy which could be achieved after opening the bolt on the hub cap. Moreover, the replacement of the case hardened bushes, which were critical parts of the harrow could be done easily after opening the hub assembly. The shaft of the harrow had a good salvage value as it could be further utilised for other purposes.

Materials and Methods

The performance evaluation of tubular oil bath type and improved harrow was carried out to evaluate their suitability for various tillage operations in the farm. Two types of tests were carried out.

Availability and Durability Tests – In these tests, long term records were maintained as regards to number of hours operated, details of breakdowns and repair downtime. Records were maintained for a period of 18-28 months for this purpose. The durability of a harrow was indicated by the number of hours of operation of the harrow before breakdown. The availability of a harrow for a certain time period was the percentage of time the harrow remained fit for operation during that period. This was irrespective of the actual use of harrow during the time period. The availability of a harrow is dependent on the downtime of the harrow for repair and maintenance. Frequent repairs mean more downtime and thus decrease in availability. Since maintenance time is only a small part of total downtime for both harrows, this was disregarded and only the repair downtime was taken as an indicator of harrow availability.

Field Performance Tests – Field performance tests were carried out to ascertain any significant difference in the quantity of soil manipulated and quality of field operation which may be caused due to the weight difference of the harrows. The other operating factors were kept unchanged or constant. The following factors were evaluated: area covered, volume of soil tilled, soil pulverization, and field efficiency.

The harrows were operated in the same field using the same Belarus MTZ-5MC tractor. Both harrows were trailed type 16-disc offset harrow. They had a manual angling system of the gangs for setting the disc angle.

The soil moisture content was measured by oven dry method on the basis of three random samples. Bulk density of the soil was measured with the use of a cone sampler.

Observations were taken to determine the average depth of cut, area covered, turning loss, time lost due to other reasons and time taken to cover the length of field. Average depth of cut was decided on the basis of 20 observations in each case.

Three random samples of soil were taken for evaluating soil pulverization on the basis of mean weight diameter of soil clods. A set of sieves of size 10 mm, 4 mm, 2 mm, 1.5 mm, 1.25 mm and 1 mm was used for the analysis. For clods which were bigger than the above mentioned sizes, measurement of diameters along three diametral planes were done. About 5-6 observations were taken in each case. The equivalent diameter was obtained as the mean of the diameters along the three diametral planes. The mean weight diameter was obtained as follows:

$$\text{Mean weight diameter} = \Sigma WD / \Sigma W$$

where,

W = weight of soil clod or weight of soil held by particular sieve.

D = equivalent diameter of clod or size of sieve

The mean weight diameter was considered as an index of soil pulverisation where the harrow was used as a primary tillage implement. For secondary tillage operations, soil pulverization was obtained as follows:

$$\text{Soil pulverization, \%} = \frac{M)_B - M)_A}{M)_B} \times 100$$

where,

$M)_A$ = Mean weight diameter of soil after harrowing

$M)_B$ = M.W.D. of soil before harrowing

Results and Discussion

Availability and Durability of Harrows

Tables 1 and 2 show details of breakdowns for a period of 18 months for tubular harrow and 28 months for the improved harrow. The percentage of total time spent for repairs during each three monthly period is also shown.

Table 1 shows that tubular oil bath harrow gave trouble-free operation for 585 h before the front gang axle, bushes, collars, etc were worn out and needed overhauling. After repairs, the harrow was operated

Table 1 Operational Record of Tubular Oil Bath Harrow

Total period under consideration	Actual number of days in operation	Hours of operation	Total cumulative hours	Days lost in repairs	Repair downtime (%)	Details of repair	Type of repair	Hours operated since last major repair	Cumulative hours till breakdown
Dec. 1980 – Feb. 1981 (90 days)	17	65.5	65.5	Nil	Nil	Nil	–	–	–
Mar. 1981 – May 1981 (92 days)	56	214	279.5	Nil	Nil	Nil	–	–	–
June 1981 – Aug. 1981 (92 days)	67	305.5	585	4	4.35	a) Lock nut worn out–replaced	Minor	–	–
						b) Harrow bushes and axle worn out–under repair	Major	585	585
Sept. 1981 – Nov. 1981 (91 days)	29	124	709	60	65.93	a) Repair of above.	–	–	–
						b) Flange of pipe broken–repaired	Minor	–	–
Dec. 1981 – Feb. 1982 (90 days)	68	272	981	12	13.33	a) Wear of bushes and axle–repaired	Major	158.5	743.5
						b) Front gang pipe and axle broken, and axle got bent –gang discarded and repaired gang fitted	Major	97	840.5
Mar. 1982 – May 1982 (92 days)	33	114	1095	24	26.09	a) Front gang, axle and bushes worn out	Major	181.5	1022.0

Table 2 Operational Record of a Solid Shaft Casehardened Bush Harrow

Total period under consideration	Actual number of days in operation	Hours of operation	Total cumulative hours	Days lost in repairs	Repair downtime (%)	Details of repair	Type of repair	Hours operated since last major repair	Cumulative hours till breakdown
Feb. 1980 – Apr. 1980 (89 days)	49	176	176	33	31.08	a) Overheating observed, shaft broken at one end.	Major	35	35
						b) New shaft made. Shaft bent again after operation.	Major	49	84
						c) Axle checknut came out, fitted.	Minor	–	–
						d) Front gang shaft broke. New shaft under fabrication.	Major	92	176
May, 1980 – July, 1980 (92 days)	45	251	427	20	21.74	New axle fabricated.	–	–	–
Aug. 1980 – Oct. 1980 (92 days)	59	324	751	Nil	Nil	–	–	–	–
Nov. 1980 – Jan. 1981 (92 days)	77	318	1069	Nil	Nil	–	–	–	–
Feb. 1981 – Apr. 1981 (89 days)	20	134	1203	1	1.12	Front gang discs changed.	Minor	–	–
May 1981 – July 1981 (92 days)	37	165	1368	Nil	Nil				
Aug. 1981 – Oct. 1981 (92 days)	49	218	1586	Nil	Nil				
Nov. 1981 – Jan. 1982 (92 days)	70	291	1877	19	20.65	Front shaft hub came out and shaft got bent. Repair of shaft carried out.	Major	1701	1877
Feb. 1982 – May 1982 (120 days)	54	213.5	2090.5	35	29.17	a) Repair of above completed.			
						b) Front gang shaft broke	Major	213.5	2090.5

for 158.5 h before the same defects were observed and the harrow again needed complete repair. The period stated was exclusive of minor reparis which took place in between. The front gang pipe and one of the axle broke and the second axle was bent after further 97 h of operation. The front gang was, therefore, rendered unserviclable after a total of 840.5 h use. A new repaired gang was fitted in its place. This was operated for 181.5 h before it again needed overhauling. There was no damage or repair involved in the rear gang.

Table 2 shows the operational record of a solid shaft, casehardened bush harrow. It was observed that for the first 196 h of operation, overheating was observed in the bush assembly and there was frequent damage in the front gang shaft of the harrow. Ultimately, the front gang shaft broke after 176 h. This was because the harrow was in the developmental stage during this period. The overheating and damage to shaft was caused by misalignment due to fabricational defects. After these defects were removed and a new shaft was fitted in the front gang, the harrow gave trouble-free operation for 1701 h. After this period, the harrow shaft got bent due to poor maintenance as the clamping bolts became loose and the hub came out. The MS rings shown in **Fig. 3** were not fitted in the harrow at this stage. The harrow shaft was repaired and the casehardened bush bearings were replaced. However, the shaft was probably weakened at the cross-section of bending and as a result it broke after further 213.5 h of operation. The front gang was thus operated for a total period of 1914.50 h (without considering first 176 h) before breakdown. There was no damage or repair involved in the rear gang.

On comparing the performance of both harrows, it could be observed that a tubular oil bath harrow gave 585 h of trouble-free operation during the first run. It could be further used for periods ranging from 97-158.5 h after necessary repairs. The solid shaft casehardened bush harrow, however, gave trouble free operation for 1701 h. It was also observed that the front gang of oil bath harrow became unserviceable after 840.5 h of operation as compared to 1914.5 h in case of solid shaft harrow. The life of the improved harrow was thus observed to be almost double of the tubular oil bath harrow. This was due to improved thrust-resisting surfaces as well as bearing surfaces which were casehardened. Moreover, due to easy adjustments of the play between the inner bush collar and outer bush, the chances of breakdown caused due to undesired relative movement of the parts were eliminated and this resulted in longer life.

The MS rings shown in **Fig. 3** were incorporated as a safety device in the design at a later stage in order to keep the hub in place in case of accidental loosening of clamping bolts. It was felt that the harrow gangs would have given a much longer life if this safety device was incorporated in the early stages of development.

Tables 1 and 2 also show the percentage downtime for repairs computed for 3 monthly intervals for both harrows. On comparison, it was found that the tubular oil bath harrow worked for a 6-month period from December, 1980 to May, 1981 without any repair downtime. A repair downtime of 4.35% was observed for the next 3 months from June to August, 1981. The repair downtime ranged from 13.33 to 65.93% for the remaining period. On the other hand, the improved harrow gave a trouble-free operation for 15 months period from May 1980 to January, 1981 and May, 1981 to October, 1981. In the period of February, 1981 to April, 1981, the repair downtime was 1.22%. During the first three months, however, the repair downtime was 31.08% which was quite high. This was due to the fact that the harrow was still in developmental stage and gave more breakdowns till necessary modifications were incorporated. The repair downtime ranged from 20.65 to 39.17% for the remaining periods other than those described above.

The total repair downtime was calculated for solid shaft and tubular oil bath type harrow. It was observed to be 18.28% for a period of 18 months for tubular oil bath type harrow. The repair downtime was calculated for the developed harrow assuming first three months as developmental period. This period was not considered while calculating the total repair downtime. It was found to be 9.98% for the remaining 25 months period. The reduction in repair downtime was observed to be 45.30% which was quite significant. Since availability of a harrow for farm use is inversely dependent on repair downtime, it can be observed that a substantial increase in harrow availability is possible by using the improved solid shaft casehardened bush harrow.

Field Performance Tests

The comparative data for field performance tests of both harrows are given in **Tables 3 and 4**. From **Table 3** it can be observed that there was considerable increase in depth of cut obtained by solid shaft harrow as compared to the tubular harrow. The increase in depth ranged from 5.40 to 14.2% depending on the weight of the harrow. The larger weight of the solid shaft harrow caused significant increase in depth. However, the increased weight and penetration of a solid shaft harrow caused a small decrease in forward speed of the tractor (0 to 1.2% range). The area

Table 3 Comparative Field Performance of Harrows

Parameters	Trial No. 1			Trial No. 2			Trial No. 3		
	Solid shaft harrow	Tubular harrow	Percentage difference	Solid shaft harrow	Tubular harrow	Percentage difference	Solid shaft harrow	Tubular harrow	Percentage difference
Soil moisture content, % db	10.28	10.25		3.81	3.81		5.80	5.65	
Bulk density of soil, kg/cm³	1160.50	1150.00		1869.29	1844.00		1728.45	1726.55	
Length of field, m	84.00	84.00		350.00	350.00		225.00	225.00	
Speed of tractor, km/h	5.86	5.86	Nil	4.91	4.92	0.20	4.95	5.02	1.20
Average depth of cut, cm	10.92	10.10	7.54	11.21	10.07	11.06	11.65	10.10	13.30
Area covered, ha/h	0.61	0.63	3.17	0.52	0.54	3.70	0.49	0.52	5.77
Volume of soil tilled, m³/h	666	636.30	4.67	587.43	543.86	7.44	570.85	525.80	8.00
Field efficiency, %	59.51	61.46	3.35	60.94	63.38	3.86	56.45	59.18	4.61
Remarks about field	Field was irrigated after one initial harrowing operation followed by levelling before this operation.			Field in ploughed condition			Field in ploughed condition.		
Remarks about tractor performance	Due to short length of field and more overlap between runs, field efficiency was low.			Due to ploughed condition, speed of tractor during operation was reduced due to slippage resulting in poor field efficiency and out put.			Due to operation on ploughed soil, speed was less due to considerable slippage hence field efficiency and area covered were less.		
Soil moisture content, % db	4.60	8.35		11.12	11.10		4.52	3.95	
Bulk density of soil, kg/m³	1300.00	1560.00		1255.00	1255.00		989.00	942.00	
Length of field, m	195.30	195.30		480.00	480.00		195.80	195.80	
Speed of tractor, km/h	5.00	5.02	0.39	5.40	5.45	0.92	5.41	5.46	0.92
Average depth of cut, cm	10.41	8.93	14.20	14.10	13.30	5.68	14.25	13.48	5.40
Area covered, ha/h	0.61	0.64	4.69	0.82	0.84	2.48	0.80	0.82	2.44
Volume of soil tilled, m³/h	639.50	569.00	11.05	1160.00	1119.00	3.54	1140.00	1106.71	2.93
Field efficiency, %	76.00	74.00	2.64	85.52	88.07	2.55	84.49	86.31	2.10
Remarks about field	Field in dry condition after harvesting and contained lot of stubbles.			Field was ploughed, harrowed, levelled, irrigated and harrowed before this operation.			Field was harrowed thrice before this operation.		
Remarks about tractor performance	Reasonably good field efficiency area covered and volume of soil tilled.			Good field efficiency, area covered and depth of cut obtained.			Good field efficiency, area covered and depth of cut obtained.		

Table 4 Comparative Soil Pulverization of Harrows

Replications	Mean weight diameter of soil before harrowing (in case of previous operation) (cm)	Mean weight diameter of soil after harrowing with solid shaft harrow (cm)	Mean weight diameter of soil after harrowing with tubular harrow (cm)	Pulverization percentage with solid shaft harrow (%)	Pulverization percentage with tubular harrow (%)	Percentage increase in pulverization with solid shaft harrow (%)
1	–	3.650	3.842	–	–	–
2	10.460	2.323	6.238	77.790	40.360	93.00
3	8.690	3.454	5.254	60.250	39.540	52.00
4	–	4.073	4.212	–	–	–
5	4.290	3.520	3.850	15.380	10.260	52.00
6	4.100	3.265	3.515	20.36	11.83	72.00

covered, which was dependent on the forward speed of the tractor, decreased within a range of 2.44 to 5.77%. However, the volume of soil tilled was increased by 2.93 to 11.05%.

Variation in field efficiency was observed in both harrows under varying field conditions. This was due to the variation in the speed of the tractor, length of plot, amount of overlap, time lost, etc. However, in nearly all the cases, the field efficiency was greater for the tubular harrow mainly due to the increased speed of the tractor. The difference was small ranging from 2.10 to 4.61% only.

The soil pulverization obtained by both harrows under different field conditons is shown in **Table 4**. It can be observed that in all cases, the soil pulverization obtained by solid shaft harrow was better than that of the tubular harrow. For secondary tillage operations, soil pulverization obtained by solid shaft harrow increased by 52 to 93% as compared to tubular harrow. The increased pulverization was probably due to the larger weight of the solid shaft harrow. The increased weight was more

effective in breaking the big soil clods and also more soil was handled by the heavier harrow due to its increased penetration.

Conclusions

1. The developed solid shaft case-hardened bush harrow had more than double the life of tubular oil bath harrow. The total life of the front gang of this harrow was 1914.50 h as compared to 840.5 h for tubular oil bath harrow.
2. Repair downtime of the developed harrow was almost half.
3. Depth of penetration of the developed harrow was due to its heavier weight.
4. Soil pulverization was more efficient for the developed harrow for all observations.
5. There was an easier access to critical parts in the developed harrow, thus simplifying its repair and maintenence.
6. The shaft of the developed harrow had a good salvage value as it could be further utilised. However, this was not the case with tubular oil bath harrow.

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Animal-Drawn Wheeled Tool Carrier: An Appropriate Mechanization for Improved Farming Systems

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Abstract

The animal-drawn wheeled tool carriers were developed to carry out transportation and other agricultural operations by one single frame thus reducing the cost of machinery systems. They have not gained the expected popularity among a large majority of farmers because until recently they tried as alternative to traditional single-purpose machinery system which did not present sufficient time saving advantage to justify heavy investments. The recent experiences at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India and the Centre of Agricultural Research for the Semi-Arid Tropics, Petrolina (PE) Brazil (CPATSA) in the adoption of this type machinery system as an integrated component of improved farming systems has shown the possibility of increasing crop production and better time saving advantage even for small land holdings.

Note: This paper is based on author's own experience and available literature and need not represent the thoughts of ICRISAT or CPATSA.

Introduction

The animal-drawn wheeled tool carrier is a multipurpose machine based on the idea of a linked sequence of operations. It is possible to use this machine for numerous agricultural operations using one single frame to which various implements can be attached. It can perform virtually all the operations that a tractor can, thus providing to many farmers the versatility and precision previously available to only a few. The other type of multipurpose animal-drawn machine commonly used are called tool bars. The basic distinction between tool bars and tool carriers are, whereas the former are used solely for field work, the later can also be fitted out as carts for transport work.

The concept of animal-drawn wheeled tool carrier is not new. Approximately 25 years ago such machines could be found in East Africa, India and Senegal. This type of machine has been defined by various authors (ICRISAT, 1983, Bansal and Thierstein, 1982, Mexico, 1977, and Lal and Nunes, 1980, 81 and 82) as a machine designed to perform various agricultural operations and transportation; consisting of rigid frame (chassis) supported by two wheels (often pneumatic tyres) with a provision of attaching implements behind the chassis and a lifting mechanism to raise and lower them, and a beam connecting the frame to the yoke of the animals.

Basically the animal-drawn tool carrier is a frame with a built-in versatility to provide a link between the power source (animals), and soil working and other tools used with it, keeping the latter in a definite orientation with respect to the soil.

This concept of agricultural mechanization for small and medium farmers has been tried with varing success in many countries. In most cases it has not received the popularity among a large majority of farmers even with the numerous advantages in terms of low cost of operation, comforts for the operator(s) and animals, and quality of operations.

The objective of the paper is to analyse the reasons for its limited adoption rate, the basic aim of developing this type of machine, the research experiences in terms of its economic and technical viability and identification of special cases (if applicable) under

which they should be recommended for use.

Traditional Animal-Drawn Implements

The traditional implements for animal traction commonly used can be divided into following two categories:

(a) *Implements developed by farmers themselves:* These type of implements are generally found in places where the use of draught animals has a long tradition, such as India, in countries of north of the Sahara and in Ethiopia (Africa). The lengthy history of these implements has resulted in a variety of designs. Although these type of implements (**Fig. 1**) look crude at first sight, they have been evolved by centuries of experience of the farmers and have stood the test of working in particular regions endowed with their specific agro-climatic conditions. The size and shape of these implements often vary from region to region depending upon soil type, cultural practices, and size and type of animal used, etc. But there are no radical differences among the implements meant for similar operations. These implements are generally made and repaired by local artisans (blacksmiths and carpenters). In India, particularly, the mode of payment for these implement is through goods-exchange.

(b) *Implements developed by specialized institutions or industries:* These type of implements, generally made of steel and are manufactured on commercial scale by specialized industries. The basic design feature of these implements do not vary much. It gives the impression that the know-how of these implements has been diffused from a single point of its origin. The typical example of such implements, a mouldboard plow, is shown in **Fig. 2**.

Fig. 1 Traditional wooden plow commonly used in India.

Fig. 2 Animal-drawn steel moldboard plow.

Wheeled Tool Carrier, its Reason for Development

A common package of implements for farmers using animal traction consists of plow and harrow for land preparation, planter or seeder for planting and animal-drawn transport carts. Most of these traditional implements do not make the best use of available energy from their power source because of their low draft utilization (Goe and McDowell, 1980). At the same time the work done is inefficient and involves considerable strain and drudgery for the operator(s) and the animal(s). Another major drawback is that each implement has its own frame and beam in addition to its principal functional component. The main idea behind developing wheeled tool carrier type of mechanization has been to enable to carry out transportation and other agricultural operations by one single frame, thus reducing the cost of machinery system. This type of mechanization makes things easier for the person operating the machine since he can ride on its frame. Experience has shown that with the driver seated, greater speeds are attained as compared to walking along or behind the implement, with the tractive resistance remaining the same. The stable support given to the tool carrier by its two wheels and the fixed tool bar results in precise depth control during the operation with the attached implement. This guarantees a better quality work. The various models of wheeled tool carrier developed in different parts of world has been listed by Lal and Nunes (1980 and 1981), Bansal and Thierstein (1982). The list and addresses of manufacturers of wheeled tool carriers have been published by ICRISAT, 1983. The basic components of wheeled tool carrier could be grouped into the following:

(a) Frame and support wheels: basic structure to mount other components.

(b) Implements attaching and lifting mechanism: a set of well designed linkages for fixing the attachment(s) and for raising and lowering them as desired; controlled by its driver through a well positioned handle.

(c) Animal hitching and power transmission mechanism: a solid beam made of steel or wood to connect the frame to the animal(s) yoke.

(d) Implements and attachments: the real working components that depend upon the type of operations to be carried out.

Working Capacity, Economics and Draft Utilization Efficiency

The area that can be covered in a day using animal traction with traditional implement or wheeled tool carrier depends on many factors such as the effective working width of the machine, speed of

operation and the field efficiency. The working width of the machine is generally prefixed and depends on the type of the operation to be carried out, the model and make of the machine. In the case of animal traction it can vary from 0.20 m (e.g. single mouldboard plow) to 1.50 m when majority of the operations are carried out using wheeled tool carrier.

The speed of operation depends upon the draft or load of the implement, soil conditions, size of animal, climatic conditions and accumulated working hours. The working speed of oxen is about 2.5 to 3.5 km/h; and that of horses and mules, a little higher. Animals can generally pull 7.5 to 20% of their body weight depending on the type of loading and type of animals, their breed, physical condition, and type of loading.

The field efficiency or operational field efficiency is the percentage of useful working time to the total registered time of the machine in operation. It depends on many factors such as the skill of operator, size and configuration of field, its condition at the time of operation and type of operation itself. If the field is long, less time is wasted in turning than if turning has to be done frequently in a short field. Lal (1983), based on the conventional field efficiency equation (i) developed a simpler equation; (ii) which facilitates estimating field efficiency based on the parameters which can be measured on a sample basis.

$$Ef = \frac{To}{Te + Ta + Th} \times 100 \qquad \text{(i)}$$

where

Ef = Field efficiency or operational efficiency

To = Theoretical time per ha of the operation depending on the theoretical working width and speed to operation

Te = Effective time per ha of the operation depending on the effective working width and speed of operation

Ta = Time lost per ha due to interruptions that are proportional to area

Th = Time lost per ha due to interruption that are not proportional to area.

$$Ef = \frac{\frac{1}{V}}{\left(\frac{1}{V} + \frac{T}{L}\right)\frac{1}{Eff}} \qquad \text{(ii)}$$

where

V = Speed of operation, T = Turning time, L = Length of the field, and Eff = Time efficiency.

All the terms in equation (ii) are self-explanatory except time efficiency (Eff) which is defined as a percentage of operative time which includes turning time and transport time from farmstead to field and back in relation to the total time registered for the operation. It could vary between 60-90% as listed by Lal (1983) for various operations with wheeled tool carrier.

The comparison of the economics of mechanization by wheeled tool carrier with traditional implement package is not straight forward. The traditional single-purpose implements are designed for individual specific operation whereas the wheeled tool carrier, as mentioned earlier, can carry out various operations by changing the attachment only. The other differences such as higher command area, precision, accuracy and comforts for the operator(s) and animals achieved during the operation with wheeled tool carrier need to be taken into account when comparing its economic performance with traditional implements.

Lal and Freire (1982) elaborated on various steps to estimate and compare the cost of individual operation separately and that of complete crop cycle with and without transport activity with animal power using wheeled tool carrier and traditional implement package when used on different sizes of land holdings. In the first case the analysis has been made for two types, the traditional and the modified cultivation systems. In the traditional system, the complete plowing of the field with one unit of mouldboard plow is done every year. And in the case of modified system the plowing is done only on the cropped rows using a set of right and left hand plows to increase the field capacity of the operation. The analysis of traditional implements, due to its operational limitations, is carried out only for the traditional system of cultivation.

