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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.XII, NO.3, SUMMER 1981

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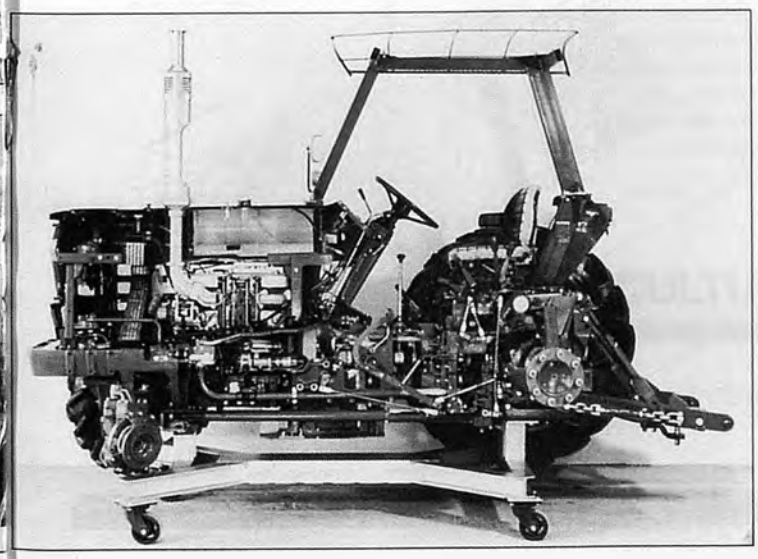

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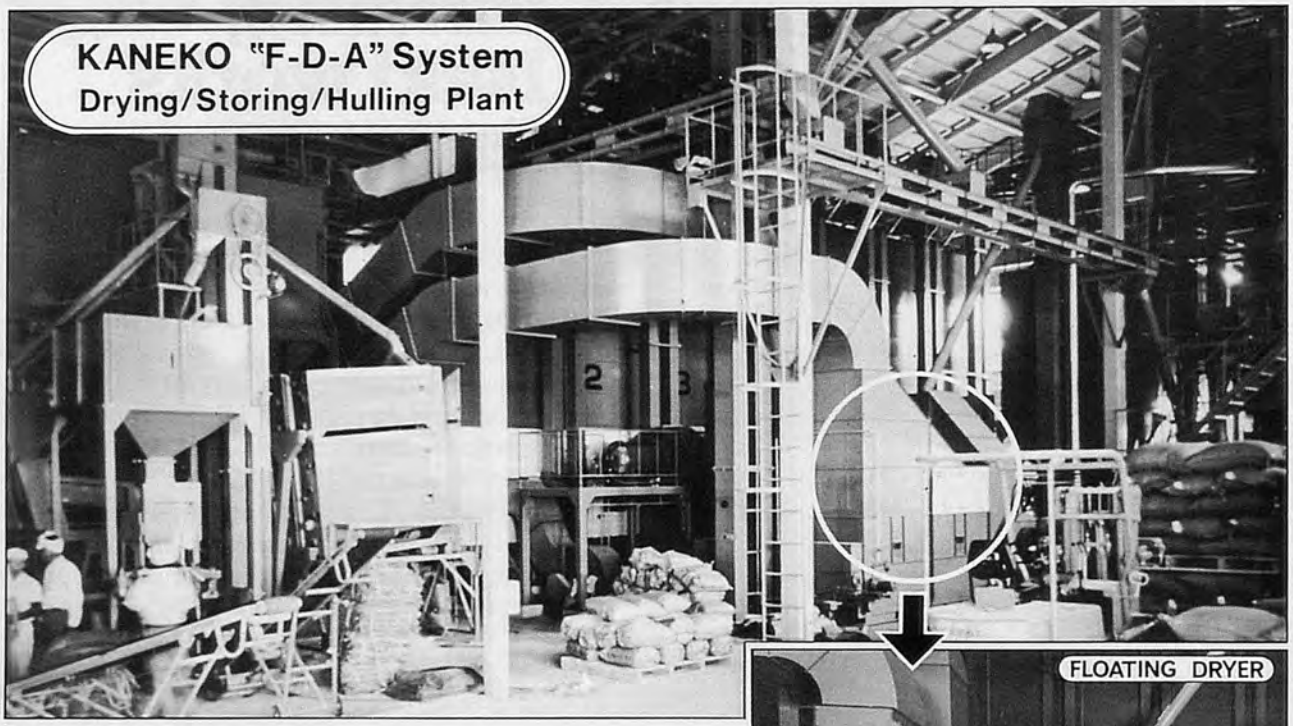