The cost per ha of the operations of the crop cycle varies by system of mechanization. The variation depends on the size of land holding, cultivation system, inclusion of transport activity or not in the analysis and the command area of the machinery system. With the assumption of equality of command area (15 ha) for the both type of mechanization systems, the cost per ha of using single-purpose implement set is always inferior to that of the wheeled tool carrier for traditional system of cultivation with or without inclusion of transport activity. In the modified system of cultivation the cost of using wheeled tool carrier becomes cheaper for land holding more than 8 or 10 ha depending upon the integration of transport activity in the analysis. However, with the limit of command area of 5 ha for traditional equipment and 15 ha for wheeled tool carrier type of mechanization, the operational cost of traditional equipment becomes higher than that of other type from 5 ha onward for both the systems analyzed. For large holdings, the traditional equipments need to be supplemented by second or even third set of implement along with their power source (animals) to meet the operational requirements during critical periods.

The cost of the wheeled tool carrier type of mechanization can be considerably reduced by maximizing the annual use of the machine. The cost of wheeled tool carrier was estimated to be Rs. 166/ha on a 14 ha farm with broad-bed and furrow system of cultivation (Bansal and Thierstein, 1982). The cost was reduced to Rs. 155/ha when 400 h/year of transportation was added.

The large price difference between traditional implement package and the wheeled tool carrier type of machinery system does not imply equally large difference in their cost of operation and rental rates. In the cost analysis of an integrated machinery package (power source: animal, machinery and the operator(s)) the cost of bullocks and the operator(s) contribute a large percentage in its operational cost. Therefore, a 50% reduction in machinery cost generally reduces rental rate of the entire package by approximately 27% only. (Binswanger *et al*, 1979).

Apart from the advantages of higher operational capacities and low cost of operation, the tool carrier type of mechanization system has demonstrated the added advantage of improving the draft utilization efficiency of power source. The pull to drag the machine without any implement varies between 10-20 kg and to carry out different operations the variation has been observed in the range of 90-220 kg (Lal, 1979). In general, it is higher for plowing, ridging and bedforming. The pull recorded for these operations seems rather high as compared to the general belief that animals (especially bullocks) can pull loads equivalent to 10-12% of their body weight. Bansal *et al* (1980) also reported that draft observed for plowing and ridging with tool carrier is high and appear beyond the capacity of animals to sustain a full work day. That bullocks could still perform these operations on consecutive working days without any sustained visual fatigue needs a detailed study about animal performance with this type of mechanization. Klaij (1983) stated that at ICRISAT, using wheeled tool carrier, bullock pairs were able to exert a force of 225.0 kg while plowing during a 6-h work day. At first sight this would correspond to a very high power level of 1.9 kW, assuming a walking speed of 3 km/h sustained over a period of a 6-h working day. However, it must be realized that with wheeled tool carrier the bullocks are intermittently loaded, as turning time at each and of the field may be as high as 1 min resulting in a net working period with observed draft to less than 50% of total registered operating time. It could be one of the reasons for the ability of animals to sustain higher drafts specially when used with wheeled tool carrier.

*U$ 1 = approximately Rs. 10.00

Utilization of Wheeled Tool Carriers

The wheeled tool carrier type of mechanization has been under trials for more than 2 decades, but until recently it has been tried as an alternative to traditional equipment packages with little effort to look at farming systems as a whole. Under such circumstances the wheeled tool carrier type of mechanization really did not present sufficient time-saving advantages over single-purpose implements to convince farmers to undertake heavy investment for this new type of mechanization system. Bansal and Thierstein (1982) showed a saving of only 6% in the case of rainy season castor bean crop and that of 27% for rainy season pearl millet/pigeonpea intercrop by using tropicultor (a well-tested wheeled tool carrier) over traditional single-purpose implement on a conventional method of flat farming. Baron and Anjos (1983) reporting the time required for plowing and cultivation with traditional implements and wheeled tool carrier type mechanization showed the advantage of 29.15% for plowing and that of 31.23% for two passage of cultivation. They also showed an increase in specific pull for plowing with wheeled tool carrier (Policultor 1500) when compared with the other light weight tool frames called Policultor 600 and Policultor 300. They also showed that time required for cultivation with a traditional cultivator when pushed by a mule is minimum in the two passages separately or summed together.

The wheeled tool carrier type of mechanization system can be utilized most profitably by integrating it into an improved system of farming. This has been clearly demonstrated at ICRISAT and CPATSA where the wheeled tool carrier has been adopted as an integral component of improved farming systems. At ICRISAT the system evolved is based on the construction of broad beds separated by furrows at a regular interval of 150 cm. **Fig. 3** shows the cross-section of such broad beds with several cropping patterns at 75, 45 and 30 cm spacing. The furrows serve as drainage channels for carrying excess water into grassed waterways, as a pathway for animals and the tool carrier wheels and also as channels for supplemental irrigation. The use of wheeled tool carrier with various attachments for this system of cultivation has been explained in Bansal and Srivastava (1981), ICRISAT (1978) and Lal (1981).

A net profit of 43% in time saving has been shown by Bansal and Thierstein (1982) when wheeled tool carrier is used on this system as compared to traditional imple-

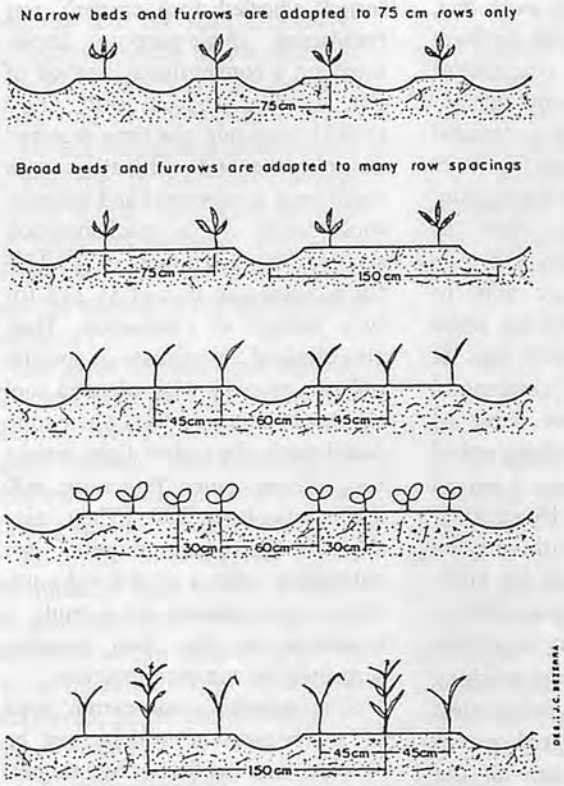

Fig. 3 Crop combinations and row arrangements of 75 cm ridges and 150 cm broad beds.

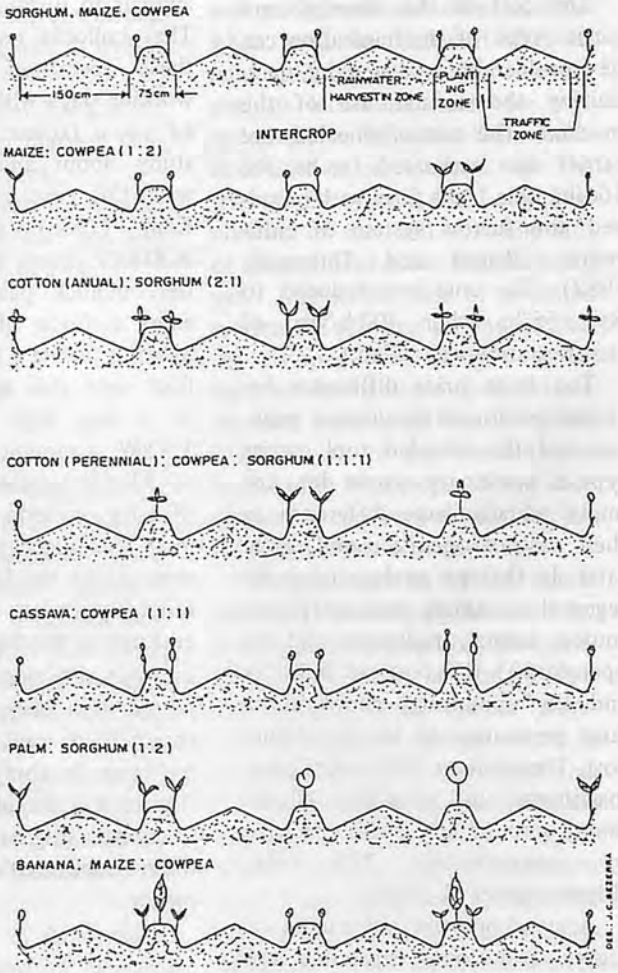

Fig. 4 Crop combinations on a new type *in situ* rainwater harvesting technique.

ments when used for flat cultivation.

At CPATSA, located in a very arid zone of northeast Brazil (Hargreaves, 1974) the wheeled tool carrier has been used for a new type of *in-situ* rainwater harvesting technique (Lal *et al*, 1983).

This system consists of broad and narrow ridges alternatively spaced on contour. The broad ridges serve as rainwater harvesting zone, the narrow ridges as planting zone and furrow between the two as waterstorage and pathway for the animals and tool carrier wheels and also as drainage or irrigation channel when the system is laid out on some slope. **Fig. 4** shows the schematic diagram of this system with the crop configurations under test at research centre and on farmers' field. The sequence of operations required to implant the system consist of ridging the field with three ridgers spaced at 75 cm followed by an operation with a ridger-blade, (Lal *et al*, 1983) specially developed for the purpose and attachable to the wheeled tool carrier (**Fig. 5**). This represents a net saving 69.6% of time required for pre-planting land preparation operations (when it is possible to implant the system with one passage of each operation) as compared to traditional system of one plowing and one cultivation even when tool carrier is used. The number of passage required for each of these operation to achieve the required shape depends upon the soil condition at the time of its implantation and size of bullocks. The experience so far has shown that under good soil condition it is

Fig. 5 Implantation of new type of *in situ* rain water harvesting technique with ridger-blade.

Fig. 6 A pair of sugarcane ridgers reforming planting zone in a new type of *in situ* rain wate technique.

possible to implant the system without initial land preparation operations of plowing and harrowing. As the new system is semi-permanent, in the consecutive years the operations required for its reformation consist of re-ridging the planting zone with a set of sugarcane ridgers (**Fig. 6**) and re-forming the water harvesting zone with the ridger-blade leading to the net saving of 73.9% and 78.6% as compared to conventional land preparation using wheeled tool carrier and traditional equipment, respectively. **Table 1** shows the sequence of operations and estimated time required for pre-sowing field preparation using wheeled tool carrier and traditional equipment under conventional flat cultivation and for *in-situ* rainwater harvesting technique.

Table 1 Estimated Time Required for Pre-sowing Field Operations.

Machinery system	1st year		Consecutive year	
	Operations	Time required BPH/ha	Operation	Time required BPH/ha
Traditional implement for flat cultivation	Plowing	20	Plowing	20
	Cultivation	8	Cultivation	8
	Total	28	Total	28
Wheeled tool carrier for flat cultivation	Plowing	20	Plowing	20
	Cultivation	3	Cultivation	3
	Total	23	Total	23
Wheeled tool carrier for *in situ* rainwater harvesting system	Ridging	3	Re-ridging Planting zone	2
	Ridger-blade Utilization	4	Ridger-blade Utilization	4
	Total	7	Total	6

Conclusions

The animal-drawn wheeled tool carrier type of mechanization system developed to integrate field operation and transportation through one single frame (chassis) has not reached many farmers. Until recently it has been mainly looked upon as an alternative to single-purpose implements. Under such situation this type of mechanization system did not provide sufficient time-saving advantages to justify the higher initial investments. The ICRISAT and CPATSA have been successful in integrating this type of machinery into the package of improved farming systems. In both cases the use of traditional implements to carry out different operation was questionable. It leads to thinking that these type of implements should be compared with tractor rather than the traditional equipment packages.

Under traditional system of farming the wheeled tool carrier type of mechanization is economical for a command area of about 5 ha. For an improved farming system, the limit of land holding to make heavy investment for wheeled tool carrier type of machinery package depends upon the net time saving advantages for various operations coupled with the added yield advantages of the new farming system. Under such conditions it could be estimated that even the land holding of 2-3 ha could give sufficient return to justify heavy investment on wheeled tool carrier.

The machinery should be looked upon as a requirement to support the farming system that has been formulated (Inn, 1979). It is specially true in case of wheeled tool carrier which are heavier, more expensive and less manoeuvrable than light weight traditional single-purpose implements. Otherwise their fate could be similar to what has been stated by Munzinger (1982) that in some cases, specially in Africa, it has been discovered that the technically attractive but also elaborate and expensive wheeled tool carriers are simply used as carts for transportation.

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The Use of Fluid Drilling and Soil Conditioning Techniques for Spring-Sown Onions

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Abstract

Fluid drilling is a novel sowing technique whereby seeds (either untreated or pre-germinated) are dispersed in a fluid medium and subsequently extruded into the soil. Soil conditioning is a process whereby the soil particles are coated in a high molecular weight compound thereby improving the soil resistance to capping. In this study the use of fluid drilling and soil conditioning techniques were examined for spring-sown onions (cv. Hygro). The results indicate that, while fluid drilling of pre-germinated seed reduces the emergence interval by approximately 29%, it has no significant effect on the total crop yield or percentage saleable onions.

The use of a soil conditioner (polyvinylalcohol) reduced the force required to penetrate the soil crust by approximately 35%, but this had no significant effect on the total crop yield. It was found, however, that soil conditioning had a highly significant effect on the percentage saleable onions in the case of fluid drilled pregerminated seeds.

Introduction

Fluid drilling is a novel sowing technique whereby seeds are suspended in an aqueous medium and subsequently extruded into the soil. This system is unique as it offers the possibility of sowing pre-germinated seed. Experiments at the U.K. National Vegetable Research Station (NVRS) and elsewhere have shown that fluid drilling can reduce the emergence interval* and increase the percentage emergence, uniformity, and total yields of various crops. For example, Biddington *et al* (1975)[1] reported that the inhibition of celery seed prior to sowing reduced the emergence interval by more than 40 days, compared with untreated seed. Currah *et al* (1974)[2] reveal that fluid drilling of pre-germinated seeds dramatically increased the percentage emergence. Recent progress and future prospects in fluid drilling have been reviewed by Currah (1978), Gray (1981) and Salter (1978 a,b).[3-6]

Soil conditioners have attracted considerable attention in recent years because of their ability to reduce soil capping**. The use of polyvinylalcohol (P.V.A.) as a soil conditioner on silty soils has been examined by Page (1979).[7] A comparison of the effectiveness of organic polymers as soil anti-capping agents is made by Page and Quick (1979).[8]

The major objective of this study was to compare fluid drilling with precision seeding for spring-sown onions (cv. Hygro). The secondary objective was to evaluate the performance of P.V.A. as a soil conditioner.

*Emergence interval = Time from sowing to 50% seedling emergence.

**Soil capping is a process whereby a soil crust is formed by the combined effects of rainfall and soil drying.

The Experiment

Laboratory Design

A fluid drill was fabricated based on a prototype developed by Ward (1981) (**Fig. 1**).[9] The system operated as shown in **Fig. 1**.

Approximately 10 *l* of the seed/gel mixture was placed in the conical hopper A and gravity fed

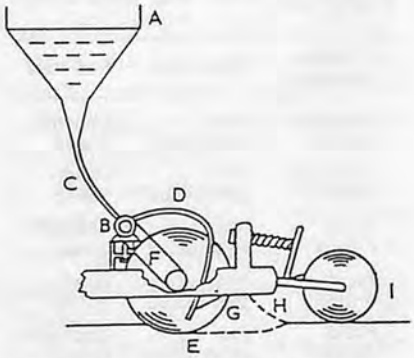

Fig. 1 Prototype fluid drill. (Ward, 1981) (9).

to the pump B via a flexible transparent tube C, of internal diameter 6.35 mm. The seed/gel mixture was then extruded through a similar tube D onto the furrow bottom E, 38 mm below the soil surface. The pump B was driven by a belt F from one of the circular furrow openers G. The rotary self-cleaning action of the furrow openers gave this drill an unique ability to operate under sticky soil conditions. Furrow closure was via a chain H and a press wheel I.

Field Experiments

The field experiments reported in this study were carried out at the Kildalton Agricultural and Horticultural College, Piltown, Co. Kilkenny, Irl.. The results of soil analysis are given below:

24% Coarse Sand; 17% Fine Sand; 34% Silt, 25% Clay; 1.92% Organic Carbon (W/W).

where

Sand:
$2 \times 10^5 - 2 \times 10^6$ nm;
Fine Sand:
$5 \times 10^4 - 2 \times 10^5$ nm;
Silt:
$2 \times 10^3 - 5 \times 10^4$ nm;
Clay:
$< 2 \times 10^3$ nm.

Experimental Design

The following six treatments, arranged in a randomised block design, were compared in the field experiments:

Drilling technique	Seed state	Soil state
Precision drilled	Non-germinated	Unconditioned
Precision drilled	Non-germinated	Conditioned
Fluid drilled	Non-germinated	Unconditioned
Fluid drilled	Non-germinated	Conditioned
Fluid drilled	Pre-germinated	Unconditioned
Fluid drilled	Pre-germinated	Conditioned

A Stanhay* drill was used as the precision seeder. As this machine is not suitable for use with pre-germinated seeds, only dry, non-germinated seeds were sown with this seeder. The soil conditioner, Polyvinylalcohol ((CH CH20H)n) was applied in a 2% solution using a knap-sack sprayer.

Seed Germination Technique

Seed germination was carried out as follows: A 25 mm layer of cotton-wool, covered by a single layer of kitchen paper towelling, was placed on the bottom of trays measuring 700 x 700 x 70 mm. The cotton wool was saturated with water and the seeds were then spread evenly over the surface at a density of approximately 0.125 kg/m^2 (Currah *et al*, (1975)[10]). It is important not to exceed this concentration as germination inhibitors, present in the seed coat, cannot diffuse out of the seed at high densities (Currah *et al*, (1975)[10]). The seed layer was then lightly sprinkled with water and an additional sheet of moistened paper towelling was placed on top. The trays were stacked on top of each other and a plastic cover was placed over the top tray. This arrangement helped to conserve moisture within the trays. The trays were placed in an oven at 24°C for 48 h. After this incubation period the average radicle length was 2 mm. It is advisable to ensure that the radicles do not exceed 10 mm in length (this study) as they may be prone to damage during handling. Furthermore, the tiny root hairs from adjacent radicles may entwine thus causing blockage in the seed pumping mechanism. It was found, however, that radicle growth rate could be reduced by decreasing the oven temperature to 4-6°C. In this way the seed could be held for approximately 6 days in the germination trays. Gray and Stechel (1975)[11] recommend a radicle length in the range 5-12 mm for onions.

A germination test on the seeds reveals an average germination percentage of 79%.

Sowing Technique

In the fluid drilling trials, a thixotropic gel preparation (Agrigel*) was used as the seed-carrying medium. This was necessary in order to prevent seed sedimentation in the hopper and to ensure free flow of the gel-seed mix through the pumping mechanism. Work carried out by Ward (1981)[9] showed that a 0.65% solution (W/W) of agrigel gives the ideal balance between seed holding ability and viscosity.

Both the pre- and non-germinated seed were mixed into the gel by hand. This technique achieved a fairly uniform seed distribution but no definite criterion of uniformity could be established. The seed must be sown as soon as possible after their inclusion in the gel. It is not advisable to store the seed-gel mixture over-night as the seeds may suffer from oxygen deficiency (Currah *et al*, 1975).[10]

Seed spacing was achieved by calculating the required seed-in-gel concentration, based on in-field measurements of pump output. The crop was sown on a bed system, each bed consisting of four twin rows, each 0.46 m apart.

The Stanhay seeder was fitted with a double coulter in order to achieve twin rows, while the fluid drill was fitted with a flow divider on the output tube. Sowing was carried out on April 10, 1980. The soil conditioner was applied post-sowing.

*Trade name for a flexible belt type precision seeder marketed by Stanhay, (UK), Ltd.

*Trade name for Na/Ca alginate mixture produced by Alginate Industries, (UK), Ltd.

Results

Emergence Interval

Estimates of the emergence interval were made by daily counts of the number of seedlings emerged per metre run of plot. The results show that, while the fluid drill *per se* did not enhance overall seedling emergence, nevertheless the use of pre-germinated seed reduced the emergence interval by approximately 29% (**Fig. 2**). This is in agreement with the results quoted elsewhere (Ward, 1981;[9] Salter and Darby, 1975[12]; Salter 1978b[6]; Gray and Stechel, 1975b[13]; Gray, 1981[4]).

Similar emergency profiles were obtained for the soil conditioned and non-conditioned plots. It was, therefore, concluded that soil conditioning had no effect on the emergence interval in this particular soil and under the weather conditions experienced during this trial (**Table 1**).

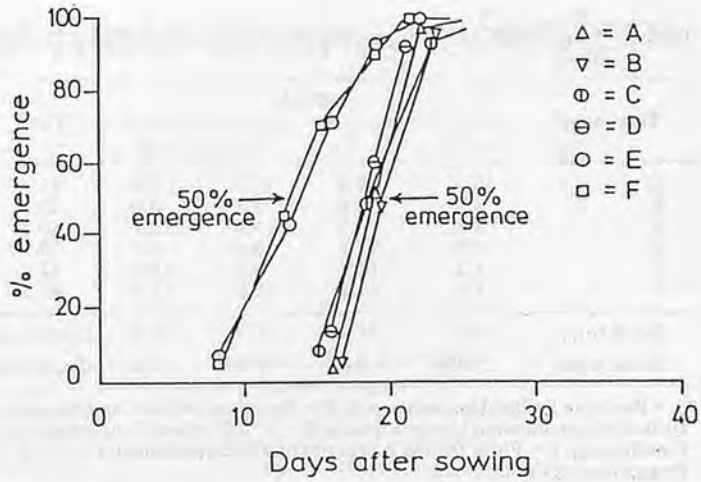

Fig. 2 Emergence profile* for each treatment.

Table 1 Daily Rainfall Records during the Period April 10-23, 1980.

Unit: mm

Date	Rainfall
April 10	0
April 11	0
April 12	3.3
April 13	3.4
April 14	24.09
April 15	1.51
April 16	0
April 17	0
April 18	0
April 19	0
April 20	0
April 21	0
April 22	0
April 23	0

Soil Crust Strength

Soil crust strength was evaluated using a "pocket" penetrometer. The authors considered this device more suitable than a cone penetrometer as the cylindrical probe is of small diameter (6.3 mm) and only penetrates the top 6 mm of soil. It was also found that it gave more consistent results than a cone penetrometer. Measurements of soil crust strength were taken on all plots on day 13 after sowing. The results are given below:

Measurements of soil crust strength (Day 13)

Soil treatment	Mean crust strength (kN/m^2)	Coeff. of variation (%)
Conditioned	77.254	39.6
Unconditioned	119.68	67.83

The above data shows that the use of the P.V.A. soil conditioner reduced the force required to penetrate the soil crust by an average of 35%. Furthermore, the soil-conditioned plots demonstrated a more uniform crust strength than the non-conditioned plots. This latter effect is exemplified by the coefficients of variation of 39.6% and 67.83% for the conditioned and unconditioned plots, respectively.

Yield

Harvesting was carried out on November 4, 1980. The following data was collected for each plot.