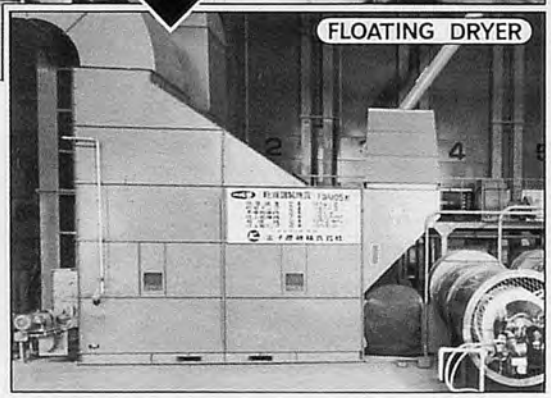

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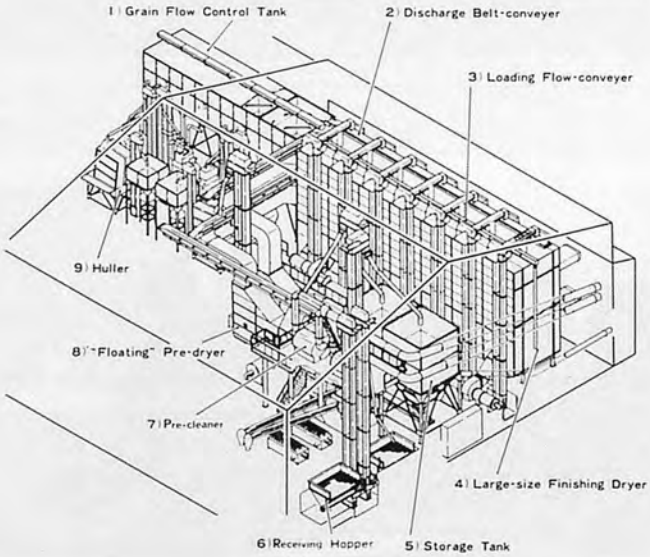

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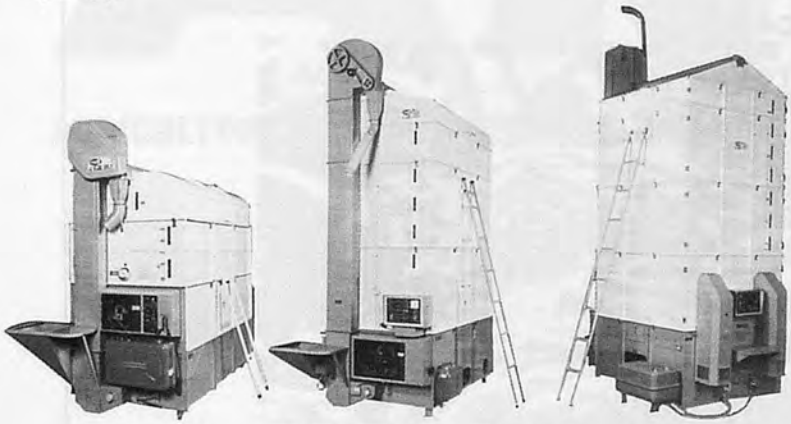

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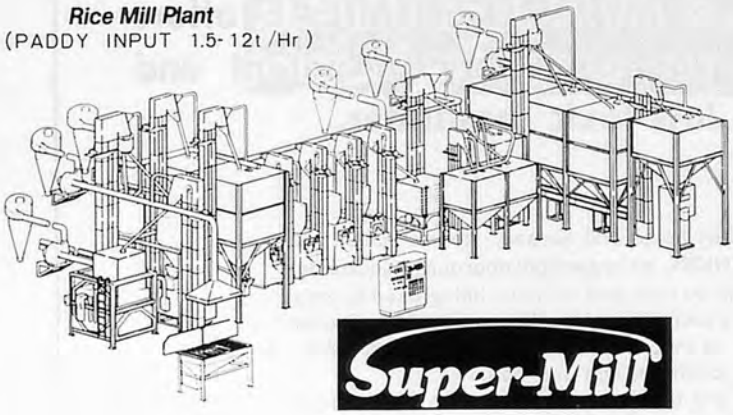

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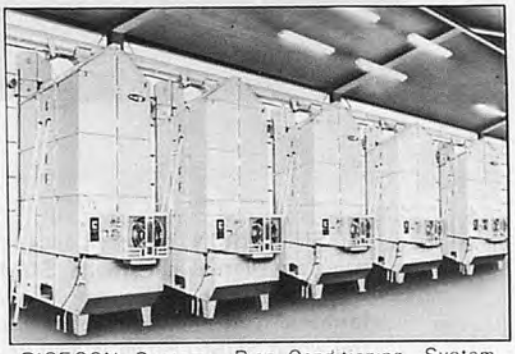

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This is the 32nd issue since the issue, Spring of 1971.

EDITORIAL

Japanese Agriculture: a Side-Issue

Many well-meaning critics have written about the success of Japanese farming which they invariably attribute to such factors as i) farm management efficiency that fully utilize modern technology (mechanization, HYVs, irrigation and adequate farm inputs); and ii) firm government assistance (price support, credit provision, market information, etc); among others – all which, in large measure, is true. As a matter of fact, over the last 15–20 years, observers by the hundreds from far and wide come to Japan annually to study the many facets of farming in order to understand what makes it "tick". They come away with the impression that, among others, the discipline and industry of the Japanese farmers loom large in the success of Japanese agriculture – which, also, to a large measure, is true.

But the success notwithstanding, Japanese farming remains subject to the vagaries of Nature like elsewhere. For instance, the disastrous cold summer spell last year wrought havoc to most summer crops, notably paddy, that caused the surplus rice stock of 7.0 million mt of brown rice to decrease by 1.5 million mt! And this year's summer months threaten to be equally cold and short which could again damage the crops. Also, the food self-sufficiency in Japan has already dropped to a low of 50 percent.

When this is the case, the Japanese policy makers are not apt to take these situations and contingencies very lightly. A point in fact is that the current price support scheme for rice is adjusted annually and rice acreage restrictions and adjustments are brought to bear on the prevailing problems whenever necessary. To be sure, the government invokes without delay various agricultural laws and policies that protect agriculture and the Japanese farmers when it deems fit. Because of this fierce government support to farming and the farmers, other critics are wont to argue that the protection system to agriculture, like in other advanced countries, should be abolished – the argument being that the prevailing world market prices for farm products should guide the Japanese government. (Japanese rice, for example, cannot be listed in the Chicago Board of Trade or other world market trading centers because it sells for about 5 times the going international price in view of its high cost of production).

And this is where other critics fall short of their judgement and arguments: they fail to realize that many of the world market prices are based on large-scale agriculture which need not be the international standard. If those critics examine the issue in the light of existing realities in much of Asia where farm units comprise only of a few acres each vis-a-vis hundreds of acres each in Canada and the United States, they will appreciate why the Japanese farmers are "pampered" to the extent that they are now regarded as the world's most prosperous even as some 70 percent of their annual income is derived from non-farm sources.

What this side-issue all boils down to is that in the face of a burgeoning population and dwindling food supply, the international market price levels for agricultural products need not average down the case of most Asian countries, developed or developing. For in these countries, agricultural policies give precedence over and priorities to domestic problems and realities, the promotion of agricultural mechanization, included.

To our great delight, Dr. E. U. Odigboh, Co-Editor of AMA, has received the Kishida International Award from ASAE. We would like to congratulate him on his honor in this editorial and besides, inform all of you of his honorable receiving.