1. Yield of onions per metre of row length; and
2. Yield of saleable onions* per metre row length.

The results are given in **Tables 2 to 5**. The following conclusions can be drawn from this data:

The use of the soil conditioner in conjunction with precision drilling dramatically reduced the mean yield and percentage of saleable onions. This is a surprising result and it is the authors' opinion that additional field tests are required in order to evaluate its validity.

There was no significant difference between the total plot yields obtained from any of the other treatments. This is in broad agreement with results obtained elsewhere. For example, in a review of three years' trials on the fluid drilling of onions, Currah (1975)[14] states that "in general, bulb yields were at least as good as those from dry seedlings and on some occasions the rapid establishment of fluid-sown seed gave yield increases of up to 13%." Hiron (1975)[15] states that, in many trials, the earlier emergence achieved with fluid drilling did not result in improved crop yield.

The use of a soil conditioner on fluid drilled pre-germinated plots gave a highly significant increase in the percentage of saleable onions (49.5% v. 22%). As the yield of saleable onions is related to the leaf area available for photosynthesis during the early growth stage of

*Saleable onions are onions with no "thick necks" and with bulbs greater than 40 mm diameter.

Table 2 Total Yields (kg/10 m row length) of Onions Grouped by Treatment and Block

Treatment*	Block 1	2	3	4	Total	Mean
A	13.4	7.6	11.0	9.0	41	10.25
B	5.9	6.8	5.1	6.0	23.8	5.95
C	8.3	8.2	11.4	12.4	40.3	10.075
D	9.9	12.7	8.6	8.1	39.3	9.825
E	11.2	11.4	9.8	10.0	42.4	10.6
F	11.2	11.1	10.8	12.4	45.5	11.375
Block total	59.9	57.8	56.7	57.9	Grand total = 232.3	
Block mean	9.983	9.63	9.45	9.65	Overall mean = 9.679	

*A = Precision Drilled Unconditioned; B = Precision Drilled Conditioned; C = Fluid Drilled Nongerminated Unconditioned; D = Fluid Drilled Nongerminated Conditioned; E = Fluid Drilled Pregerminated Unconditioned; F = Fluid Drilled Pregerminated Conditioned.

Table 3 Analysis of Variance of the Data Presented in Table 2

Source of variation	Degrees of freedom	Sum of squares	Mean square	Calculated F-value	Required F-value (from Tables) 1%	5%	Significance
Total	23						
Blocks	3	0.888	0.296	0.089	5.42	3.29	N.S.
Treatments	5	72.54	14.51	4.38	4.56	2.90	*
Error	15	49.69	3.13				

Least Significant Difference (LSD) (5% level) = 2.743
+ N.S. = Not Significant
* = Significant at 5% level

Table 4 Percentage Saleable Onions per Plot Grouped by Treatment and Block

Treatment+	Block 1	2	3	4	Treatment total	Treatment mean
A	36	25	24	21	106	26.5
B	10	12	9	16	47	11.8
C	37	33	35	14.5	119.5	29.9
D	37	33	20	43	133	33.3
E	26	28	13	22	8.9	22
F	31	60	54	53	198	49.5
Block total	177	191	155	170	Grand total = 6 925	
Block mean	29.5	31.8	25.8	28	Overall mean = 28.83	

+ A = Precision Drilled Nongerminated Unconditioned
B = Precision Drilled Nongerminated Conditioned
C = Fluid Drilled Nongerminated Unconditioned
D = Fluid Drilled Nongerminated Conditioned
E = Fluid Drilled Pre-germinated Unconditioned
F = Fluid Drilled Pregerminated Conditioned.

Table 5 Analysis of Variance of Data Presented in Table 4

Source of variation	Degrees of freedom	Sum of squares	Mean square	Calculated F-value	Required F-value (From tables) 1%	5%	Significance+
Total	23						
Block	3	140.99	46.997	0.567	5.42	3.29	N.S.
Treatment	5	3 153.338	630.67	7.614	4.56	2.90	**
Error	15	1 242.45	82.83				

Least Significant Difference (L.S.D.) @5% = 13.714, @1% = 18.97
+ N.S. = Not Significant
** = Significant at 1% level

the onions, the above finding indicates that initial leaf development, in pre-germinated seeds, is highly influenced by the ease of penetration of the soil crust.

Discussion and Conclusions

The following conclusions can be drawn from this study:

1. Fluid drilling of pre-germinated seed reduced the emergence interval for onions by approximately 29%.
2. The use of pre-germinated seed has no significant effect on the total crop yield or percentage of saleable onions.
3. The use of polyvinylalcohol as a soil conditioner reduced the force required to penetrate the soil crust by approximately 35%. While this phenomenon had no significant effect on the total crop yield, it did, however, have a highly significant effect on the percentage of saleable onions, in the case of fluid drilled pre-germinated plots only. The mean percentage of saleable onions, in the above case, increased from 22% to 49.5% by using the soil conditioner.

The above conclusions are specific to the experimental conditions outlined in this report. The soil type and weather conditions are likely to have significant effects on the results obtained. It is the authors' opinion that additional experimental data is required for different soil types and weather regimes in order to evaluate the responses under various agronomic conditions.

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(Continued on page 54)

Design Parameters of Mole Drainage System in Bangkok Soil

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Abstract

A field experiment was conducted to evaluate the design parameters of a mole drainage system with application to Bangkok clay where clay content was 48%. Mole drains were drawn at 40, 50 and 60 cm depths of 2, 3 and 4 m spacings with the help of a 7.62 cm diameter torpedo. For each depth and spacing four mole drains were drawn per plot. The ground surface slope was 1%. There were in total five experimental plots of different combinations of mole drains. The force required to draw the mole plough at three different depths was found to be greater than 3 t. Mole drainage behaviour was evaluated in terms of basic infiltration rate and the outflow characteristics. It was found that mole drains constructed at 50 cm depth of 3 m spacing were more stable and more effective in terms of extent of fissures and cracks and outflow behaviour.

Introduction

Mole drains are cylindrical channels artificially produced in the subsoil without digging a trench from the surface. In the moling operation a steel bullet attached to a plough is pulled through the ground at a suitable depth. This operation produces a mole channel, a central slit and cracking which stems from the top of the mole channel at an angle of about 45° to slit. Its primary aim is not to control the ground water table, which may be very deep, but to remove excess water from the field surface or from top soil where it may constitute a "perched water table". The water reaches mainly through fissures and cracks that are formed when moles are being drawn. There is no known mole drainage practice in this part of the world (Southeast Asia). A mole drainage system is suitable for heavy clay soils with a small percentage of sand. According to the UNO (1972) report, soils of central plain of Thailand is of heavy type, the slope of the soil being 0-1%. Due to low slope and permeability, the soil remains wet part of the year. Mole drains may be suitable in such soils.

Design and layout of a mole drainage system includes the drain depth, spacing, gradient and length of lines. Field experiment was conducted to determine the effectiveness of mole drains in the improvement of Bangkok clay (Singh 1978). Some model studies were done in the laboratory to determine the design parameters (Gupta 1978, Chaudhry 1979). But no field experiment was done to determine the design parameters of mole drainage with application to Bangkok clay. Therefore, the field experiment was conducted in continuation of the previous studies to determine the design parameters with application Bangkok clay having one type of soil with one length and one slope of mole drain using the same mole plough for different depths and spacings.

Experiment

Initially the field was too much undulating and covered with long grasses. A motor grader was used to cut the grasses and to level the field having cut and fill about 2 to 3 cm maintaining a slope of 1% toward the ditch and to make the ridges of a height of 0.4 m to prevent the movement of water from plot to plot. The experimental layout is shown in **Fig. 1**. The mole drains were installed in all the five plots using the mole plough (**Fig. 2**) and frame (**Fig. 3**) at different depths and spacings as shown in **Table 1**.

At the time of installation of the mole drains in each plot, soil samples were collected to determine the soil moisture content at moling time. After the installation of mole drains, the outlets of the drains were dug for a distance of one meter and provided with one meter P.V.C. pipe of 7.62 cm inner diameter to prevent erosion of the mole channels during outflow. The slits left for drawing the

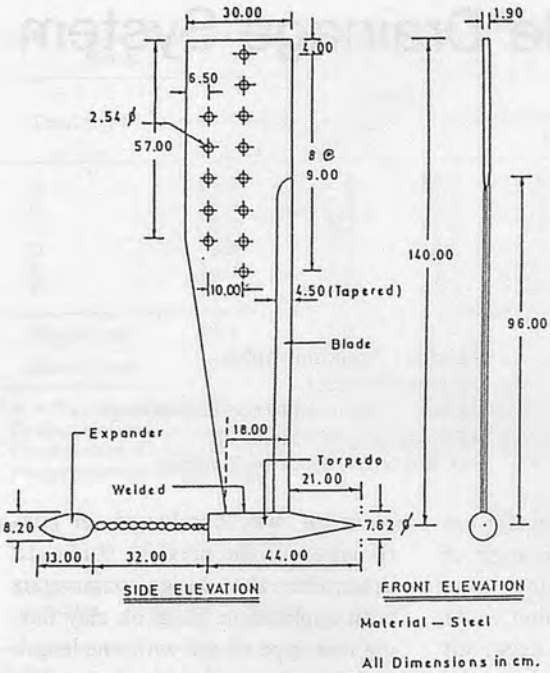

Fig. 1 Mole plow used in the construction of mole drains (Singh, 1978).

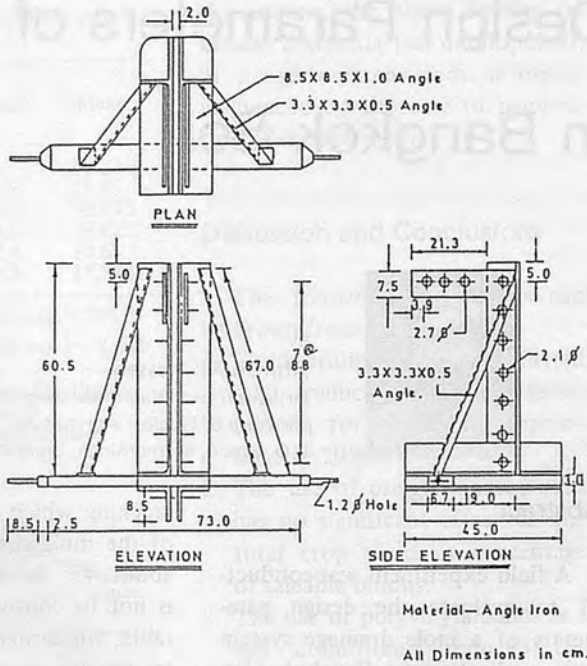

Fig. 2 Mole plow frame (Singh, 1978).

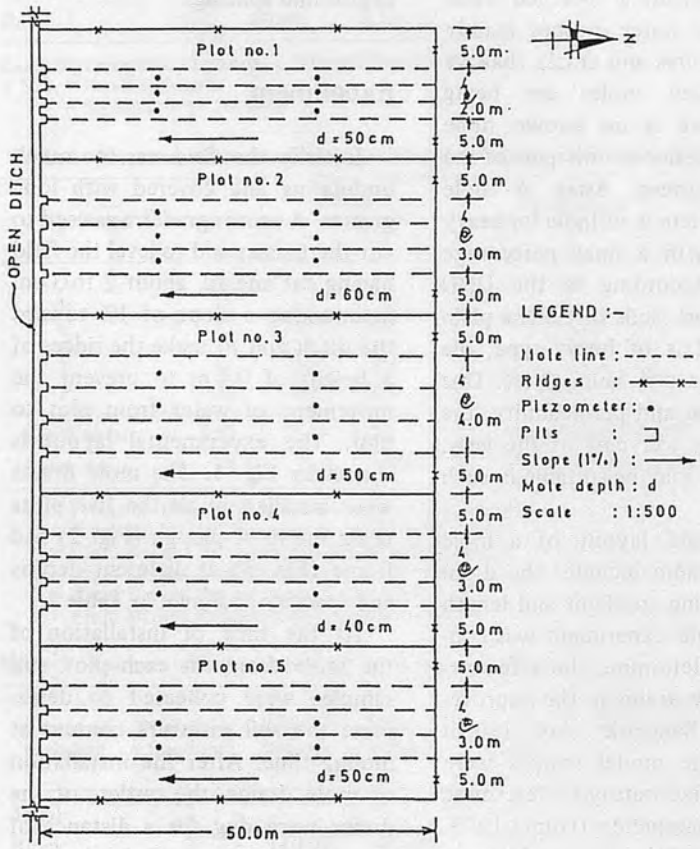

Fig. 3 Layout of experimental plots.

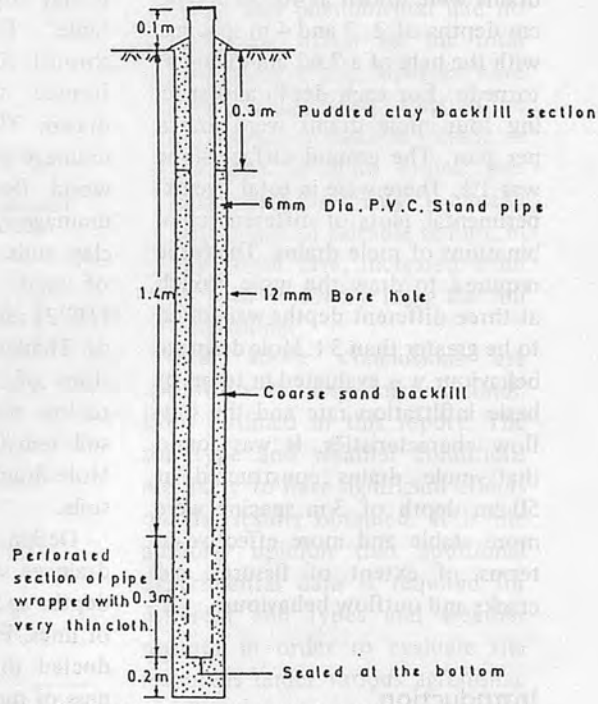

Fig. 4 Details of an open standpipe piezometer.

Table 1 Mole Drain Depth and Spacing Specifications

Plot No.	Depth cm	Spacing m
1	50	2
2	60	3
3	50	4
4	40	3
5	50	3

mole channels were closed manually to prevent direct entry of irrigation or rain water which would cause damage to the mole channel. To measure the power required to draw the mole plough, a three-ton capacity dynamometer was used. Each time, the dynamometer readings exceeded the capacity of the meter. Piezometers were installed (Fig. 4) just after drawing the mole channels to check the depth of water table with the help of a multimeter. The water level never came above the drain level. Field sprinklers were used for irrigating the plots. Soil sampling was done especially to check the soil moisture level before and after each irrigation or rain. Mole outflow was measured for a single mole drain out of four mole drains per plot just from the starting of the mole drain discharge.

Results and Discussion

The force required to pull the mole plough through a certain soil is equal to total resistance of the soil against the mole plough. The total resistance or force against the mole plough is the sum of the bearing resistance (Chaudhry 1979). The force required for pulling the mole plough at various depths for Bangkok soil (Table 2) is presented in Table 3.

In conducting the experiment, suitable moling moisture content appeared to be between 27-43%. Moling moisture content and drainage behaviour is explained in Table 4.

The extent of fissures and cracks were evaluated in terms of basic infiltration rate, application rates, total application times, time of outflow start, peak and draining (Table 5). In this aspect, it was found that the extent of fissures and cracks were highest for 50 cm mole depth with 3 m spacing which gave the fastest respense of outflow both for sprinkler application as well as for natural rainfall.

Drainage behaviour of mole drains for different depths and spacings were investigated by measuring the outflow rate, maximum discharge in relation to application rate and times of draining, *i e*, base time from the hydrograph. The discharge measurements for single mole drain in all five plots and respective outflow hydrographs are

Table 2 Physical Preperties of Bangkok Soil (Gupta 1978)

Soil type	Clay soil (Clay 48% silt 49% sand 3%)*
Bulk density	1.3 t/m³
Liquid limit	70.2%
Plastic limit	22.8%
Plasticity index	47.4%

*Values from the test analysis of 50 cm depth soil sample.

Table 3 Force Required for Pulling the Mole Plough at Various Depths

Moling depth cm	Moisture content by wt % (M)	d_c value m	W_a m	Bulk density γ ton/m³	Calculated forces ton	Average forces ton
40	25.1	1.07	0.23	1.3	3.2	
	26.9				3.0	
	27.0				3.0	3.0
	27.1				3.0	
50	37.2	1.27	0.24	1.3	3.3	
	37.4				3.3	
	37.5				3.3	3.3
	38.0				3.2	
60	40.9	1.48	0.26	1.3	4.3	
	41.0				4.2	
	41.9				4.2	
	43.1				3.9	

Calculated using functional relationship $F/\gamma d_c^3 = f(W_a d_c M)$ developed by Gupta 1978. d_c = characteristic depth, W_a = average operational width of the blade.

Table 4 The Influence of Moling Moisture Content on the Formation and Behaviour of Mole Drain

Moiling depth cm	Spacing cm	Moling moisture centent by weight %	Form of mole drain viewed at outlet	Drainage behaviour in terms of time of peak and water quality
40	3	25.1	Soil fall from the top in the drain	Response late and turbid water
40	3	27.0	Smooth	Response late and turbid water
50	3	37.2	Smooth and clean	Quick response and clear water
60	3	41.9	Smooth and clean	Late response with very clear water

Table 5 Mole Outflow Behaviour from Hydrograph

Mole depth cm	Spacing m	Sprinkling time or rain duration h	Time of outflow after sprinkling or rain h	Time to peak T_P h	Time of recession T_R h	Time of draining T_P+T_R h
50	2	6.00	3.50	1.50	2.33	3.83
60	3	6.00	4.50	1.50	2.17	3.67
50	4	6.00	5.00	1.33	2.67	4.00
40	3	5.00	3.50	1.50	2.00	3.50
50	3	5.50	4.50	1.17	1.83	3.00
50*	3	1.50	0.75	0.75	1.00	1.75

*From rainfall record.

drawn (Fig. 5). Mole outflow behaviour was summarized from outflow hydrographs (Table 5). The maximum outflow added to the average basic infiltration rate of the field after mole drain construction gave the maximum application rate or maximum rainfall intensity which was drained out safely.

The mole drainage system was evaluated using the functional relationship developed by Gupta (1978). The maximum I_{am}/I_{ip} value explains about the maximum application rate. I_{am}/I_{ip} values were calculated using the mathematical formula developed by Chaudhry (197) from the test result of Gupta (1978).

The equation is

$$I_{am}/I_{ip} = 77 + 1.27\ d/D - 1.1\ S/D$$

where,

I_{am} = maximum water application rate

Lip = average basic infiltration rate of the field prior to construction of mole drains

d = operating depth (Distance from the soil surface to the central line of torpedo)

D = diameter of the bearing area of the torpedo

S = spacing of the mole drain

The sprinkling rate could not be varied to high application rate which caused lower I_{am}/I_{ip} value. But the theoretical values calculated from the above formula were higher than the experimental values. This shows that application rate can be increased more which can be drained safely. Two observations were taken from plot No.1, plot No. 3 and plot No. 5 for two different rainfall intensity is higher than the artificial sprinkler application.

The outflow hydrograph for plot No. 1 (Fig. 5) shows that although a constant application rate was maintained, the maximum discharge after reaching certain limit started to decrease. This may be

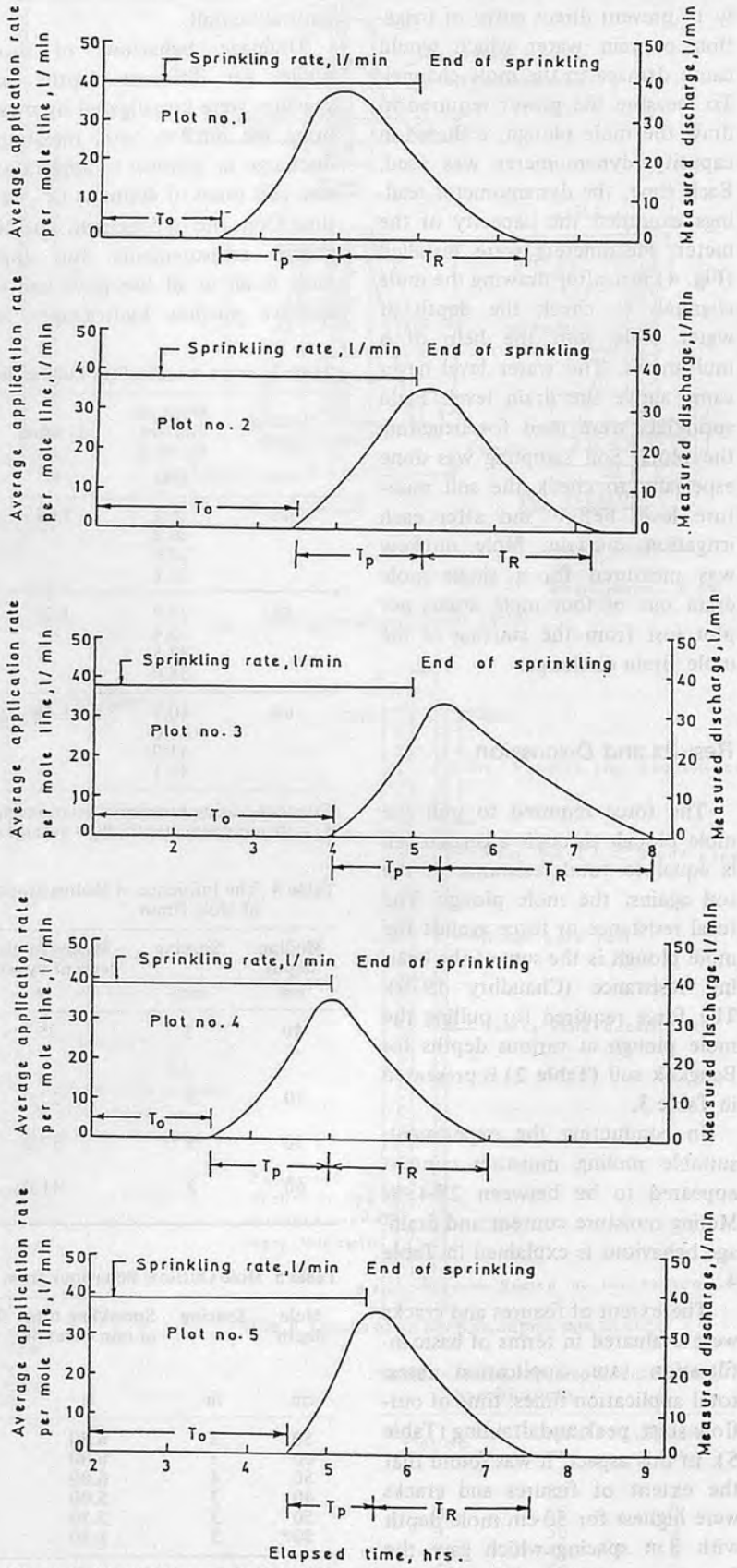

Fig. 5 Outflow hydrographs for single mole channel in different plots.

due to the crack interference of two mole drains which caused the cracks to collapse, or swelling and closure of cracks, in general. Theoretical I_{am}/I_{ip} value was highest for 2 m spacing mole drains at 50 cm depth but outflow hydrograph did not respond as expected. Again, mole drains of 3 m spacing at 40 cm depth did not give higher outflow in relation to application rate except in few cases, although some maximum outflow was constant with constant application rate time (Fig. 5 for plot No. 4). In this respect mole drains at 50 cm and 60 cm depth at 3 m spacing (plot No. 5 and plot No. 3) showed good response. Among them plot No. 5 gave the best response both for sprinkler application as well as for natural rainfall (Table 5). Different I_{am}/I_{ip} values were calculated for maximum application rate and plotted against d/D values for certain S/D value equal to 39.37 (Fig. 6). The figure shows a relationship similar to that developed by Gupta (1978).