Chief Editor
Yoshisuke Kishida

July, 1981
Tokyo

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The Australian Sugarcane Cultural System: A Fully Mechanized, High-Yield, High-Efficiency Way to Produce Sugar

by
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Senior Vice-President
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Introduction

The Australian sugar industry enjoys a high standing throughout the world for efficiency of operation and product quality. From the 295 000 ha harvested in 1977, 3.3 million t of sugar was produced by 33 mills for an average of 11.3 t sugar per ha (178.7 piculs per ha). The average cane tonnage is 80 t per ha with a 2.24 pstc (7.04 t cane per t sugar).

Australia exports about 2.5 million t sugar (76 % of production) mainly to Japan (700 000 t), Canada (600 000 t) and the US (400 000 t). This generates an export income of A$500–800 million.

The average Australian sugarcane farm is about 48 ha. A law allows only 85 % of the assigned area to be harvested each season thus the other 15 % is left fallow or idle, preferably planted to a green manure crop to be plowed in to improve the organic matter and nitrogen level of the soil. The average rainfall is 1 845 mm and ranges from 1 200 mm (in Bundaberg – Maryborough in Southern Queensland to 3 600 – 4 520 mm in Innisfail – Tully in the extreme North of the country's 1 200 km sugar belt. The mean temperature is 26°C with a low of 24°C in the South and 28–30°C in the North. Low temperatures at early planting times in the South is a critical factor in germination. Being in the southern hemisphere, Australia's milling season is the opposite period to that of the Philippines and the rest of the northern hemisphere.

The Australian sugar industry was forced to fully mechanize its field operations from planting to harvesting with rapid developments in the 60's because of labor scarcity and its escalating costs. They have demonstrated that increased efficiency through mechanization can enable them to weather periods of low world sugar prices and reap enormous windfall profits during times of high prices.

Adoptability of the System to the Philippines

The Philippine sugar industry can benefit from the experience of Australia. The Philippines is fortunate that the sugar growers do not have to go through decades of developmental work which the Australians had to undertake to reach their present state of efficiency. However, attempts in the past in the Philippines to adopt the Australian system and hardware have not met with great success. In the early 70's, when it was first promoted, the country was still enjoying high sugar profits and relatively low labor and other input costs thus the absence of pressures to improve yields and production efficiency. The hardware was also being forced to suit traditional cultural practices, e.g. 1 m row spacing, use of cane tops for planting material, semi-vertical planting, ridge culture at harvest, etc. Oftentimes, only parts of the system were used and consequently significant increase in yields and efficiency were not obtained.

Three years ago, an Australian implement manufacturer, Mick Hodge, convinced some local planters to adopt the complete Australian system. Results were more encouraging and interest heightened especially with the current awareness for the necessity to improve yields and production

efficiency.

This paper attempts to describe the Australian system of growing sugarcane and its possible application in the Philippines. It will likewise comapre the system with traditional practices. It does not encompass the entire cycle of producing sugar but focuses on salient field operations, some of which may differ from traditional practices. It is based on observations and interviews with farmers in Australia and the Philippines, discussions with sugarcane experts and a review of literature on the subject.

Background of Australian Sugar Farm System

The average Australian farm is a self-sufficient farming unit with little or not hired labor. Many Queensland sugar farmers or their parents migrated to Australia from Italy, Malta and other European countries as cane cutters. They therefore have the propensity to work hard. All farm operations are mechanized with implements developed by farmers and small shops over the years. Mechanical harvesting and transport is contracted; so is any land forming and other development works which require expensive, specialized equipment.

The industry is strictly controlled by a strong government/industry organization. Cane is purchased from the farmers by the mill based on sampled sugar content formula as against the sharing arrangement on the end products practised in the Philippines, with the notable exception of the Victorias-Panay cane purchases.