Initial water levels at the time of moling were 1.45, 1.45. 1.46, 1.49 and 1.47 m for plot No. 1, plot No. 2, plot No. 3, plot No. 4 and plot No. 5, respectively, from the ground surface. Variation of water table with respect to time is shown graphically for two plots (Fig. 7). The water level never came above the drain level. So it had no effect on mole drains.

Conclusions

Test results obtained from the experiment can be summarized as follows:

1. The force required to draw the mole plough at three different depths was higher than 3 t.
2. The suitable moisture content for moling in-field condition was in the range of 27-43%. But the mole drains constructed at 37-38% moisture content gave the

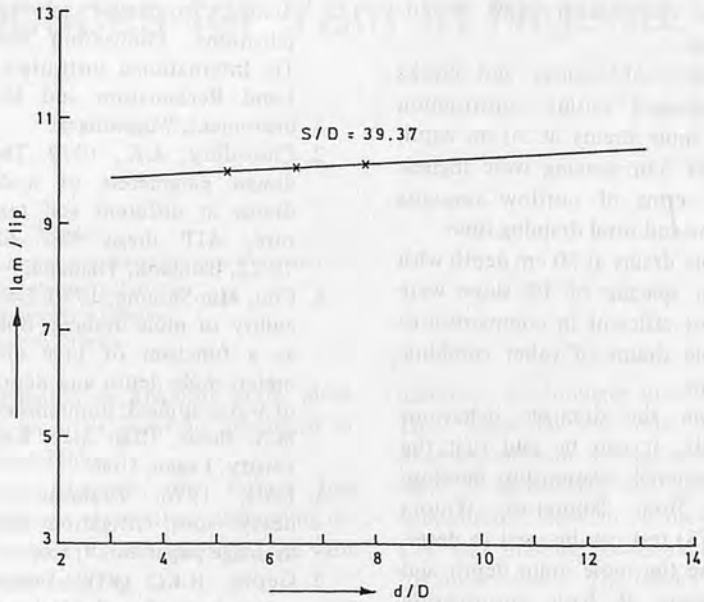

Fig. 6 Functional relationship.

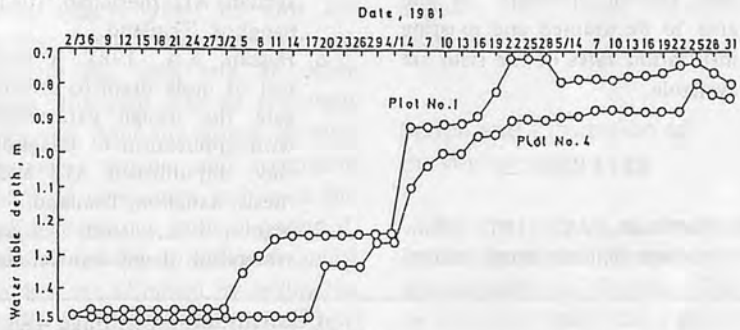

Fig. 7 Water table fluctuation with time.

Fig. 8 60 cm-long PVC pipe fitted to mole-drawn outlet.

Fig. 9 Slit left by mole plow.

Fig. 10 Mole outlet after drawing mole plow.

best response in terms of outflow.

3. Extent of fissures and cracks developed during construction of mole drains at 50 cm depth with 3 m spacing were highest in terms of outflow response time and total draining time.
4. Mole drains at 50 cm depth with 3 m spacing of 1% slope were most efficient in comparison to mole drains of other combinations.
5. From the drainage behaviour study, it can be said that the functional relationship developed from laboratory (Gupta 1978) test can be used to determine the mole drain depth and spacing, if basic information like rainfall intensity in the area to be drained and existing infiltration rates of the field are available.

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Storage Practices for Yam in Nigeria

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Abstract

A preliminary survey of the storage methods for yam tubers was made in order to identify the most popular ones in Nigeria. The most popular technique was later to be evaluated from an engineering point of view. The survey shows that the yam barn was the most widely accepted and practiced method. Other practices included pit, platform, heap and building storage. Losses in some of these methods were found to be high.

Introduction

Yam (*Dioscorea rotunda* Poir) is one of the two most important root crops grown for food in Nigeria. In the southern part of the country, it is an important part of the staple diet (Adesuyi, 1974). It is a source of carbohydrates, proteins and vitamins **(Table 1)**. It was estimated (Coursey, 1967) that the average annual yam production in Nigeria was 9.5 million t. This figure has since increased to 13.619 million t in 1980, making Nigeria the world's largest yam producer **(Table 2)**.

The main areas of heavy production in Nigeria include Oyo and Ogbomoso in Oyo State, Ondo State, Agbor, Kwale, Ogwashi-Uku and Ubiaja in Bendel State and Abakaliki in Anambra State. Most of Nigeria's yams are produced in Bendel State.

At harvest, the farmer has different alternatives, depending on the quantity and quality of the yam produced **(Fig. 1)**.

If the farmer has big crop of good quality yam, he opts for storage, and awaits the time of scarcity for final sale. In other cases, the yam may be processed into yam flour and stored. Because the most popular and acceptable form of consuming yam is in the tuber form, as boiled, pounded, roasted or fried, better financial returns are obtained by selling the yams as tuber rather than as processed yam flour. This explains why many farmers prefer to store most of their yams after harvest.

Stored yam is very vulnerable to attack by micro-organisms like mold, insects and rodents. This results in loss of viability, palatability, weight and financial returns when sold. It is, therefore, necessary and important to ascertain the right storage atmosphere that will minimize or eliminate these losses. This paper, surveys the storage practices of yam in Nigeria with a view to identifying the problems encountered, flaws in the method if any and making recommendation for improvement. The results of the survey would in future be used to evaluate the most appropriate technique.

Scope and Limitation of Survey

For the purpose of the survey, Bendel State was chosen as being representative of Nigeria. This is because the State can rightly be

Table 1 Chemical Composition of Yam

Moisture (%)	70-80
Starch (%)	25-28
Sugars (%)	0.5-0.6
Fats (%)	0.1-0.3
Crude protein (%)	1.1-2.8
Crude fibre (%)	0.6-1.5
Ash (%)	0.5-2.1
Vitamin C (mg/100 g)	5-8
Vitamin B_1 (mg/100 g)	0.08-0.09
Vitamin B_2 (mg/100 g)	0.02-0.03
Vitamin A (mg/100 g)	0.8

Source: Adesuyi, S.A., 1977.

Table 2 Major Yam Producing Countries

Region/Country	Yam area (100 h)	% of World yam area	Production (1000 t)	% of World production
World	1916	100	18037	100
Africa	1876	98	17701	98
West Indies	13	1	164	1
Nigeria	1334	70	13619	76
Ivory Coast	137	10	2908	16
Ghana	130	7	1046	6
Togo	107	6	803	4
Dahomey	54	3	527	3
Sudan	36	2	199	1
Jamaica	6	0.3	87	0.5

Source: West Africa Farming and Food Processing Nov/Dec, 1980.

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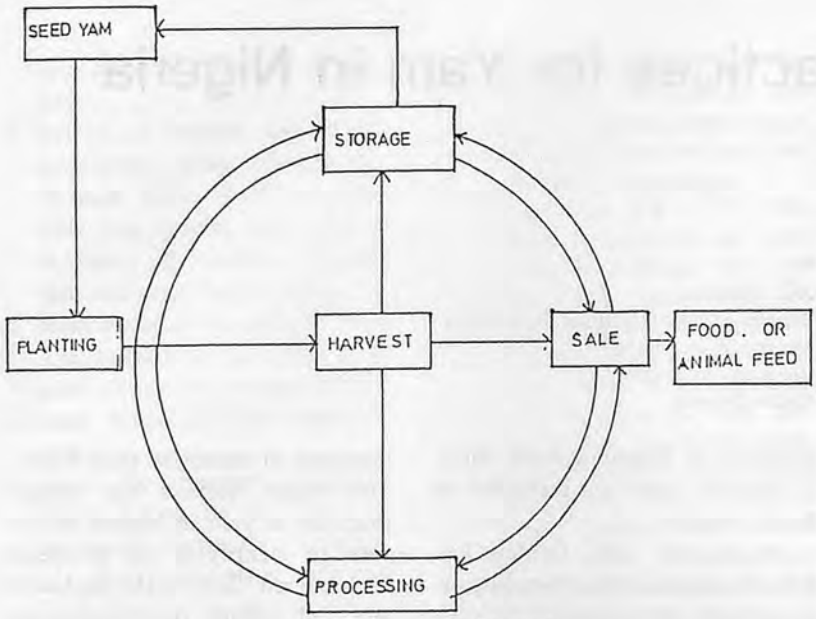

Fig. 1 Alternatives at harvest.

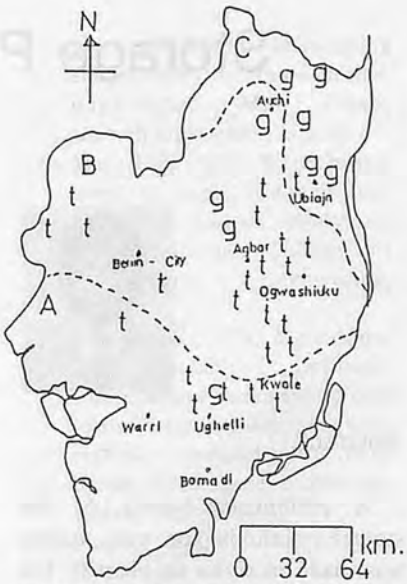

Fig. 2 Vegetational map of Bendel State. Key: A – Mangrove and fresh water swamp, B – Rainforest, C – High savannah, g – Grain crops, t – Tuber crops.

described as a microcosm of Nigeria.

Geographically, the State occupies almost a central position with the three dominant climatic conditions typical of Nigeria (tropical rain forest, tropical secondary forest and semi-savannah grassland) all cutting across it, **(Fig. 2)**. Agriculturally, crops typical of the different parts of Nigeria are grown in Bendel State.

From the aforementioned, it is obvious that any pertinent situation applicable to Bendel State can be rightly extended to apply to Nigeria as a whole.

Materials and Method of Survey

The survey was carried out in two ways. The first was by the use of questionnaire and the second was by personal interview of the farmers. Photographs of relevant storage structures were taken.

Places visited included:

(a) Government and private farms
(b) Zonal offices of the Bendel State, Ministry of Agriculture and Natural Resources (M.A. N.R.)
(c) Research Institutes.

The State was divided into six zones. These were Auchi, Agbor, Ubiaja, Kwale, Benin and Ugheli zones **(Fig. 2)**.

The information requested in the questionnaire included the following, among others:

1. Type of ownership; whether private or Government.
2. Location of storage system – farm or home.
3. Date and season yams were harvested.
4. Type and quantity of yam stored.
5. Type of storage and length of storage.
6. Nature and quantity of damage.
7. Any other relevant information.

The interviewers were agricultural engineering undergraduate/postgraduate students under the author's supervision.

The survey and observation time was 21 months. This period covered and included two harvest seasons and one planting season. So the farmers were regularly visited to, observe their harvesting, handling, storing and planting operations.

Results

The information and data from completed questionnaires were analysed by the author. A total of 50 farmers were surveyed in each zone making a grand total of 300 farmers.

The survey revealed that the most popular technique practiced was the barn method **(Table 3)**. In general, the percentage loss in this method was comparatively low. A summary of the survey findings is given in **Tables 4a-4f** according to the zones.

Storage Methods

Four different storage methods were identified. They were the barn, platform, building and pit. Some other methods like heaps and sheds were found to be used only when the yams were on transit before final storage of before marketing.

Table 3 Types of Storage Techniques Practised in Each Zone

Zone	Pit	Platform	Barn	Heaps
Aucho	–	–	Yes	Yes
Agbor	Yes	–	Yes	Yes
Benin	–	Yes	Yes	–
Kwale	–	–	Yes	Yes
Ubiaja	Yes	Yes	Yes	–
Ugheli	–	Yes	Yes	–

Table 4 Summary of Survey Results

Zone	Agbor	Auchi	Benin	Kwale	Ubiaja	Ugbeli
Average quantity produced (t)	67.5	22.5	10	67.8	17	9.5
% stored	59	58	58	70	67.6	36.6
% of stored product damaged or lost	12	25	3	1.5	2	5
Type of storage	B, BS	B, PTS	BS	B	B, BS, PTS	BS
Average duration (months)	7-22*	8	3-6	5-12*	6-16*	3-6

*Yams left by farmers in the bran under special request by the author.

Pit Storage – This technique is sometimes called underground silo. A circular trench is dug and the bottom and sides mulched with palm leaves or other types of leaves. The yams are arranged horizontally in the pit and then covered with the mulch. This is an improved version of the original structure which was used without mulching. It is on-the-farm storage.

The reasoning behind this storage technique as explained by the farmers, was to conserve the moisture in the tuber. They believed that pit storage slowed down the drying rate of the yam tuber, and kept it fresh. Observations have shown that in as much as the moisture in the tuber was conserved, deterioration was speeded up due to high temperature and high humidity. Temperature in the pit was observed to be sometimes as high as 55°C.

Other hazards associated with this technique include susceptibility of the tubers to excessive rain, when the pit is not covered with zinc; insects, rodents, and termites.

The main source of losses is due to rot and decay. Other sources were damaged tubers due to insects and rodents, especially rabbits and mice. This method is fast being abandoned because of high losses.

Building Storage – This method is fast gaining popularity among large-scale farmers and middlemen dealers. This storage facility is usually located very close to the market outlet. The building can be fully walled or half-walled and the walls can be of mud, concrete, wood or bamboo. Different versions of the storage structure are known. The most popular one consists of wooden framework to which bamboo poles are nailed vertically to, at 5 to 15 cm apart to form the wall. The roof is of metal sheets or leaves and there is no ceiling. The tubers are arranged on shelves. The products inside the building are protected from rats by fixing iron sheet barriers, one meter high, around the walls. The advantage of this system is that it provides adequate ventilation (**Fig. 3**). The second version, used mainly by enterpreneuers, is a building with low wall level, the other half wire netting. The tubers are either stacked in heaps according to variety or date of purchase or on shelves. Most of the entrepreneurs interviewed said that they eliminated the hazard of rats by breeding two or three cats in the building.

Platform Storage – This method is not very popular and is used mainly by low productive farmers. In this method, the tuber are arranged on wooden platform and laterals. Losses are quite high with this method as the tubers are susceptible to rodents, insects and pests.

Yam Barn – The survey showed that this technique was the most widely practised method throughout the State. It varies in design and structure from area to area but they all have the same basic features. The barn consists of vertical framework. To these frames are tied the yam tubers, individually, by means of twines (**Fig. 4**). The framework is made from vertical poles, preferably live, 5-10 cm in diameter, and set 1 m apart. The height of the poles varries from 1 to 2 m. Cross members are usually of bamboo or raffia palm-leaf mid-ribs.

The tuber is fastened to the poles using a special technique which needs some practice and experience (**Fig. 5**). The yam barn is a permanent structure for the large scale farmers, and as such live poles used, develop shades which

Fig. 3 Building storage structure. Adequate ventilation.

Fig. 4 Typical yam barn.

Fig. 5 Close-up of tying method.

Fig. 6 Yam barn: Using live poles as shade.

are supplemented with palm leaves. This protects the tubers from the heat of the sun, and overwetting by rain (**Fig. 6**). The yam barn has been found very adequate by the farmers because ventilation is good, cost of construction is minimal and materials of construction are available locally from the bush.

Losses using this technique are through sprouting, rotting and sometimes excessive loss of weight through dehydration.

Discussion and Analysis

The results of the survey show that only two methods were popularly and successfully practised in the country. These are the barn storage and building storage. Losses using these two methods were found to be minimal with the barn method still less. As has been mentioned, losses can be sustained either through rodents, pest, insect, microbial attack, sprouting or rotting. With the exception of the first three sources, which can easily be controlled by good management, all the other sources of losses are controlled by the environment.

It can, therefore, be said that the storability of yam during storage and in fact of all agricultural products, is dependent on the environment. The controlling parameters or factors affecting the environment are temperature and relative humidity. The knowledge of the behaviour of yam in relation to any given temperature and relative humidity is important in analysing its storability.

Equilibrium Moisture Content of Yam – The concept of equilibrium moisture content is directly related to the storage of farm products. The storage stability of any product is related to the temperature and equilibrium relative to the sorption or desorption tendency of the product under a given ambient condition. The relationship between moisture content and equilibrium relative humidity at a given temperature is best represented by a curve known as moisture isotherm. Generally, the curve is sigmoidal in shape (Igbeka, *et al*, 1975) and its steepness depends on the material and its water holding ability. Many researchers have presented moisture isotherms (sorption and desorption) of many agricultural products (Igbeka, *et al* 1975, Igbeka and Blaisdell 1982, 1969, Labuza 1968, Chung and Pfost 1967) but little has been done in the moisture isotherm of yam. Ezeike, 1979 presented an isotherm plot of yam at only one temperature (32°) (**Fig. 7**).

Stability of Yam During Storage – The stability of yam tuber can be analysed with the help of the moisture isotherm. Referring to **Fig. 7**, yam which contains high proportion of starch and cellulose and small amounts of protein and other soluble solids, can be said to possess a L1-11 range (Rockland, 1969), which defines the products maximum stability zone within an optimum moisture range. At this range there is normal color, normal odor, normal flavor, minimal chemical changes and is microbiostatic. At 32°C, the moisture range for maximum product stability is between 240 and 280% dry basis; and this corresponds to equilibrium relative humidity range of 30 to 70% (**Fig. 7**). Therefore, any of the storage structures that meet these requirements will maintain stored yam tubers in stable condition. More work is being done on the moisture isotherms of yam at different temperatures and also work is going on by the author in evaluating the yam barn from the engineering point of view.

From preliminary works, it is likely that orientation, ventilation and materials of construction of

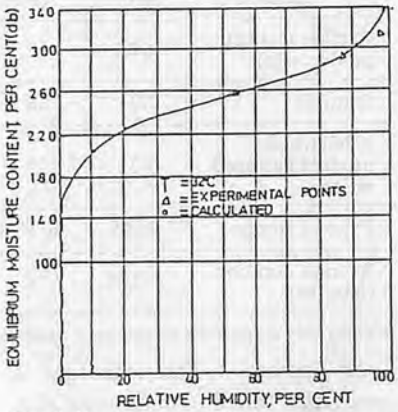

Fig. 7 Yam tuber equilibrium moisture curve (Ezeike, 1979).

the storage structures of yam play very important role in maintaining adequate environment for stable storage.

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Power Tiller Industry in India

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Abstract

The power tiller industry in India is in a developing stage. Though it has a licenced capacity of 31 000 units per annum, the annual production of power tillers is only about 2 500 units. There is need to expand the infrastructure for research, training and extension activities in the country to overcome the problems in popularising the power tillers in Indian agriculture. Recently the Government started a programme to introduce power tillers in Indian agriculture with the help of All India Coordinated Scheme for Intensive Testing of Power Tillers and Research and Development of New Machines.

Introduction

From all animated and non-animated source of power available on the Indian farms today national average farm power is only about 0.4 hp/ha. India has to achieve a target of 0.86 hp/ha farm power by 2 000 A.D. For small Indian farms large tractors are not suitable because of various losses during small plots operation (fragmented land) and due to their high cost the farmers are not able to purchase them. Hence power tiller with all matching implements are more economical. A power tiller of 5 to 12 hp can develop a sufficient drawbar power for various farm operations and can easily replace bullock pairs. Thus it is a suitable unit for farmers having up to 4 ha cultivable land.

Scope

Due to land ceiling and breaking of "combined families" in the society the land is fragmented. According to statistics available the number of families engaged in Indian agriculture were 70.5 million, 80.5 million, and 85 million during 1970-71, 1976-77 and 1980-81, respectively. The land holding per family has declined from 2.3 ha/family to 1.93 ha/family over the same period. About 70% of Indian farmers farm less than 4 ha of land each and thus there is urgent need for low cost power source for this group. It is also difficult to sustain more and more number of bullocks as source of the farm power; hence small and cheap tractors are necessary.

Industrial Development

The power tillers were introduced in Indian agriculture in 1961-62 by importing few units for paddy cultivation. The indigenous production of the power tiller started in the same decade. The industry started with the multipurpose hand tractor designed primarily for rotary tilling and other farm operations where large conventional 4-wheel tractors are not practical. Besides the industrialists' view was to produce farm machines for orchard, nurseries, hilly areas etc. and for large fields as supplementary power unit for intercultivation, spraying, dusting, pumping and transporting farm inputs, etc.

The first licensed firm was Messrs Krishi Engine Ltd, Hyderabad followed by others in 1966. At present seven firms are engaged in the production of power tillers. These firms are manufacturing 5-12 hp units. Up to the year 1965-66 there were 329 units available in the market from these firms. As per recommendation of the National Commission on Agriculture in 1976 "the two-wheeled power tiller should be used for light tillage operation, specially in vegetable and floriculture plots, for light pumping of water and for plant protection operation.

Table 1 Import of Power Tillers in India

Year	Import
1961-62	2
1962-63	22
1963-64	12
1964-65	173
1965-66	23
1966-67	141
1967-68	311
1968-69	33
1969-70	N.A.
1970-71	70
1971-72	1583
1972-73	112
1973-74	147

Note: After 1974 the power tillers were not imported because the indigenous production was sufficient to fulfil the requirement.

Ref. Agricultural Engineering Today Vol. 4 No. 1 Jan-Feb, 1980, ISAE, New Delhi.

Table 2 Power Tiller Import Under Yen Credit, 1965-75

Make	Unit
Iseki	100
Satoh	100
Kubota	4037
Mitsubishi	3213
Robin	530
Others	715
Total	9603

Table 3 Power Requirement Based on the Demand for Tractor

Type of tractor	Numbers (Million)	Capacity per Tractor (hp)	Total power (Million hp)
2-Wheel power tiller	1.80	7	12.60
4-Wheel tractor (Small tiller)	0.28	17	4.20
4-Wheel medium tractor	0.12	35	4.20
4-Wheel heavy tractor	0.08	65	5.20
Total	2.28		26.20

Table 4 Indigenous Production of Licensed Capacity and Actural Production of Power Tillers

Manufacturer	Krishi Engines Ltd. Hyderabad	V.S.T. Tillers Tractor Ltd. Bangalore	Jay Kay Satoh Agril. Mech. Ltd. Kanpur	Indequip Engg. Ltd. Ahmadabad (a)	Maharastra Coop. Engg. Soc. Ltd. Kolhapur (a)	Kerala Mach. Ltd. Ernakulam	Bihar Industrial Corp. Ltd. Patna	Total
Model	Krishi (21.5.63)	Mitsubishi (6.4.66)	JK Satoh (29.2.73)	Iseki (15.2.73)	Yanmar (4.11.72)	Kubota (9.2.72)	Kubota	
HP range	5-8	8-10	5-7	5-7	8-12	9-12	9-12	
Licence capacity	3000	5000	6000	1000	4000	12000	5000	31000
Production capacity	900	5000	6000	–	–	3000	1100	16000
1965-66	329	–	–	–	–	–	–	329
1966-67	577	–	–	–	–	–	–	577
1967-68	171	–	–	–	–	–	–	171
1968-69	286	–	–	–	–	–	–	286
1969-70	314	–	–	–	–	–	–	314
1970-71	315	509	–	–	113	450	–	1387
1971-72	123	591	–	155	88	124	–	1081
1972-73	181	507	–	100	174	287	–	1199
1973-74	141	666	178	136	103	302	–	1526
1974-75	165	1069	322	113	–	446	–	2142
1975-76	159	1454	222	58	100	547	–	2540
1976-77	404	561	231	42	65	455	–	1758
1977-78	226	658	95	–	–	557	60	1596
1978-79	72	1156	135	–	–	832	141	2336
1979-80	302	1300	163	–	–	410	34	2209
1980-81	120	1523	43	–	–	256	8	1950
1981-82	129	791	68	–	–	858	70	1916
1982-83	37	1139	56	–	–	928	0	2160

Notes: 1. The figures in brackets are date of issue of license for the firms. 2. Revoked/cancelled (a) 3. (a) Revoked/cancelled gives total capacity 31000. Source: Agricultural Engineering Today, ISAE publications.

Chronological Development

Import

Starting with the import of 2 units of power tillers in 1961-62 the number of power tillers increased considerably in subsequent years. To cope with the need of small farmers in hilly areas for paddy cultivation a new idea was introduced to import more power tillers with a view to giving a suitable power unit for use and evaluate it for local conditions. Besides, the general import (Table 1) the West Bengal Government imported 200 more units in the early 1960s. During the period 1965-1975 about 9 603 power tillers were imported under various yen credits (Table 2). Though the indigenous production license was issued in 1963 the import of power tiller continued up to 1974-75. Now the import is totally closed due to sufficient indigenous production.

Indigenous Production

Starting the production in the country with only one firm 7 firms are now involved in power tiller production. The production of power tiller in 1965 was 329 units which reached 2540 units per year in 1975-76 and again came down to 1596 units per year in 1977-78. Thus there is increase as well as decrease of production in subsequent years (Table 4). The production in 1980-81 and 81-82 was 1950 and 1696, respectively. Besides the power tiller listed in this table Messrs National Engg. Co. (M) Pvt. Ltd., Madras has also started the assembly of National power tiller. There has been considerable increase in improved farm inputs like seed, fertilizer, chemicals, etc but due to various reasons power tiller production was still short of the country's requirement. Today there are about 30 000 power tillers in the country which are contributing considerable power in the farms. As per a report of National Commission on Agriculture, 1976, there was 16.8 million hp power available from small tractors out of 26.20 million hp total tractive power available (*i e*, power available from all types of tractors) (Table 3). The production

trend is fluctuating and now a few firms have also discontinued production. Only one of the original firms has continued its production since 1965.

Presently all the Indian power tillers are associated with single cylinder light diesel engines of 5-12 hp of 90-150 kg with gross weight of units ranging 315 to 495 kg with air/water cooling provision. Out of the total licensed capacity of these power tillers (31 000 units/year and the productive capacity of 1 600 units/year) they are producing only 2 500 units/year. These units can be classified in two hp range; Iseki, Jay Kay Satoh, and Krishi fall in 5 to 8 hp range whereas Kubota, Mitsubishi and Yanmar are in 8 to 12 hp range. The production of these groups is approximately equally divided among them. The total average production is about 200 units/month from all the firms.

Though the power tiller industry is quite young still the testing, training and information support is being given by the Government. The Indian Standard Institution (ISI) has already formulated standards for number of components/attachments/accessories. Recently the emphasis was laid by the government on introducing "All India Coordinated Scheme on Intensive Testing of Power Tillers and Research and Development of New Machine to make Them Versatile" through Indian Council of Agricultural Research with Coordinating Centre at Central Institute of Agricultural Engineering, Bhopal. The objective of the scheme is to investigate the usefulness of power tiller for various crops and its evaluation in hilly areas, promote power tiller utilization, production through manufacture and sale, to generate power tiller industry in rural areas, etc.

Associated Problem

Not only is the power tiller technology relatively new but also during the past few years their retail prices have increased about 2-3 times. A power tiller today costs between Rs 20 000 and Rs 30 000 and this is high investment which an average farmer with 3-5 ha holding cannot afford. Lack of promotional measures, non-availability of well matched implements which would enable the farmers to fully replace the bullock power and poor after-sales service facilities also accounted for slow development of power tillers. The presently manufactured power tillers are designed primarily for the paddy areas and the low cost multipurpose tiller suited for hilly areas and for general farming in the wheat growing areas are yet to be introduced. The problem associated with Indian power tiller industry is broadly divided into three classes in terms of technical, industrial and users aspects as discussed below:

Technical Problems

Efficiency – The drawbar horsepower available with power tillers is only 10% to 20% of the brake horsepower, whereas in case of tractor it is 30%-60%. So the transmission system should be rectified, wheel with ultra-low pressure (about 0.8 kg/cm^2) may also be a solution for increasing drawbar hp. Due to this reason a power tiller (8-12 hp) can haul 1 t, whereas a pair of bullocks (1 hp) with bullock cart can haul 2 to 3 t load.

Standardization – There is urgent need for the standardization of the product, the power developed by the unit, etc. Though test facilities are available in the country still all the power tillers are not tested. There is need to have detailed information regarding BHP, DBHP, etc and this must be done by standard testing agencies. The ISI certification mark will also be helpful in popularizing the product.

Speed – Besides off-the-road work the power tillers are also used for transportation and others on road operation. So it is necessary that there must be a provision of having sufficient high road speed.

Industry Problems

Raw Material – The manufacturers are not getting good quality steel, etc at cheaper rate. Owing to other new developing industries there is need for government subsidy and loans. The government should provide special quota of steel and other raw materials to the manufacture of the power tiller and give some concession on other facilities.

Marketing – There is no proper marketing infrastructure or network for power tiller sales, service, repair, etc without which an industry cannot run properly. There is an urgent need for this facility for the power tiller industry.

Extension Activities – These activities are undertaken by various committees where heavy investments are required for demonstration, sale promotion, publicity, etc. There is lack of extension agency who could give wide publicity for the suitability and need for power tillers in agriculture.

Over-estimated Demand – The Government estimates an annual demand of 80 000 units by the end of IVth Five Year Plan, whereas present annual sale is 2 000 units. But after taking into consideration the utility of power tiller on irrigated, medium-sized paddy holding ISAE estimated that the maximum demand the industry could reach in the foreseeable years will not exceed 2 000 units/year. Thus the industries are over-licensed, owing

to which no power tiller industry in India could be a viable venture if they manufacture power tiller alone. They must diversify and widen their product mix with other merchandise.

Users Problems

The main problems faced by the farmers in the use of power tillers are:

Manoeuvrability – Almost all the power tillers are not equipped with driver's seat, thus an operator has to walk throughout the operation. There is a lot of sound, excess vibration and jerk which tires the driver. The steering is not so smooth, thus at the time of operation and during turns it takes a lot of human effort to balance it. So the ergonomics of the power tillers at present is not favourable to operator. Hence, an operator cannot work more than 4 hours continuously.

Stability – Owing to two-wheeler and front engine mounting system there is tendency for the tiller to tilt down either forward or backward due to the operation of a less skilled operator. So even a highly skilled driver with constant attention and heavy effort is necessary for balanced operation. This tires the farmer operator unduly.

Matching Implements – Besides all agricultural matching implements like plough, rotary cultivator, etc, there is need for provisions in the operation of a small flour mill, trolley, etc with proper attachment which could easily be operated by the same power units attached with power tiller. Even if a small electrical generating unit could be evolved to work on power tiller it will be good for farmer because they can use this system during such functions as marriage, festivals, etc. The use of power tillers on road construction municipality work, etc should also be considered.

Cost – Though the cost of power tiller is less than that of a tractor, the latter has, of course, greater power. The fuel consumption/bhp-h is also about 5 times as compared to the tractor. The cost of 1 power tiller is about Rs. 25 000 (Rs. 250 per hp) whereas the cost of tractor is aobut Rs. 60 000 (Rs. 2000 per hp). Hence cost-benefit ratio is less compared with bullocks.

Technial Know-How – There are limited facilities for training farmers regarding repair, maintenance and operation of power tillers. Thus the Government and private sector should take the initiative in facilitating such training program for operation, maintenance and repair of power tillers.

Spare Parts – There are no specified local dealers through which the spare parts of the power tiller can be purchased. Even for small breakdown the farmer has to approach either manufacturer or regional dealers who are located far away from their places. Also, limited spare parts are supplied by manufacturers with the supply of new power tillers.

After-Sale Service – Owing to lack of countrywide sale service there is considerable breakdown in the system of power tillers. Even in big cities these facilities are not available and the owner faces the servicing problem. To overcome this problem the owner should follow a periodical maintenance chart as suggested by manufacturer for better machine performance. Operating instructions should be followed during driving. The drivers must have proper training before procuring the power tiller. There is also need for reorganizing the system either by Government or by manufacturer in an organized way. A logical step will be to identify "green" belts so that concentrated sale efforts can be confined to such spots, favourable areas will be medium-sized paddy holdings, plantation and holdings in hilly areas and areas of cash crops.

Interchangeability of Implements – Implements of one power tiller are not suitable to fit into another make of power tiller. All farmers desire to have a machine in which the available implements can be fitted. This can be made only by adopting a particular standard norm of manufacturing the power tiller.

Conclusion

Though there is a need for power tillers in India it is equally necessary that they be priced within the means of most farmers and that matching implements should be available. Manoeuvrability should be improved and a proper seating arrangement for driver is needed. Integrated approach for creating an infrastructure for popularization should be concentrated in a suitably selected area for the cultivation of different crops.

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Status of Dung Utilization in India and its Prospects

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Cattle is one of the oldest animals domesticated by man. It commands the highest respect in the society due to its manifold services for generations to mankind. The cow provides milk while utilizing greens, dry roughages and other coarse materials not suitable for human consumption. On the other hand, rural transportation and agricultural operations are still dominantly carried out by bullocks in India. Apart from these services, the cow dung obtained has multi-dimensional utilities. The dung is utilised as fuel, building material, soil manipulator-cum-fertiliser from time immemorial. However, in the present wake of energy crisis and scientific development, efforts have been made to study the various uses of cow dung in rural India along with alternatives for better utilisation of this precious commodity. **Table 1** shows the details of cattle population and estimated dung production in India from 1947 to 1979. Apart from it, dung produced by 65 million buffaloes can also be utilised for various purposes under consideration.

Fig. 1 gives the details of dung utilisation. Some of the uses shown have been known for a very long time. However, other uses refer to the future probabilities for extensive use of this waste matter.

It is estimated that out of the total bovine wet dung available, 69% is used as manure, 29% is used for preparing dung cakes for fuel and remaining 2% is used for other purposes. The loss due to burning of these dung cakes amounts to 0.8 million t of nitrogen, 0.961 million t of P_2O_5 and 0.961 million t of K_2O in terms of soil nutrients (Singh *et al*, 1977).

But under the existing methods of utilisation, a good proportion of the fertilizing ingredients is allowed to be wasted through improper handling, storage, use, etc. It has been observed that farm yard manure when properly prepared can give increased yields ranging from 10 to 60% (ICAR, 1971) in addition to restoring the soil fertility.

The use of dung for the production of bio-gas is another important aspect. **Table 2** shows the potential of bio-gas production in different states of India which much depends

Table 1 Cattle Population and Estimated Cattle Dung Production in India

Year	Cattle population[1] (million)	Estimated dry cattle dung production[2] (million t/year)
1947-52	155.2	135.96
1952-56	158.7	139.02
1963-64	175.8	154.00
1964-65	175.9	154.09
1965-66	176.0	154,18
1966-67	176.0	154.18
1967-68	176.1	154.26
1969-71	177.4	155.40
1977	181.0	158.56
1978	182.0	159.43
1979	181.8	159.26

1. FAO production year book, 1969 and 1979.
2. Average 0.86 t/year organic manure is voided by one animal.

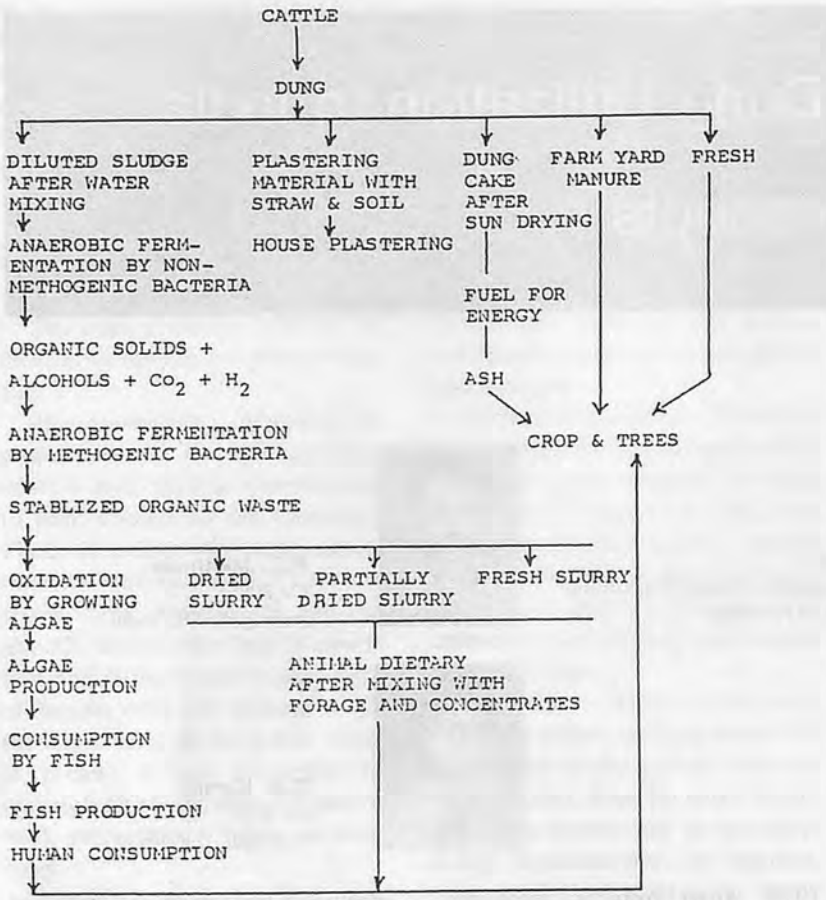

Fig. 1 Details of dung utilization.

Table 2 Potential Gobar Gas Production in Indian States

State/Union Territory	Monthy mean temperature °C		Rate of gas production (m^3/t of wet dung)
	Min.	Max.	
Andhra Pradesh	22.8	33.7	75.0
Assam	16.8	29.4	64.0
Bihar	17.0	31.7	63.0
Gujrat	20.7	32.6	71.0
Haryana	13.5	34.2	66.3
Himachal Pradesh	10.7	28.7	52.3
Jammu & Kashmir	2.2	21.0	23.2
Kerala	26.6	28.8	74.0
Madhya Pradesh	17.7	33.3	67.2
Maharashtra	21.2	30.8	68.7
Mysore	21.9	29.4	69.3
Nagaland	16.8	29.4	64.0
Orissa	20.6	31.3	72.8
Punjab	13.5	34.2	66.3
Rajasthan	15.3	33.7	69.6
Tamilnadu	24.7	31.6	77.3
Uttar Pradesh	15.1	32.9	61.1
West Bengal	18.1	29.7	66.3
Delhi	13.5	34.2	66.3
Chandigarh	13.5	34.2	66.3
Pondicherry	24.7	31.6	77.3
Manipur	16.8	29.4	64.6
Tripura	16.8	29.4	64.0
Andaman & Nicobar Islands, Dadra, Nagar Haveli, Lakshdeep Islands	28.1	31.3	82.7
All India Average			67.1

upon the surrounding temperature and many other factors. In a bio-gas plant, dung slurry having a concentration of 6 to 9% total solids is desired to be fed to inlet tank of digester.

It is reported that above the 9% concentration of total solids, there is decrease in gas production due to accumulation of gas produced at the bottom of digester. Moreover, if there is production of hydrogen sulphide, it inhibits the growth of methanogenic bacteria. The rate of supply of slurry to the digester depends upon the size of the digester, temperature, retention time of solids in the digester and concentration of the solids in the slurry. The temperature of the digester is very important from the point of view of gas production. There is significant effect of the season on the digester temperature and gas output can be decreased by 20-50% in the winter season. About the retention time, the present Indian biogas plants are designed for a period of 45-55 days. However, reports indicate that a period of 30 to 40 days is sufficient for optimum gas production.

The gas holder of conventional design is made of steel and it floats over the digester. The gas is stored in this gas holder and at the same time due to the floating of the gas holder, it is maintained at slightly higher than atmospheric pressure. The gas can be taken through gas outlet tap for necessary use. However, the corrosion of gas holder is a problem. Therefore, low cost ferro-cement and cement-cinder units have been developed to replace steel gas holder.

The height of the outlet tank exit is slightly lower than the inlet tank entrance. Therefore, when new slurry is added, the movement of slurry inside the digester takes place and an equal volume is pushed out through this exit opening.

Apart from these conventional

bio-gas plants, there is a "Chinese type plant" which does not require steel at all. There is an underground dome made of bricks and cement. It is enamel painted from inside. This type of plant has low initial cost and there is very little variation of temperature which leads to better performance. As there is no steel component corrosion of gas holder is eliminated. However, when the quantity of gas is below a certain limit, it results into inadequate gas pressure.

It has been observed that bacteria responsible for methane production grow well within mesophilic (25°-37°C) and thermophilic (45°-55°C) ranges. Therefore, effort has been made in the country to develop all-weather thermo-control biobas plant. Automatic control of temperature costs more but has definite advantage.

The stirring of the slurry in the bio-gas plant results into better bacterial action and it results in higher gas production. In small units stirring can be achieved by rotating gas holder once or twice a day. Other suitable stirring arrangement may be made for bigger plants. In the case of the Chinese type of plant, there may be need for a suitable pressure control device.

Table 3 gives a comparison of plant nutrients obtained in different manures. It is clear from the table that the manure obtained from biogas plants have more nutrients than farmyard manure with following benefits:

1. Gas is available as a source of energy. Simultaneously digested slurry can be used as organic fertiliser.
2. The amount of manure obtained through biogas plant is about 46% more than traditional methods.
3. The use of biogas results is less environmental pollution as compared to use dung cakes or wood as energy source.

Table 3 Comparison of Plant Nutrients in Different Manures

Manure	N (%)	P_2O_5 (%)	K_2O (%)
Biogas	1.4-2.5	1.0	0.8
Farmyard	0.5	0.2	0.5
Town compost	1.5	1.0	1.5

Table 4 Properties of Biogas

Gas	Sewage gas	Gobar gas
Methane	67-69%	45-55%
Carbon-dioxide	28-29%	49-57%
Nitrogen	0-1%	0-1%
Carbon-monooxide	0.1%	0.1%
Oxygen	0.1%	0.1%
Hydrogen	1-10%	1-10%
Hydrogen sulphide	Traces	–
Calorific value, Kcal/m³	5640	4215
Density, kg/cm³ at 20°C and 710 mm pressure of mercury	1.03	1.22

High calorific value of methane	13 100/ft³
Critical temperature of methane	−82.1°C
Critical pressure of methane	45.8 atm.
Boiling point at atmospheric pressure of methane	−166.6°C

Some important properties of biogas are also given in **Table 4**. Gabar-gas represents the biogas obtained by the fermentation of dung, etc. The average consumption of biogas is also shown in **Table 5**.

Table 5 Average Consumption of Biogas

1. For cooking	0.34-0.42 m³/persons/day
2. For gas lamp	0.07 m³/mantle/h
3. For gas engine	0.45 m³/hp/h

Gas pressure for low pressure gas lamp: 10 to 15 cm of water.

It has been found that the digested dung slurry (DDS) available after anaerobic fermentation in the biogas plant is a rich source of microbial protein. During the process of anaerobic fermentation, a large part of cellulosic fraction and soluble carbohydrates is converted into methane. Thus the residual DDS becomes richer in nitrogen and inorganic matter. DDS contains 13-15% crude protein, 1-3% ether extract, 20-35% crude fibre, 25-30% nitrogen-free extract and 20-25% ash on dry matter basis.

DDS after sun-drying has been successfully incorporated in the concentrate feed mixture of sheep and crossbred animals (Saxena *et al*, 1979). Due to high cost involved and the possible loss due to aerobic fermentation, the feeding of DDS either after partial drying (for 12-24 h) or fresh to the ruminant have been tried (Jakhmola and Pathak, 1981; Pathak *et al*, 1981, 1982).

In the study, one-third protein of wheat bran was replaced through DDS by mixing 3 kg wheat bran and 15 kg fresh DDS containing 9-10% dry matter. However, digestibility was significantly lower in DDS.

Cattle dung from animals fed on high concentrate diets is a rich source of soluble carbohydrates and protein. Such dung can be incorporated in the animal diet after some treatment and can play an important role during scarcity. Ensiling of cattle dung with green fodder and cereal straws gives a fermented product free of pathogens and palatable to the animals. The protein content of the wastage can also be increased if the premix is treated with 0.25-0.5% urea and 5-10% molasses. After a fermentation period of about 40 days, the wastage (cattle dung silage) can be fed to the animals. The high nutritive value of wastage in comparison to the dry roughages like wheat straw and paddy straw shows its utility as source of nutrients during scarcity period or for non-productive animals.

Much of the research has been conducted but still utilization of

animal organic waste in the feeding of livestock needs to be further investigated for its commercial use.

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Mechanization of Sugarcane Farming in India

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Present Status of Mechanization

Sugarcane is one of the important cash crops grown in India. It occupies an area of about 3.20 million ha or 2.37% of the cultivable area of the country. Sugarcane accounts for approximately 70% of the cost of production of sugar in India. It is grown by small, medium and big size farmers. Some 83% of the sugarcane farmers are of small category. Most of the cultural operations are labour intensive, hence there is urgent need to switch over to mechanize the crop to increase overall productivity. Sugarcane cultivation requires various operations like land preparation, planting, irrigation, interculture, earthing, propping, plant protection, harvesting, transportation and ratoon management which are done by indigenous equipment. Of the above operations, land preparation is done as in the case of other crops by commonly used tillage tools. Some are semi-mechanized such as planting, interculture, earthing, and transportation. Although the number of useful machines have been designed, developed and being manufactured for cultivating sugarcane but because of lack of extension agencies and socio-economic reasons they have not been much popular. Still majority of the farmers are using indigenous tools and implements.

Table 1 shows the average man/bullock pair hours required per ha for sugarcane cultivation. Harvesting, interculture, and planting are the most labour intensive operations.

Acknowledgement: Most of the tools and machines described in this paper have been developed at the Indian Institute of Sugarcane Research, Lucknow by the Agricultural Engineering Division. The author worked as a member of the group who contributed these machines to the farming community in India. The author is thankful to Dr. T.P. Ojha, Director, Central Institute of Agricultural Engineering, Bhopal for his valuable suggestions for preparing this paper.

Table 1 Average Man/Bullock-Pair Hours Required per ha for Sugarcane Cultivation, India.

Operation	Man-h	Bullock-pair h
Preparatory tillage	331.5	245
Manuring	238.0	31.2
Planting	337.5	30.6
Irrigation	392.0	64.4
Interculture and other operation	816.0	27.4
Harvesting and stripping	1 192.0	–

Table 2 Dimensional Details of Tools and Machines

Machine	Length mm	Width mm	Height mm	Weight kg	Remark
Power operated set cutting machine	960	2 440	1 283	110	
Bullock drawn sugarcane planter	1 450	1 225	765	107	
Tractor drawn semi automatic sugarcane planter	1 540	2 185	1 130	270	
Animal drawn weeder mulcher	1 500	600	960	30	
Moist hot air seed treatment unit	2 750	2 250	2 250	1 000	Weight without seed cane
Cane knife for harvesting and set cutting	550	100	–	0.550	Weight with handle
Cane knife for harvesting and stubbles shaving	620	115	–	0.760	do.
Sugarcane stripper	340	130	35	1	do.
Tractor drawn stubble shaver	2 200	2 000	500	350	

Newly Developed Cane Cultivation Tool, Machine and Equipment

A few very useful machines have been developed in India. A brief description of such machines according to the operation is given below. The dimensional details of the machines is given in **Table 2**.

Set Cutting and Planting Machines

In India the seed cane is planted in pieces of three or two buds. In the process of set cutting the sets are selected which is done manually by hand and also by semi-mechanized way by using a cutting machine **(Fig. 1)**. This is a simple machine operated by 5-7 hp electric motor/stationary engine or by a tractor. This machine can be easily transported to the field by hitching it in the three point hitch of the tractor. Two circular saw blades with suitable guards are used to cut the sets. A team of four persons is required to work with this machine. About 13 000 sets are cut per hour by this machine. The cost of this machine is approximately Rs. 1 450. The cost of set preparation by this machine is 1/6 that of the conventional method for one ha seed.

A bullock drawn machine **(Fig. 2)** is developed for flat planting. It requires a pair of bullocks as source of power. Two persons work with this machine which costs approximately Rs. 750. This machine cuts down the cost of planting to 1/3 that of the conventional method. It covers about 1.5 ha of land per day at a row spacing of 90 cm.

For medium-sized holding, a tractor-drawn machine called "Semi-automatic tractor-drawn cane planter" was developed **(Fig. 3)**. The cost of this machine is approximately Rs. 3 500.

In this machine the set is dropped manually. A two-row unit covers about 3 ha/day of work which is operated by a 25-hp tractor. Different operations such as opening of furrow, dropping of set manually by hand, application of fertilizer by the side of sets, gama BHC application over the sets, covering sets by a blanket of soil and pressing of sets is done in a single pass of the machine. Using a planter reduces the cost of planting by 1/3 approximately that of conventional planting. In addition to the machine in the **Fig. 3** few other designs are also available in the country. In one unit a rotary magazine is provided through which sets are metered, but dropping is done manually in this case also. An automatic planter design is also in the process of finalization. In this machine cut sets are dropped automatically; no manual labour is required to drop the sets.

Weed Control and Interculture

Weed control is very essential for raising a good crop. Weeding and interculture are done by manual, animal and tractor-drawn tools and implements. Chopping hoes and "Kudal" are common manual tools.

Anmial-drawn weeder mulcher used for weeding and mulching is shown in **Fig. 4**. Tractor-drawn 9 or 11-tyne tillers are also used for interculture purposes.

Plant Protection Equipment

Wide Swath Sprayboom – The sugarcane crop is very susceptible to insects, pests and disease attack. At initial stages of the crop it is easy to apply chemicals but when the growth of the plants is tall and specially during rainy season it is difficult to move inside the standing crop. Spraybooms with foot spray pump and trolley-mounted pumps have been developed and their use is more economical and efficient than other existing spraying system. This system is useful for spraying urea in ratoon crops. A

Fig. 1 Power-operated set cutting machine in operation – Srivastava and Sharma (2).

Fig. 2 Bullock-drawn sugarcane planter in operation – Yadav, Sharma, Srivastava and Singh (10).

Fig. 3 Tractor-drawn semi-automatic sugarcane planter – Srivastava (3).

Fig. 4 Animal-drawn weeder mulcher – Panje and Menon (1).

Fig. 5 Moist hot-air seed treatment unit – Srivastava, Singh and Sharma (4).

sprayboom requires two foot spray pumps or one trolley-mounted pump to operate it. A team of 4-5 persons is needed to operate it. Its cost is approximately Rs. 250 without sprayer/pump. Spraying by wide swath boom costs about 1/3 that of other spraying methods.

Sugarcane Seed Treatment Plant – For controlling seed borne diseases of sugarcane seed, heat treatment has been found very effective. A moist hot air unit (Fig. 5) has been developed to control the seed cane diseases. Its capacity is 7 quintals per batch for treatment of 4 hours. The seed canes are loaded in the drum of the unit. Temperature is maintained electrically by thermostatic-control at 54° C ± 1°C for 4 h and humidity is maintained approximately 100% inside the unit. For maintaining the humidity inside the drum unit consisting of two water heaters each of 1.5 kW is used. Steam generated by these heaters is injected from the rear side of the unit where a fan is provided to maintain uniform circulation of moist air inside the drum thereby treating the seed cane properly loaded in layers on the racks. The steam generating unit is an independent attachment to the treatment unit.

Heat treatment does not affect seed germination. Moreover, it controls scale insects, ratoon stunting disease (RSD), grassy shoot disease (GSD) and primary infection by red rot. The cost of one such unit is approximately Rs. 16 000. The cost of treatment of 1 ton of cane by this unit is Rs. 7.50. Power requirement for this unit is 12 kW load at 3-phase AC and energy consumption per batch amounts to 242 kWh electricity.

Sugarcane Harvesting Equipment

Cane knives used all over the country were surveyed and their large scale trial was done keeping in view operators' comfort, output per unit of time, quality of cane cut and stubble length left in the field. Out of the lot, two knives (Figs. 6 and 7) were found most promising. A stripper shown in Fig. 8 has been developed for stripping cane leaves and detopping.

A tractor-operated rear mounted harvester unit is under test stage. A successful harvester-cum-windrower is needed to suit the requirement of medium-and small-scale farmers.

Ratoon Management Equipment

The sugarcane crop is profitable if ratoon crop is done after harvesting the plant crop. Expenditure incurred on ratoon management is minimal. The first and foremost requirement of ratooning is that the crop should be harvested close to the ground level which is usually not done. Therefore, this calls for the development of a stubble shaver (Fig. 9). This is a tractor drawn, single row machine costing about Rs. 3 000. It covers an area of 1.5 ha/day. Stubble shaving is also done by a cane knife as shown in Fig. 7. Cost of stubble shaving by stubble shaver per ha is Rs. 106.66 as compared to Rs. 185.00 by manual shaving by knife.

Effects of Mechanization

Due to concentrated efforts of the Directorate of Sugarcane Development, sugarmills, co-operative agencies, cane federations and newly developed cane cultivation machines

Fig. 6 Cane knife used for harvesting and set preparation – Yadav and Srivastava (11).

Fig. 7 Cane knife used for harvesting and stubble shaving – Yadav and Srivastava (11).

Fig. 8 Sugarcane stripper used for detrashing and detopping – Yadav and Srivastava (9).

Fig.9 Tractor-drawn stubble shaver for ratooning – Srivastava (6).

are being distributed to the farmers and are getting much acceptance. The farmers are realizing the advantage of time saving, reduction in drudgery, efficiency of operation by the use of such machines and its effect on increasing production and productivity. These benefits can further be taken to the grass root level by introducing custom hire service.

Cost Benefit Experience

The use of improved and newly developed machines not only reduce the drudgery and make the operation efficient but this also brings down the cost of cultivation. In comparative trials it has been observed that the cost of raising the crop by improved machine is much less than crop grown by conventional methods. Set preparation by improved set cutting machine, semi-automatic planting by planters reduces the cost by 1/3 that of traditional methods. Intercultivation equipment, spraying systems and ratoon management equipment have contributed significantly in reducing the cost of operation to the extent of 30-50% that of the conventional methods.

Installed Power Input on Sugarcane Farm

Although no systematic work has been done for the estimation of hp/ha for sugarcane growing in India, some critical periods have been identified such as planting, interculture and harvesting, which affect the cost benefit ratio of the cropping system. About 2.75 hp/ha has been found reasonable for growing a good crop. It may be a combined input by human, bullock or power tiller or tractor and other power source.

Problem Areas

Spraying of tall crops, propping, earthing to stop lodging of cane and harvesting are the major problem areas of sugarcane growing. The removal of leaves and other biomass after the harvest possesses a serious problem of material handling. The present method of burning to clear the land is not desirable.

Gaps in Mechanization

Sugarcane planting, interculture, plant protection and harvesting are the operations where gaps have been visualized. In particular, harvesting which used to be done free in exchange of green tops consumed as a valuable cattle feed in the states of U.P., Bihar, M.P., Haryana, Rajasthan and Punjab is no longer popular and the system is being done as a paid operation. In other sugarcane growing states like Maharashtra, Tamil Nadu, Andhra Pradesh and Karnataka harvesting is done on contract basis with the help of paid labourers. Thus it calls for immediate attention for the research and development of a suitable harvesting machine for Indian conditions. It has to be kept in mind that the small plots of sugarcane scattered all over will pose problems of mobility for a large machine to be used for harvesting.

Pros and Cons of Mechanized Harvesting of Cane

In order to increase the overall productivity of sugarcane and other crops in various crop sequences, cane harvesting must be mechanized. Delayed harvesting causes deterioration of cane quality, poor recovery of sugar and ultimately delays the sowing of subsequent crops. Mechanized harvesting will also facilitate in systematic and smooth operation of sugarmills which are mostly suffering because of poor supply of cane. Organized harvesting will open up more job opportunities for labourers involved in the sugar industry. It will also facilitate harvesting based on maturity survey and calender of operation already planned. The use of a suitable machine will result in the reduction of losses of cane left in the field above soil surface as stubble which accounts for about 1% loss of total production. Good quality, clean, trash free cane supplied to sugarmills will increase the total productivity of the crop.

Efficiency and Economics of Sugarcane Transportation

The sugarcane industry is well knit. Most of the cane growing areas are very well connected by farm roads. It is no more a secret that sugarcane is transported to sugarmills either by ADV tyred specially built bullock carts, tractor trailors and trucks. One should only take into consideration the fact that bullock carts are suitable for transportation of cane in the radius of smaller distance from economic considerations and also from the angle of avoiding drying of harvested cane. For medium distance tractor trailers should be used. For longer distance trucks should be used. It is desirable to have a faster mode of transport to avoid stalling of the harvested cane. Judicious selection of means of transport should be done. In mechanized system of cane cultivation, tractor/powertiller transport would be preferable as it may increase the use of these machines annually.

Scope for Further Mechanization of Operations

Seeing the present trend of scarcity of farm labourers during the peak-periods, *ie*, planting and harvesting and non-availability of a suitable machine for harvesting, there is a dire need to concentrate on design and development of a harvester. Harvesting may be in phases, *ie*, harvesting cum-windrowing cum-stripping.

The scarcity of available water for irrigation calls efficient systems such as drip and sprinkler for irrigating sugarcane should be devel-

oped. These systems apply irrigation water economically and efficiently but the initial investment is excessively high. Probably the use of sprinklers would be good compromise.

How to Popularize Cane Cultivation Equipment

Seeing the economic conditions of Indian farmers and the size of holdings (about 83% farmers holding is less than 4 ha) it will be advisable to advocate the use of newly developed machines through custom hire system at block, "tehsil" and district levels. In the past some efforts were made with reference to the popularization of improved cane cultivation equipment through custom service. Results were very encouraging. A brief account of cost benefit ratio was worked out. It is estimated that with an investment of approximately Rs. 2.5 million (U.S.$312 thousand) in a sugar factory area, the factory can also earn a profit of Rs. 0.4-0.5 million (U.S.$50-62 thousand) annually from custom service, in addition to helping about 20 000 farmers in their factory zone to improve their economic condition thereby raising their social standard.

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ERRATA

The pictures of the "New Co-operating Editors" which appeared at p.85 of AMA autumn issue, 1984 should have been placed reverse. Hence, the corrected article is printed again at p.37 of this issue.

Vol. 15, No. 1, page 63:

Fig. 7 should read "An animal-drawn rotary weeder (developed at I.A.R.) led to the development of a rotary hoe developed and manufactured by M/s John Holt Agricultural Engineering Ltd, Zaria.

Measurement of Properties of Rice Husk Boards:

Part I Physical and Mechanical

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Abstract

The practical suitability of rice husk boards can best be established by evaluating their engineering properties. For testing the various properties of particle and hard boards, the Indian Standard Institution (ISI), British Standards (BS) and American Society of Testing Materials (ASTM) have recommended standard procedures. But due to lack of inexpensive instruments and development of accurate apparatus, proper evaluation of rice husk boards has not been attempted before by researchers.

Based on the recommendations of the ISI, BS and ASTM for testing the particles/hard boards, the procedures and necessary apparatus for evaluating the rice husk boards, were developed. Rice husk boards were prepared and tested. The results were compared with the recommendations of the ISI, BS, ASTM and other published literatures.

* Part II (Thermal Properties) will be published in the next issue, *i e*, AMA Vol. XVI, No.2, Spring 1985.

Acknowledgements: The authors would like to acknowledge the efforts and care taken by Jocelyn R. Platon for typing the manuscripts of this paper.

Introduction

Over 18 million t of rice husks are available in India annually from the rice milling industries (Kaupp and Goss, 1982). A very small amount of husk is being used in rice mills for the production of steam and the rest is either heaped to get decomposed by natural process or burnt to ashes. Thus, the disposal of husk is a problem for every rice miller in India, and possibly elsewhere.

Researchers in the past (Lathorop, 1952; Staackman and Goodale, 1970; Beagle and Beagle, 1971, Chittenden, 1971 and Chattopadhaya *et al*, 1973) have suggested several uses of rice husk among which is its use for making boards.

Several attempts were also reported by various research workers (Williamson and Lathrop, 1951; Baixuli, 1953; Jain and Gupta, 1964; Staackman and Goodale, 1970; Chittenden, 1971; RRL-Jorhat, 1972; Vasishth, 1971 and 1973; Lantin, 1982 and Pablo, 1983) in the past to develop a process for manufacturing boards from rice husk but none was able to produce the board in commercial scale. Recently, a pilot plant under the guidance of Vasishth (1973) of Cor-Tech. Research Ltd., Canada, was set up in the Philippines for commercial production of husk boards. However, the final product has yet to reach consumers as there are several drawbacks in the quality of the boards (Pablo, 1983). Therefore, it is essential to evaluate all the engineering properties of rice husk boards in the laboratory and to establish its quality before going for commercial production.

Procedures for testing the properties of similar type of boards have been described by the ISI, BS and ASTM. However, the lack of proper instruments and accurate apparatus restrict the researchers from measuring all the properties of rice husk boards and judge the final product from quality point of view. Therefore, keeping in view the need for testing and evaluating the various engineering properties of husk boards, this research project was undertaken at the Indian Institute of Technology (I.I.T.), Kharagpur, India, to develop suitable and inexpensive apparatus and instruments according to the recommendations of the ISI, BS and ASTM with the necessary modifications. The husk boards were prepared and their various engineering properties were tested. As the scope of this paper does not permit discussion of all the properties, only the physical and mechanical properties which are related with the strength of the boards are describ-

ed.

Experimental Procedure

The required apparatus were designed and developed and their constructional details along with the experimental procedure involved in measuring the various properties of rice husk boards are described below.

Preparation and Conditioning of Test Specimens

The required test specimens of specified size (length and width) for a particular test were cut with the tolerance of ±2 mm with a sharp saw. The specimens were exposed for 48 h in a freely ventilated room before conducting the test.

Accuracy of Dimensions of Boards

The length and width of the boards were measured with the use of a Vernier's calliper with an accuracy of ±2 mm. The thickness was measured with a micrometer and a dial gauge with an accuracy of ±0.1 mm.

Moisture Content

All the tests were performed almost on a constant moisture content level of conditioned samples. When required, the specimens were put into the air-oven for 8 h at 100 ±5°C, and the moisture content on dry weight basis was calculated by dividing the weight of water by the weight of dry matter.

Density

Density (D) is one of the most important physical properties of the boards which affects the other engineering properties. The density of the test materials was determined by weighing the test specimen and measuring its dimensions (length, width and thickness) for the calculation of volume. The density of each test specimen was calculated as follows:

Density = (Weight of the test specimen in grams) / (Length x width x thickness (mm)) x 10^6 = kg/m^3 . . . . . .(1)

Modulus of Rupture (MOR)

About 11 cm in length and 5 cm in width the test specimen was cut from the conditioned rice husk board. The thickness of the test specimen was kept as the original thickness of the board.

The specimen was placed on the span supports of a universal testing machine. One cm of the test specimen rested on the supports of both sides of the machine, thus, only 10 cm was counted as span length (centre to centre distance between the supports). The specimen was loaded at the centre of the span length and the load was applied continuously throughout the test at a uniform rate of 5 mm/min of movable cross head of the machine. The breaking load was recorded for the calculation of MOR.

$$MOR = 3\,Pl / 2bt^2 \quad \ldots\ldots(2)$$

where, MOR = modulus of rupture of rice husk board, kg/cm^2

P = breaking load, kg

l = span length, cm

b = width of test specimen, cm

t = thickness of test specimen, cm

In all the tests, the length and width of specimen were kept constant at 10 cm and 5 cm, respectively

$$\therefore MOR = 3\,P / t^2 \quad \ldots\ldots(3)$$

Thus, equation (3) was used in the calculation of the MOR of rice husk board with the following assumptions:

(1) The specimen of board sample was assumed like a simple supported rectangular beam.

(2) Breaking load was applied at centre of span length.

(3) The maximum horizontal fibre stress had not exceeded the proportional limit of material.

Tensile Strength Parallel to Surface

The test specimen as shown in Fig. 1. was prepared. The reduced section was cut to required size with a sharp hand saw. It was resized with a fine grinder roll. The thickness of the board and the minimum width of the reduced section was measured with an accuracy of ±0.3% with the use of a micrometer. These two dimensions were used to determine the net cross sectional (c.s.) area in the calculation of maximum tensile stress.

The specimen was placed into the gripping heads (jaws) of a universal testing machine and the load was applied continuously throughout the test at a uniform rate of movable cross-head of 5

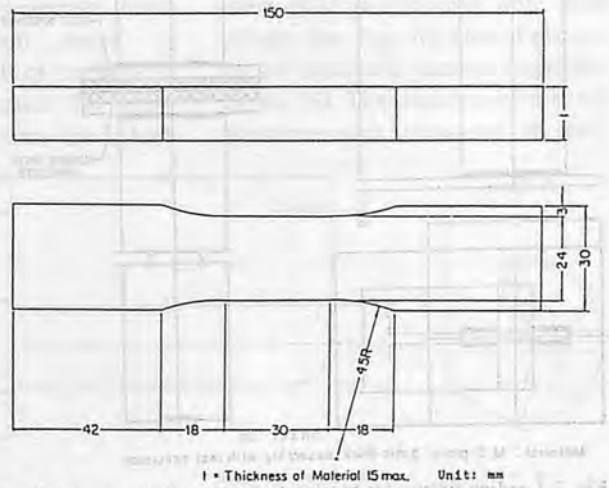

Fig. 1 Specimen for tension test parallel to surface.

mm/min. The maximum load at which the specimen failed was noted from the dial of the machine. The stress was calculated by dividing the maximum load at failure by the reduced c.s. area of the specimen.

$$T_p = P/A \quad \ldots\ldots\ldots \quad (4)$$

where, the c.s. area of the specimen, A = 2.4 x t as shown in Fig. 1.

$$\therefore T_p = 10\,P/24\,t \quad \ldots\ldots \quad (5)$$

where, T_p = tensile strength perpendicular to the plane surface of board, kg/cm²

P = breaking load, kg

A = c.s. area of test specimen, cm²

t = thickness of test specimen, cm

Tensile Strength Perpendicular to Surface

This is also called the internal bond (IB) strength of boards. The specimen of 50 x 50 mm size was cut from the conditioned rice husk board. The loading blocks of steel, 50 mm sq and 3 mm thick (Fig. 2), were bonded on both surfaces of the test specimen with Araldite (CIBA) adhesive. The blocks attached to the specimen were fixed in upper and lower jaws of the universal testing machine. The specimen was stressed until it gave in. The load was applied continuously through the movable cross-heads at a constant speed of 5 mm/min. Thus the maximum load at failure of the specimen was recorded and dividing it with the c.s. area of the specimen, the tensile strength of board was obtained.

$$T_i = P/A \quad \ldots\ldots\ldots \quad (6)$$

where, T_i = tensile strength perpendicular to surface (IB strength) of board, kg/cm²

P = breaking load, kg

A = c.s. area of test specimen, cm²

Resistance to Shear in the Plane Surface of Board

In actual use, the boards are sometimes subjected to cross-bending and compressive shear. Shear stress is also related to the binding strength of the board.

The shear strength test was made by laminating the test specimen surfaces with block of the same size used for the measurement of IB strength. Araldite adhesive was used for fixing the test specimen with fixtures (Fig. 3). The blocks with the test specimen were fixed

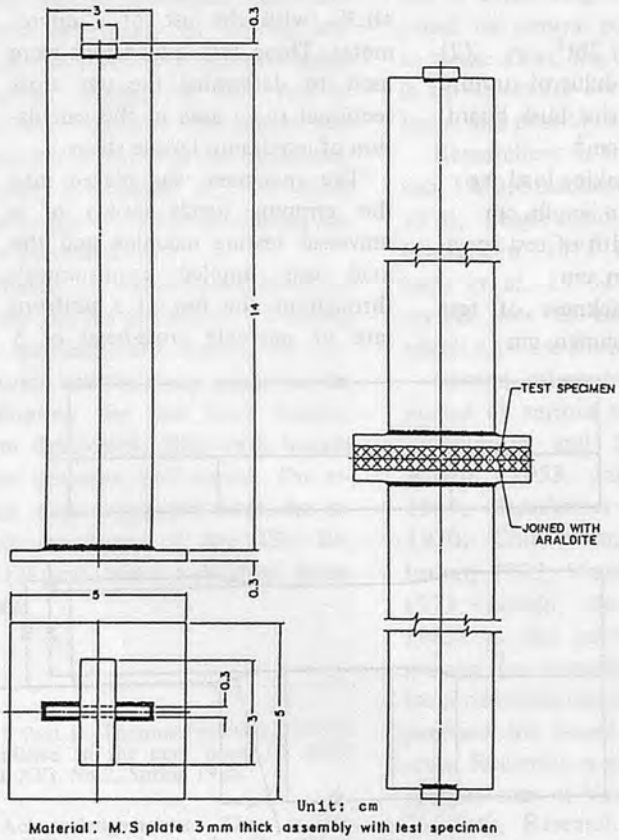

Fig. 2 Loading fixture for tension test perpendicular to the plane of the board.

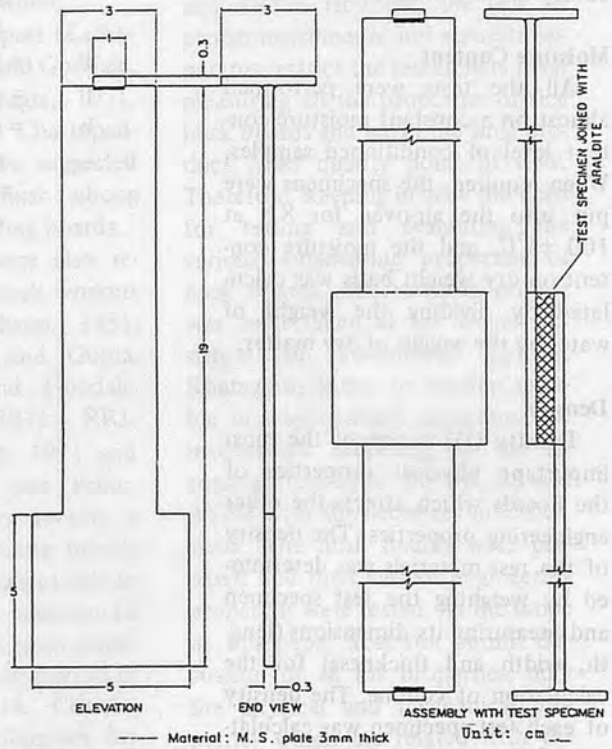

Fig. 3 Fixture for shear strength test.

in the jaws of the machine. The lower head of the machine was fixed while the upper portion was moved with a constant speed of 5 mm/min. Whenever the failure at the base of specimen extended back on to the supporting surface, the test was rejected and repeated. The shear stress was calculated using the following formula:

$$\sigma = P/A = P/5t \quad \ldots\ldots\ldots\ldots (7)$$

where, σ = shear strength or shear resistance (SR), kg/cm^2

P = load required to shear the surfaces of specimen, kg

A = c.s. area of the test specimen, cm^2

t = thickness of the specimen, cm

Resistance to Axial Withdrawal of Wood Screw

The screw, which was inserted into the specimen was pulled by means of a testing machine and the maximum load to pull the screw was recorded as resistance to screw withdrawal.

The test specimens of dimensions 75 x 75 mm each and of varying thickness were used for this test. A wood screw of 5.23 mm nominal shank diameter and 25 mm length (No. 11 wood screw as per specification of IS: 451-1961) was used. The screw was threaded into the centre of the specimen for two-thirds of its length with a screw driver.

The screw was attached with the movable jaw whereas the test specimen was fixed with the unmovable head of the Instron machine. The pulling load was applied at a constant speed of 5 mm/min and maximum load to withdraw the screw from the rice husk board specimen was recorded.

Resistance to Nail Withdrawal

The same procedure described for the screw withdrawal test was followed except that at the place of screw a nail of 2.80 mm diameter was driven at the centre of the specimen. The maximum load required to withdraw the nail from the test specimen was recorded as the resistance offered by the board material to direct nail withdrawal.

Hardness

Generally, the resistance to indentation is used in most of the cases to determine the hardness. The ISI (IS: 2380-1963) has suggested a number of methods to determine the hardness of particle boards and out of them the Janka Ball Test Method, with some modification, was utilized in the test.

Two or three test specimens of 125 x 125 mm each were laminated together with the use of Araldite adhesive to achieve the required thickness. As suggested by the ISI (IS: 2380-1963) the thickness of the test specimen was always kept more than 25 mm in all the tests.

A steel indenter with a hemispherical end of 11.3 ±0.05 mm in diameter (one sq cm projected area), as shown in **Fig. 4** was made in the laboratory and used for measuring the hardness of the rice husk board. The test specimen was placed on the lower load shell and the indenter was fixed in the upper movable jaw of the universal testing machine. The indenting ball was allowed to penetrate (with 5 mm/min constant speed of machine) to one half of its diameter into the test specimen. The maximum load to penetrate the indenter was recorded. Three penetrators were made on each of the two faces of the test specimen. The location points for penetration were kept at least 25 mm away from the edge of the specimen but far enough to prevent them from affecting each other.

The average maximum load required to penetrate the indenter ball was recorded. Dividing the load by the projected area of ball (1 cm^2), the hardness of the board was obtained.

Compressive Strength

The ISI (IS: 2380-1963) suggests that the compressive deformation in the boards is to be determined on the application of 15 kg/cm^2 pressure for 5-min duration. Generally, this type of boards (similar to rice husk boards) are not recommended for use at a place where temperature is more than 95°C. Therefore, the tests were conducted on both temperatures, *ie*, at room temperature of 30 ±1°C and at an elevated temperature of 95 ±2°C.

Compression at Room Temperature

The resistance to compression at room temperature was determined by finding the dimension in thickness of the board on the application of a constant pressure normal to its plane surface. The test specimens (125 x 125 mm) were kept 10 mm less than the size of platens of the hydraulic press as suggested by the ISI. The thickness of the test specimen was measured at each

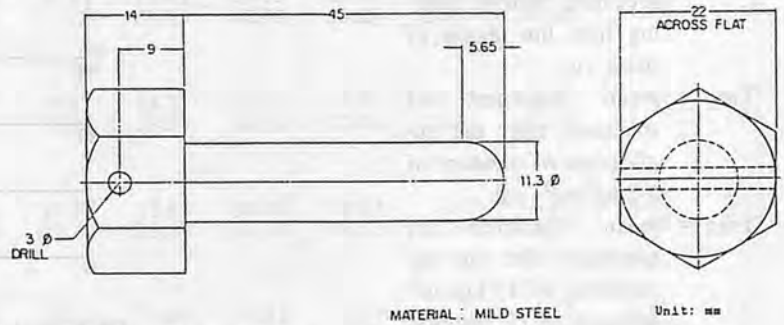

Fig. 4 Indenter for hardness test.

corner, approximately 15 mm inside the edge to an accuracy of ±0.025 mm with the use of a micrometer. The average of four measurements was recorded at Tm_1.

The test piece was then placed on the press under a pressure of 1-2 kg/cm². The distance apart from the platens were measured at four corners with the help of a Vernier's calliper. The average of these four measurements was recorded as Tm_2. The pressure was then increased to 15 kg/cm² within half a minute and maintained for 5 min. At the end of this period, the distance between the platens was recorded at four corners to the same accuracy as before and the average of these four measurements were recorded as Tm_3. The pressure was then released and the test piece was taken out of the press. The thickness of each corner of specimen was re-measured. The average of four measurements was recorded as Tm_4. The difference between Tm_2 and Tm_3 was reported as the value of compressibility and that of Tm_1 and Tm_4 was reported as retention of compression. The following equations were used for the calculations.

$$PC = (Tm_2 - Tm_3) / (Tm_1) \times 100 \quad \ldots\ldots (8)$$

$$RTC = (Tm_1 - Tm_4) / (Tm_1) \times 100 \quad \ldots\ldots (9)$$

where,

PC = percentage compressibility

RTC = percentage retention of compression

Tm_1 = mean thickness of test specimen before putting into the platen of press, cm

Tm_2 = mean thickness of specimen after the application of pressure of 1-2 kg/cm², cm

Tm_3 = mean thickness of specimen after the application of 15 kg/cm² pressure for 5 minutes, cm

Tm_4 = mean thickness of specimen when taken out from press, cm

Compression at Elevated Temperature

The same procedure described for the compression test at room temperature was followed except that during pressing, the temperature of the press platens were maintained at 95 ±2°C and that after removal from the press the test specimen was allowed to cool at room temperature.

Water Absorption and Thickness of Swelling

The test specimen of the rice husk board (125 x 125 mm) was submerged into distilled water at a temperature of 27 ±2°C as specified by the ISI (IS: 2380-1963). No extra arrangement was required for controlling the temperature as the tests were made in the months of July and August when the water temperature was itself in the range required for the test. The specimen was submerged horizontally under 25 mm of water. After two hours of submergence, the specimen was taken out of the water and was suspended for 10 min to drain the excess water on its surface and was weighed. At the same time, the thickness was measured at four pre-marked points on the specimen. The average of the four readings was recorded for the final calulations. Before starting the test, the original thickness of the specimen was also measured at the same four marked points. The same specimen was submerged for additional 22 h and the above weighing and thickness measuring procedures were repeated. After 24 h of submergence, the specimen was dried in a hot air oven at 100 ±5°C for 8 h and final weight after drying was recorded.

The amount of water absorbed in 2 and 24 h of immersion in water was expressed in percentage

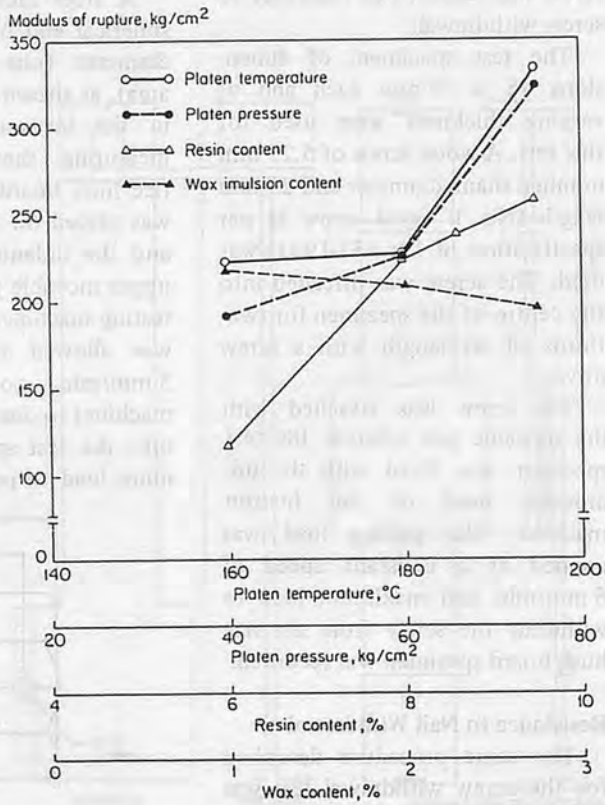

Fig. 5 Relationship of the variables with modulus of rupture for making ideal rice husk boards.

based on the dry weight of the specimen. The thickness of swelling was also expressed as the percentage increase of the original thickness of the specimen after 2 and 24 h of immersion in water.

Results and Discussion

The ideal conditions (Fig. 5) under which the rice husk boards were prepared for the evaluation of their properties were: the platen temperature of 180°C, the press hold time of 10 min and phenol formaldehyde (PF) resin content of 8% (Shukla 1976 and Shukla *et al* 1983). The physical and mechanical properties of the board were determined and studied. The average value of three replications of each test was reported in the results.

Density

All the properties of the rice husk board were related with its density. The density of the board was affected by the press platen pressure and the amount of adhesive content contained in it (Shukla 1976).

Modulus of Rupture

Actual densities of rice husk boards were obtained in the range of 615.20 to 1368.60 kg/m^3 and MOR correspondingly ranged from 122.35 to 369.92 kg/cm^2, respectively, (Shukla 1976). The values of MOR were plotted against the density of the rice husk board (Fig. 6). The following linear equation was obtained by regression analysis with a correlation coefficient (R) of 0.9857:

$$MOR = 0.36\,(D) - 130.637 \quad \ldots\ldots (10)$$

With the use of Euation (10) the MOR for different board densities were calculated and shown in Table 1. It appears from Fig. 6 that the MOR increases with an increase in the density of the rice husk board. Gatchell *et al* (1966) states, "A decrease in flake thickness resulted in an increase in the static bonding properties of the particle boards". In the case of rice husk board, the husk particles were also small in size and a high density board was obtained on the

Table 1 Properties of Rice Husk Board

Properties	Density, kg/m^3								
	600	700	800	900	1000	1100	1200	1300	1400
1. Modulus of rupture, kg/cm^2	86.02	122.14	158.25	194.35	230.46	266.57	302.68	338.79	374.90
2. Tensile strength parallel to surface plane, kg/cm^2	122.18	1136.51	150.84	165.17	179.20	193.83	208.16	222.69	236.82
3. Tensile strength perpendicular to surface plane or Internal bond (IB) strength, kg/cm^2	3.04	4.48	5.92	7.36	8.80	10.24	11.68	13.12	14.56
4. Shear resistance, kg/cm^2	5.15	11.05	16.95	22.85	28.75	34.65	40.55	46.45	52.35
5. Load to pull the nail, kg	11.85	16.55	21.25	25.95	30.65	35.35	40.05	44.75	49.45
6. Load to pull the screw, kg	18.09	27.69	37.29	46.89	56.49	66.09	75.69	85.29	94.89
7. Hardness, kg/cm^2	505.34	651.54	797.74	943.94	1090.14	1236.34	1382.54	1528.74	1674.94
8. Retention of compression at room temperature of 30±1°C, %	12.00	10.40	8.80	7.20	5.60	4.00	2.40	0.80	–
9. Compressibility at room temperature of 30±1°C, %	5.11	4.46	3.81	3.16	2.51	1.86	1.21	0.56	–
10. Retention of compression at elevated temperature of 95±2°C, %	25.33	22.29	19.53	16.63	13.73	10.83	7.93	5.03	2.13
11. Compressibility at elevated temp. of 95±2°C, %	11.53	9.80	8.07	6.34	4.61	2.88	1.15	–	–
12. Water absorption of unwaxed board, %									
2 h immersion	37.83	33.63	29.43	25.23	21.03	16.83	12.63	8.43	4.23
24 h immersion	64.25	57.15	50.05	42.95	35.85	28.75	21.65	14.55	7.45
13. Thickness of swelling of unwaxed board, %									
2 h immersion	19.17	16.87	14.57	12.27	9.97	7.67	5.37	3.07	0.77
24 h immersion	36.73	33.13	29.53	25.93	22.33	18.73	15.13	11.53	7.93
14. Water absorption of waxed board, %									
2 h immersion	16.93	15.53	13.63	11.73	9.83	7.93	6.03	4.13	2.23
24 h immersion	30.92	27.32	23.72	20.12	16.32	12.92	9.32	5.72	2.12
15. Thickness of swelling of waxed board, %									
2 h immersion	9.27	8.32	7.37	6.42	5.47	4.52	3.57	2.62	1.67
24 h immersion	16.26	14.21	12.16	10.11	8.06	6.01	3.96	1.91	–

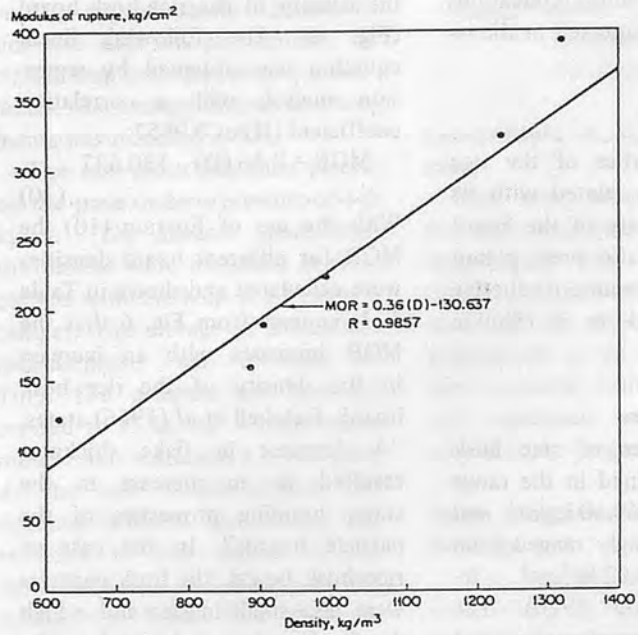

Fig. 6 Modulus of rupture and density of the rice husk board.

application of a high platen pressure. The uniformity in the distribution of binding stresses, perhaps, occured because of better contact among the particles due to compression of the mat. Therefore, the MOR increased with the increase in the density of boards.

Tensile Strength

Fig. 7 shows the relationship between the density and tensile strength parallel and perpendicular to the plane surface of the rice husk boards. The following linear relations between the density and tensile strength were obtained with the use of regression analysis technique:

$$t_p = 0.143\,(D) + 36.20 \quad \ldots\ldots (11)$$

$$R = 0.9544$$

$$T_i = 0.014\,(D) - 5.595 \quad \ldots\ldots (12)$$

$$R = 0.974$$

Since all the board specimens tested for MOR broke or failed on the lower plane surface due to tension, the MOR should also correlate well with the tensile strength parallel to the plane surface of the rice husk boards. Fig. 8 confirms the above fact and the following linear relationship between T_p and MOR was determined with R = 0.990:

$$T_p = 0.364\,(MOR) + 93.674 \quad \ldots\ldots (13)$$

It appears from Fig. 7 that like the MOR, the tensile strength increases with an increase in the density of boards and vice-versa. In fact, all the mechanical properties

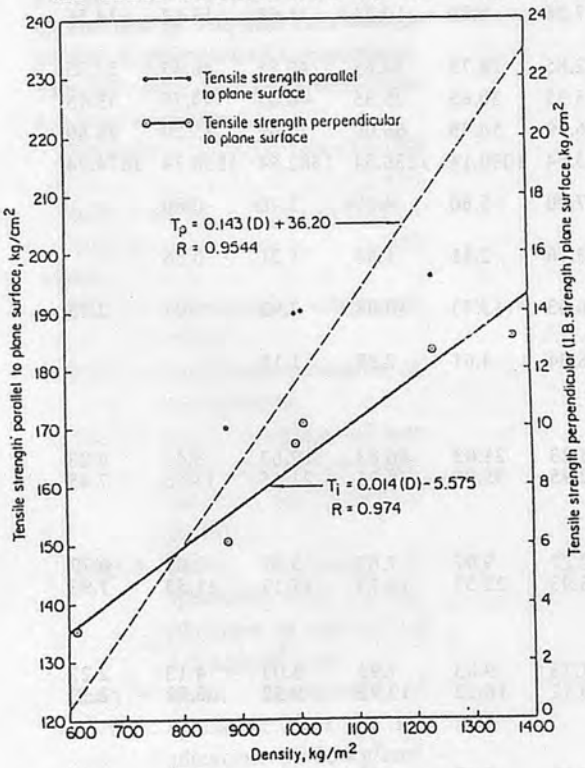

Fig. 7 Density of rice husk board and its tensile strength.

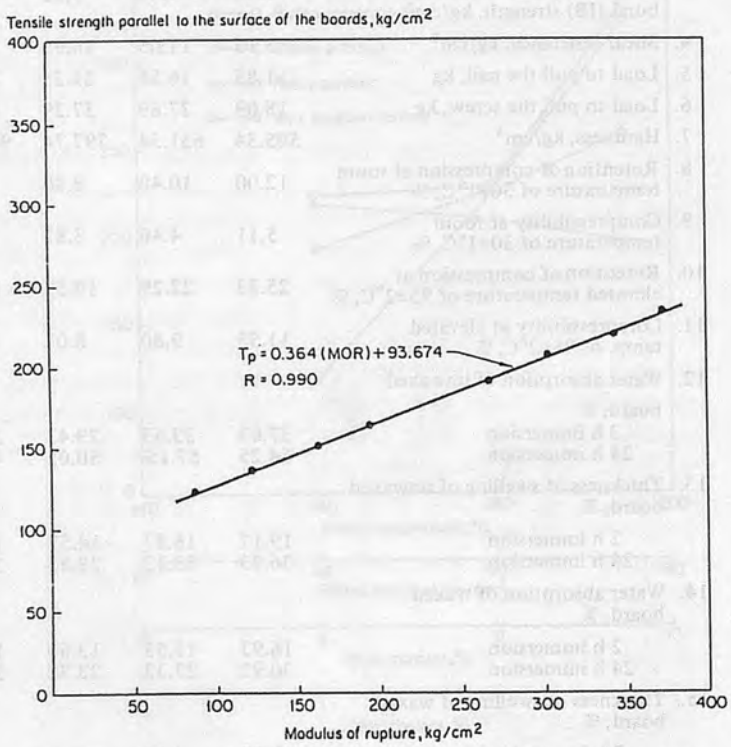

Fig. 8 Tensile strength parallel to the plane surface of the board and its modulus of rupture.

were found to be dependent on the board's density. This could be explained by the reason given by Marra (1960) and Gatchell *et al* (1966) that at higher density, resin utilization was better in obtaining superior glue bonds in between the husk particles, hence, the properties like tensile strength and MOR increased with an increasing the density of the board. The values of T_p and IB in **Table 1** satisfy the requirements of ISI and BS (IS: 3087-1965; IS: 3129-1965 and BS: 2604-1963).

Shear Resistance

Resistance to shear of both surfaces of the board signifies more or less its IB strength. Due to non-uniformity in the particles of rice husk complete shearing of one surface of rice husk board against the other was difficult. However, only those data were recorded when it was judged that test specimen was sheared during the test. **Fig. 9** shows the relationship between the shear resistance (SR) and the density of husk board. The following linear equation with R value of 0.971 was determined.

$$SR = 0.059\,(D) - 30.246 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

As it is evident from **Figs. 6, 7 and 9** that like the MOR and IB strength, the SR also followed the same trend with the density of the board. Neither ISI nor BS has fixed any limit to shear strength for such type of boards and also very little data are available. McNatt (1973) tested some commercial boards for shear strength and reported the values in the range of 10 to 46 kg/cm^2. In the case of rice husk board, the values of SR were obtained in the range of 5.15 to 52.35 kg/cm^2 (**Table 1**) which seemed to be quite reasonable in comparison with the results obtained by McNatt (1973).

McNatt (1973) also observed that certain strength and the elastic properties of the particle boards and panel products were closely related to each other. For example, interlaminar shear strength and IB strength are the measure of the quality of bonds between the particles in the boards and panel products. Therefore, there must exist some relationship between the IB strength and SR of the boards. This fact is illustrated in **Fig. 10** and the following relation between the IB strength and SR with the R value of 0.99 was obtained:

$$SR = 0.410\,(IB) - 7.320 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

Nail and Screw Holding Capacity

The maximum loads to pull out the nail (NPL) and screw (SPL) were plotted against the density of the rice husk board and shown in **Fig. 11**. The following equations of straight lines were obtained with the use of regression analysis technique:

$$NPL = 0.0471\,(D) - 16.349 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

at R = 0.982

$$SPL = 0.096\,(D) - 39.505 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

at R = 0.987

It appears from **Fig. 11** that the load required to pull the nail from the same density of board was lower than the load required to pull the screw. It so happened that the screw teeth cut the board's material and got fixed in it, hence, produced resistance when being pulled out

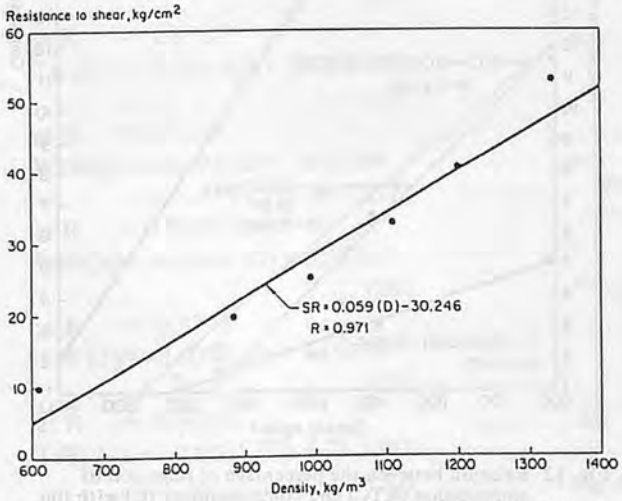

Fig. 9 Density and resistance to shear in the plane of the board.

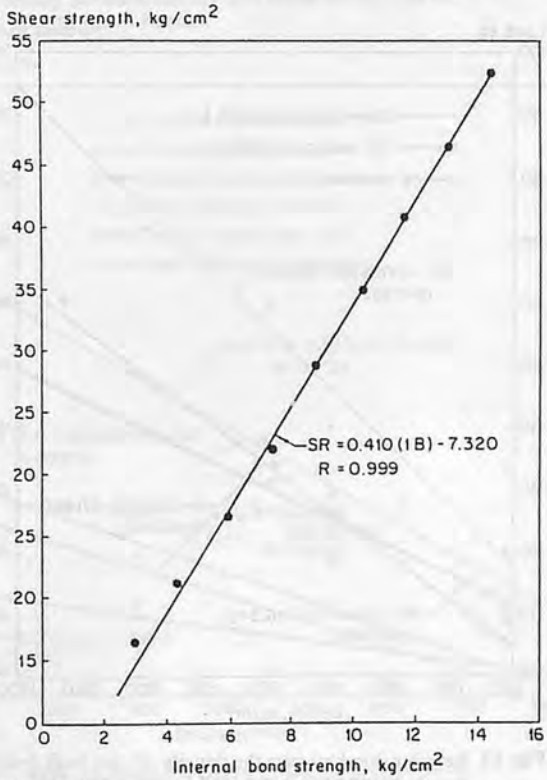

Fig. 10 Shear strength and internal bond strength of board.

from the specimen. The nail, due to its smooth surface, showed less resistance and pulled out easily. The values of NPL and SPL are given in **Table 1**.

Hardness

Hardness (H) is also somewhat related with the screw and nail pulling resistance but mainly considered as the upper surface strength of the board. It is also dependent on the density of the board. The relationship between the density and hardness of rice husk board is shown in **Fig. 11** and the following regression equation with R value of 0.976 was obtained:

$$H = 1.462\,(D) - 371.86 \quad \ldots\ldots (18)$$

No published literatures are available to compare the hardness of rice husk boards. However, the values of hardness obtained in the range of 505.34 – 1674.94 kg/cm^2 **(Table 1)** confirmed that the board surface was quite hard.

Compression Test

Fig. 12 shows the relationship between the percentage of retention of compression (RTC) and compressibility (C) with the density of the board at room and elevated temperatures of approximately 30 and 95°C, respectively. The following equations were obtained using the technique of regression analysis:

At room temperature:

$$RTC = -0.0166\,(D) + 21.6059 \quad \ldots\ldots (19)$$

at R = 0.9794

$$C = -0.0065\,(D) + 9.0164 \quad \ldots\ldots (20)$$

at R = 0.9851

At an elevated temperature:

$$RTC_e = -0.0292\,(D) + 42.730 \quad \ldots\ldots (21)$$

at R = 0.9897

$$C_e = -0.0173\,(D) + 21.917 \quad \ldots\ldots (22)$$

at R = 0.9889

It is clear from **Fig. 12** that the compressibility and retention of compression decreases with increasing density of the board. The rice husk mat was already pressed at 60 kg/cm^2 platen pressure during its preparation (Shukla 1976) and the high density board was obtained by increasing the platen pressure of the press. Hence, on the application of 15 kg/cm^2 pressure at room temperature, the high density boards did not exhibit appreciable decrease in thickness as compared to low density boards. Probably, the presence of more air spaces in a low density board allowed the husk particles to come closer on compression, whereas the high density boards were already compressed and had no air space for further compression.

It was also observed that the same density board was more compressed at elevated temperature than at room temperature. At

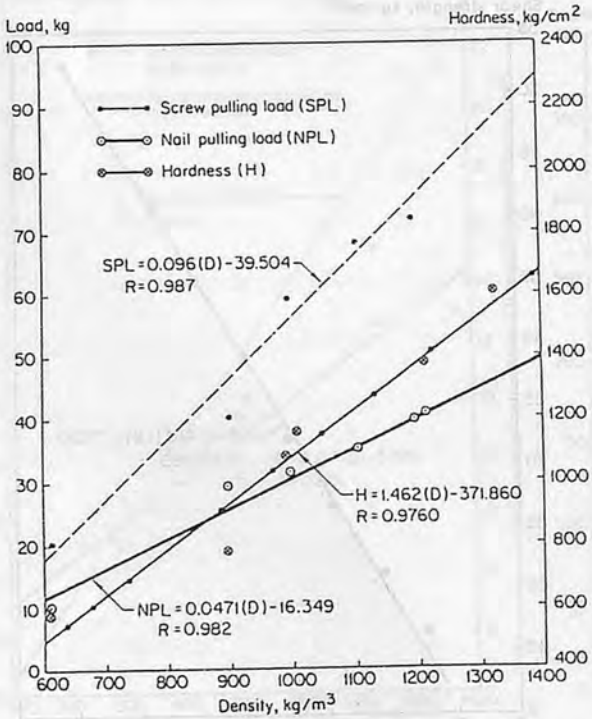

Fig. 11 Relationship between the density of rice husk board and its hardness (II) and load to pull screw (SPL) and load to pull screw (SPL) and nail (NPL).

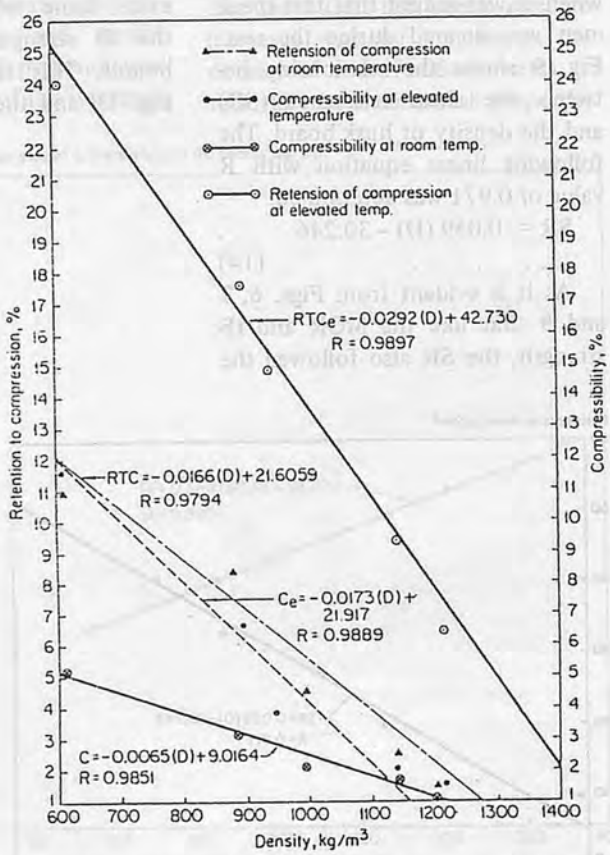

Fig. 12 Relation between the percentage of retention of compression (RTC) and compressibility (C) with the density of rice husk board.

elevated temperature, probably the glue bond started loosening and hence, the board was compressed. Therefore, the rice husk board can give better service at ambient temperature than the heated environment or place.

Water Absorption and Thickness of Swelling

The dimensions of the panel products changed in response to changing moisture content. This property is considered more important in many applications than the strength properties of the boards. On the addition of 2% (based on dry weight of husk) paraffin wax emulsion, the water absorption and as well as thickness of swelling were reduced to a great extent (Shukla 1976, and Shukla, et *al* 1983) in the rice husk boards.

The water absorption and thickness of swelling of the rice husk board (waxed and unwaxed) are plotted against its densities in Figs. 13 and 14 and the following linear equations were obtained by using the regression analysis technique:

WA(2) = -0.0424 (D) + 63.0313 . . . . . (23)

at R = 0.9609

WA (24) = -0.0714 (D) + 106.8513 . . . . . (24)

at R = 0.9264

Ts(2) = -0.0235 (D) + 32.9763 . . . . . (25)

at R = 0.9787

Ts(24) = -0.036 (D) + 58.3373 . . . . . (26)

at R = 0.9320

WAW(2) = -0.0193 (D) + 28.8336 . . . . . (27)

at R = 0.9549

WAW(24) = -0.0364 (D) + 52.5203 . . . . . (28)

at R = 0.9798

TsW (2) = -0.0095 (D) + 14.9699 . . . . . (29)

at R = 0.9359

TsW(24) = -0.0205 (D) + 28.5592 . . . . . (30)

at R = 0.9722

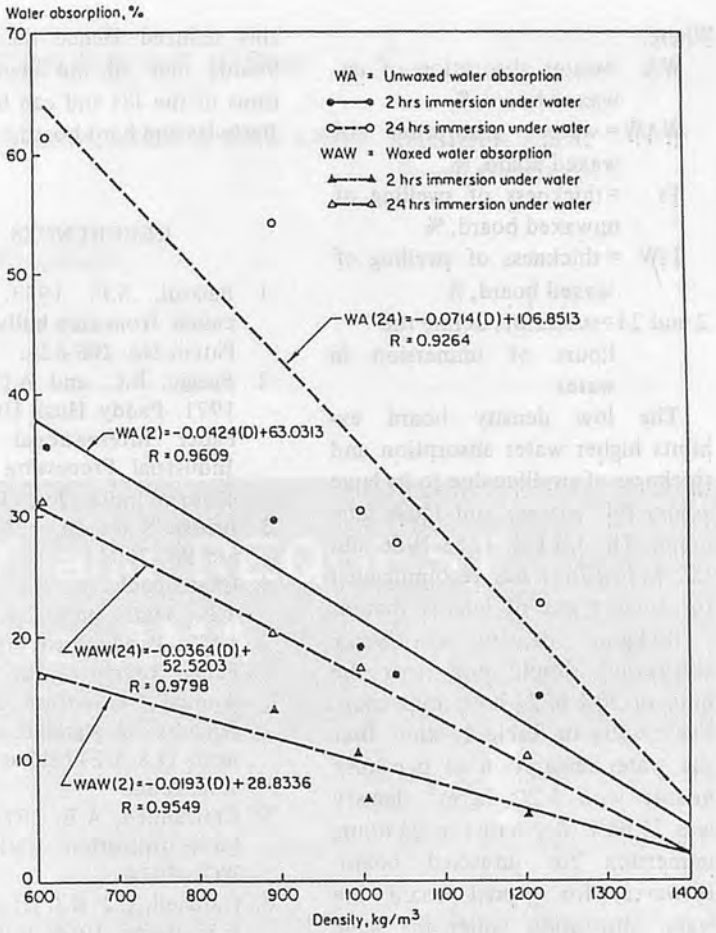

Fig. 13 Relationship between density and water absorption of waxed and unwaxed boards.

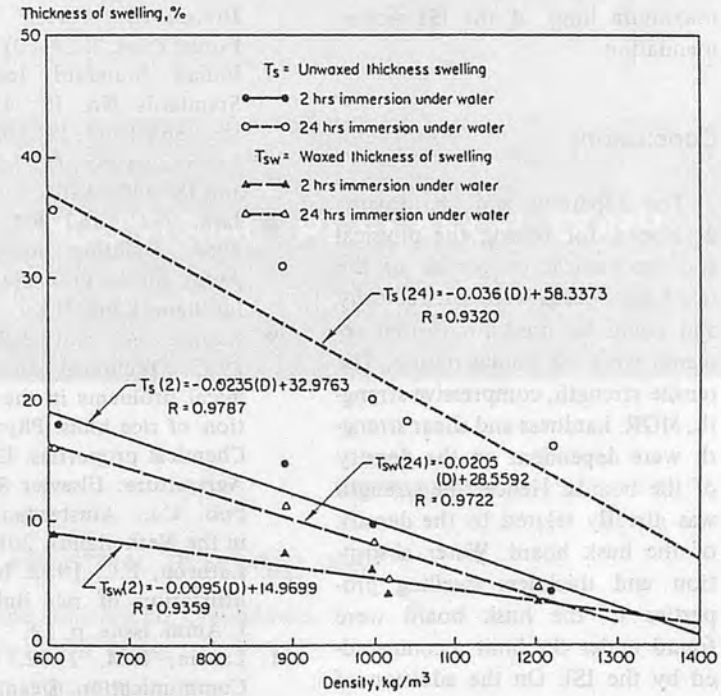

Fig. 14 Relationship between density and thickness of swelling of waxed and unwaxed boards.

Where,

WA =water absorption of unwaxed board, %

WAW= water absorption of waxed board, %

Ts =thickness of swelling of unwaxed board, %

TsW = thickness of swelling of waxed board, %

2 and 24=subscripts define the hours of immersion in water

The low density board exhibits higher water absorption and thickness of swelling due to its large voides (air spaces) and loose glue bonds. The ISI (IS: 1658-1966 and IS: 3478-1966) has recommended for such types of boards that at 1 200 kg/m^3 density, the water absorption should not cross the limit of 20% in 24-hour immersion. The results in Table 1, show that the water absorption of rice husk boards with 1 200 kg/m^3 density was 21.65% (dry basis) in 24 hours immersion for unwaxed board. However, for waxed board the water absorption under the same conditions was only 9.32% (d.b.) which is appreciably less than the maximum limit of the ISI recommendations.

Conclusions

The apparatus and instruments developed for testing the physical and mechanical properties of the rice husk boards were satisfactorily and could be used for further research work of similar nature. The tensile strength, compressive strength, MOR, hardness and shear strength were dependent on the density of the boards. Hence, the strength was directly related to the density of the husk board. Water absorption and thickness swelling properties of the husk board were found under the limit recommended by the ISI. On the addition of 2% wax-emulsion, these two properties of the board were appreciably reduced. Hence, the rice husk boards met all the recommendations of the ISI and can be used as particles and hard boards.

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This conference aims at international meeting of scientists and engineers to exchange information on physical properties of agricultural materials, methods of their investigation and application of results in theory and practice.

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Middle East Agriculture '85
Oct. 13-17, 1985, Dubai, United Arab Emirates

Middle East Agriculture '85 comes at a time when the Arab Gulf States are committed to a multibillion US dollar investment of their oil revenue in projects leading to agricultural self-sufficiency throughout the region. Heavy investment on overseas agri-business technology is a vital part of the plan to enable the area to feed itself. The UAE are in the forefront of the region's agricultural development.

Under the current development plan (1980-1985), the government is investing US$1.04 billion in irrigation, agricultural and fishing projects. Private investment takes this figure to well over US$2 billion. Further large-scale expansion is expected in the next decade as more water supplies and heavy investment, both government and private, yield returns. Dubai, with easy access to the UAE's most fertile north, central and eastern regions, is the home of the Federal Ministry of Agriculture and Fisheries, with total responsibility for all agriculture in the area.

States throughout the Gulf, and the 6 members of the Gulf Co-Operative Council – the UAE, Oman, Qatar, Saudi Arabia, Bahrain and Kuwait – have committed themselves to a joint plan for agricultural development.

Latest figures show that the combined agricultural budget for GCC States in 1983 stood at US$10 billion. This is confidently expected to reach US$13 billion in 1984 and to dramatically increase over the coming decade.

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Agrotech China '85
Nov. 4-9, 1985, Tianjin, China

China is 'striving for an overall upsurge of agricultural production and modernization of agriculture' by 'transforming its agro-industry into an intelligence-intensive sector through absorbing scientific and technological achievements', stated in the National Rural Work Conference (Dec. 1981). To achieve this target, the responsibility system is introduced and agricultural mechanization resumes increasing pendulum. Over RMB 70 billion yuans have been spent in purchasing agricultural machinery in the first 4 months of 1984, representing an increase of 70% when compared with 1983. Yet, the demand for agro-machinery remains high and the Chinese Government is more determined than ever to develop its young agro-machinery sector by self-manufacturing as well as by importing modern equipment and technology.

It is under this circumstance that Agrotech China '85 is launched. The Exposition is specifically designed to expose Chinese end-users to modern equipment and technology on agriculture, forestry,

husbandry, fishery, poultry and side-line occupation so that they can employ relevant ones to upgrade their productivity and technological level. Manufacturers and suppliers all over the world are invited to exploit this distinct opportunity to meet their qualified prospects in the exhibition. The vendors who participate might expect several benefits:

1. Developing new sales leads.
2. Maintaining customer contact.
3. Launching new product lines.
4. Demonstrating new technology and machinery operation.
5. General goodwill can be enhanced, free publicity is generated.

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Tenneco Inc. purchases selected assets of International Harvester's agricultural equipment operations

An agreement for the purchase of selected assets of International Harvester's North American and European agricultural equipment operations by Tenneco Inc. was announced on November 26, 1984 by James L. Ketelsen, Tenneco Chairman and Chief Executive Officer.

Under the terms of the agreement, Tenneco will pay $260 million in cash and $170 million in preference stock. The transaction is expected to be completed early next year, following necessary government reviews.

International Harvester's farm equipment operations join with Tenneco's J I Case affiliate, headquartered in Racine, WI. International Harvester will continue as the leading independent manufacturer of medium and heavy duty trucks.

Included in the transaction are the following International Harvester facilities:

- Combine plant in East Moline, IL
- Implement facility in Hamilton, Ontario
- Engineering operation in Hinsdale, IL
- Machine tools from International Harvester plants in Rock Island, IL. and Memphis, TN.
- North American dealership and related field support organization
- International Harvester's subsidiary in the U.K., which includes its tractor production facility in Doncaster, England.

Tenneco also has entered into agreements to acquire other IH agricultural operations in Germany, France and Denmark, subject to the completion of certain studies and the conclusion of satisfactory arrangements with private lenders and government authorities.

Amir U. Khan received LDC Innovation Award

Dr. Amir U. Khan received the American Association of

Engineering Societies (AAES) LDC Innovation Award for his contributions to the Mechanization of Agriculture in the developing countries and more specifically for the development of the axial flow thresher. The AAES is an apex organization in which all the major engineering disciplines are represented and various engineering societies are its members. Dr. Khan was nominated by the American Society of Agricultural Engineers (ASAE) for this prestigious award. The Award consisted of a $25,000 cash award and was presented at the annual meeting of ASAE at New or leans on Dec. 13, 1984.

Dr. A.U. Khan has been responsible for the development of many commercially successful machines which have benefited millions of farmers in Asia. His design of the axial flow thresher is the most popular paddy thresher in Asia today. The axial flow concept, which was pioneered by Dr. Khan at IRRI in the early seventies, is now accepted worldwide as an efficient mechanism for multicrop threshing. Three major U.S. Farm Machinery manufactures now offer combine harvesters which are based on the axial flow principle. The IRRI axial flow threshers are commercially manufactured in the Philippines, Thailand, Indonesia, India, Pakistan and Sri Lanka.

Dr. Khan has been honored earlier by the Indian Society of Agricultural Engineers (ISAE), the Pakistan Society of Agricultural Engineers (PSAE), the Governments of the Philippins and the United Staes of America for his contributions to the mechanization of agriculture in the developing countries. ■■

BOOK REVIEW

Directory of Machinery and Implements for Agriculture and Forestry (Netherlands)

by D. Foeken and G. Kiers

Established in Wageningen is Holland's Institute of Agricultural Engineering (IMAG – Institut voor Mechanisatie, Arbeid en Gebouwen). Recently, the Mechanization Department of IMAG has compiled and published a voluminous, 644-page Directory.

Edited in Four Languages

This copiously illustrated directory is edited in four languages (German, English, French, and Dutch) and intended for anyone concerned with farm mechanization. Due to its wide coverage this guide is indeed a complete directory of suppliers of agricultural, horticultural and forestry machinery. It comprises a classified list of all types of machinery and tools available on the Dutch market. Where applicable it also mentions the trade marks and the names plus addresses of the Dutch manufacturers and importers concerned.

As for the forms of cultivation practised in the Netherlands, Dutch agricultural engineering can compete with the latest types of farm mechanization found anywhere in the world. Thus the systematically listed range of products published in this guide may be regarded as representative of the present overall state of mechanization in agriculture, horticulture, and forestry. As a result it constitutes an essential contribution towards publicizing and explaining modern machinery, thereby benefiting the trade, research, information, education, and users.

Copies can be obtained by transferring Dtl. 60 – to the giro account 3514771 on the name of IMAG, Mansholtlaan 10-12, 6708 PA Wageningen, The Netherlands.

Annoted Bibliography on Improvisation of Animal Drawn Vehicle Transport in India and Abroad (India)

by S.D. Deshpande and T.P. Ojha

This bulletin contains research and development activities on improvisation of animal drawn vehicle (ADV) system in general and bullock-cart in particular in India and abroad by various organizations, institutions and individuals. The complete volume has been divided into 23 chapters covering road damage, survey studies, traction studies and studies on powered wheel. ADV wheel studies included wheel sinkage, wheel slippage, pneumatic tyre design, testing and deflection.

General aspects such as centre of gravity, balancing of cart, bearing and braking systems, instrumentation and fabrication process have also been covered. Author index and subject keyword index have been provided at the end for quick retrieval of the information.

It is hoped that this bulletin will be helpful in fulfilling the desired need of the literature which was not easily available to the scientists, administrators and policy makers in a single publication.

Size: 27.5 x 20.5cm, 178 p, softcover.

Price: Rs. 12 (U.S.$10, including air postage.)

Published by the Director, Central Institute of Agricultural Engineering, Nagi Bagh, Berasia Road, Bhopal-462 018, M.P., India

Monograph on Traditional and Improved Bullock Carts of India (India)

by S.D. Deshpande and T.P. Ojha

This monograph deals with the traditional and improved bullock drawn carts available in various parts/regions of India along with dimensional details, photographs, engineering specifications, test results, cost economics, source of availability, salient features, suggestions for future improvements.

The monograph has been divided into three broad sections, namely traditional carts, improved carts and critical review on various bullock carts of India. Each section is subdivided into sub-sections containing the information on traditional and improved carts with respect to axle material, payload carrying capacity, braking system, type of wheel, etc. In all 35 carts of different designs are included in the monograph. At the end, additional information regarding glossary of standard terms related to off-the-road transport and a list of institutions engaged in research and development as well as list of component manufacturers of farm transport equipment is also included in the appendices.

This monograph will serve as a reference material and a springboard for users of carts, industry, scientists, policy makers, voluntary organizations and extension agencies.

Size: 24 x 18 cm, 165 p, softcover.

Price: Rs. 40.00 or U.S.$25.00, including air postage.

Published by the Director, Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal-462 018, M.P., India

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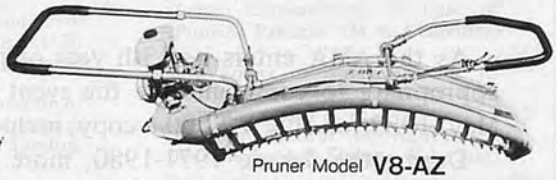

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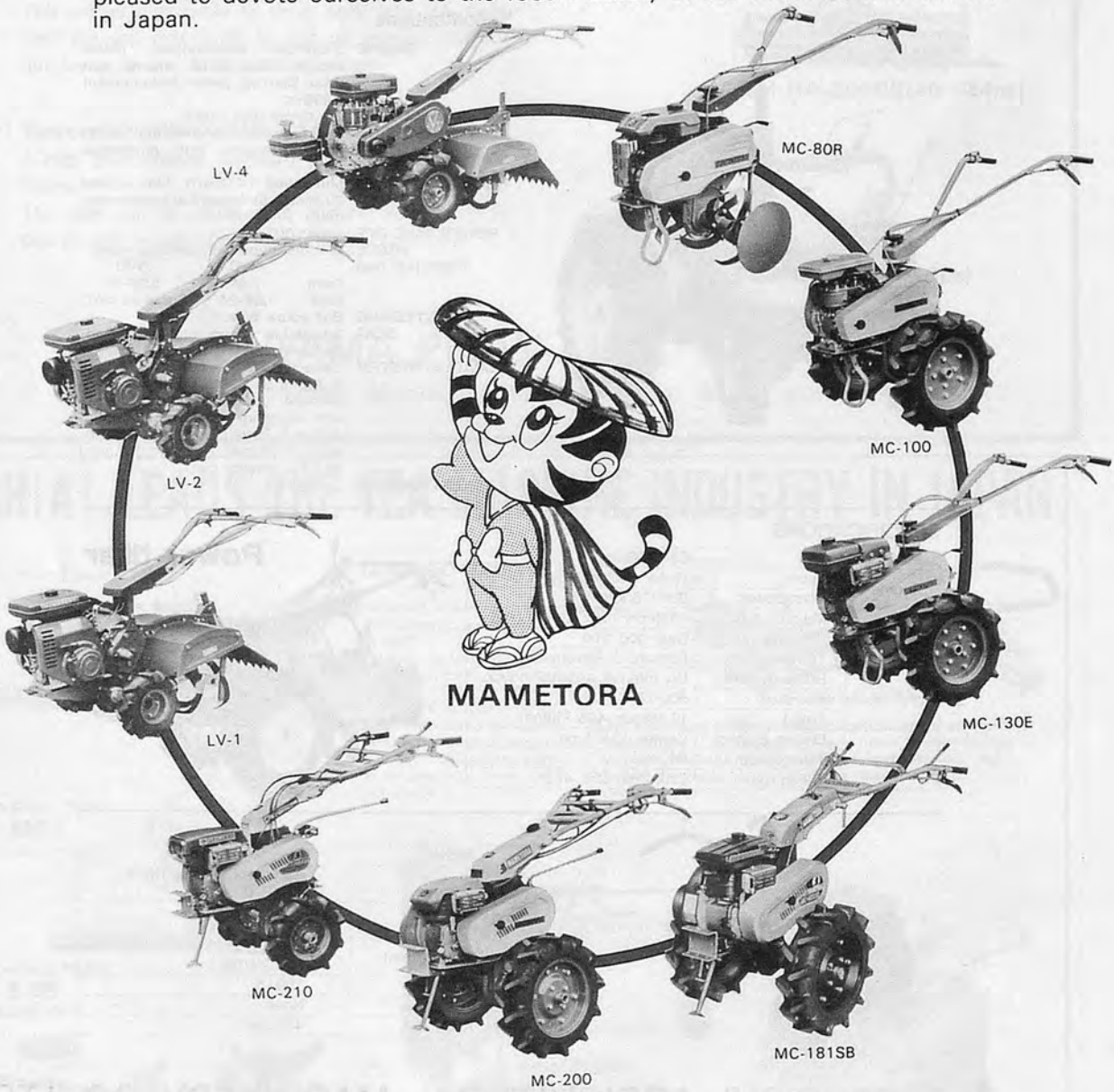

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