Key Elements of the System

The primary elements of the Australian sugar farm system can be summarized as follows:

1) Efficient mechanization – Field layouts, land forming, wide row spacing and other aspects are geared towards efficient mechanization. To obtain optimum efficiency from high capacity machines, the Australian farms have:

a) Large, rectangular or square fields of up to 5 ha to minimize idle time in turning at the ends. Lot sizes are also designed to the daily capacities of mechanical harvesters and other machinery.

b) Land forming for improved drainage to minimize bogging down in water basins and soil compaction and for efficient furrow irrigation. In some instances, "beds" are formed by plowing in to the center while the "Dead furrows" between beds act as drains and left in grass. These contribute to improved crop growth.

c) Wide row spacing of 1.5 m to allow fast travel of tractors when cultivating and for efficient harvesting.

d) Headlands and the absence of cross drains to facilitate access to and turns at the end of the field.

Table 1 Comparison between Australian and Philippine Sugar Industries and Farming Systems

Item	Australian	Philippine
A Industry		
Area planted (1 000 ha)	295	450
Production (million t)	3.3	2.3
Export (million t)	2.5	1.1
Mills (number of units)	33	42
Yield:		
t cane/ha	80	52.5
Piculs (sugar /t cane)	2.24	1.61
Piculs (sugar/ha)	178.7	84.6
Average farm size (ha)	48	15
B Cultural Practices		
Field size	Large	Small to medium
Tillage	Deep, 35 – 50 cm	Shallow-medium 20 – 30 cm
Planting	Deep, 20 – 30 cm flat	Shallow, 10 – 15 cm flat to slant
Material	Cutbacks	Tops
Row space	1.5 m	1.0 m
Cultivation process	Mechanical Gradual filling up of furrow	Carabo, Off-bar, On bar, Hand hoeing
Field at harvest	Flat, Ridged, Irrigated	Hilled up
Ratoons (number)	2–3	1–2
Harvesting	100 % Mechanical	Manual
Lead time to milling (h)	14 h	24 – 36 h

2) Deep tillage – This allows deep percolation of rain water to prevent waterlogging, conserve moisture, and provide a deeper root zone for the plant. The hard pan is ripped to 40–50 cm with a "grubber," chisel plow or subsoiler. This is then followed by a heavy disc plow penetrating 30–45 cm. Where fields have been land formed, reversible plows are used to maintain the field level.

A fine soil tilth is then obtained with a heavy, trailing disc harrow or Rotavator so as to have a good seedbed and minimize moisture loss through air movement.

3) Deep planting – Seed pieces are planted 20–25 cm below ground level to provide a deep rooted plant and encourage tillering. At this depth, soil moisture is also more favorable for germination than that nearer the surface. Soil cover varies from 5–10 cm depending on moisture condition, with a thick cover during dry periods to conserve moisture and a shallow cover during wetter periods.

Healthy, 6 month old stalks are fed into a mechanical planter which

cuts them into pieces of about 37 cm, dips or sprays them with a fungicidal solution, deposits the seed pieces (horizontally) at adjustable intervals at the bottom of the furrow shaped by the planter, places the proper amount of fertilizer in a band about 5 cm beside and slightly lower than the seed pieces, applies the appropriate soil cover and compacts the soil cover to improve soil contact with the seed piece when necessary. Higher labor costs have recently induced the development of billet planters which take seed pieces harvested by chopper harvesters.

In wet or very moist conditions, it has been observed that the furrows are made one day or more prior to planting to hasten evaporation and drainage of excess moisture. Very thin soil cover is then placed over the seed pieces at planting time. This is somewhat akin to a local practice in the Baicol Region, Philippines, where farmers wait until soil moisture is ideal before planting mechanically so as to have better germination.

4) The logic of deep planting – is that the primary shoots which develop from healthy buds in the seed piece form short joints or nodes similar to those of the seed piece. The buds on the joints of the primary shoots, under favorable conditions, germinate into secondary shoots and the root bands on these joints develop root systems to feed the shoots and replace the roots from the original seed piece. Tertiary shoots also develop from secondary shoots. Since more joints in the shoots of a deep planted seed piece can develop into healthy secondary and tertiary shoots, more tillering and a deeper, more extensive root system is encouraged. The plants are better established to withstand dry periods and strong winds. They also ratoon better because shoots have more deeply located buds. (Two to three ratoons are normal in Australia.)

5) Cultivation – There are many variations in cultivation practices and implements used by Australian farmers depending on climatic and soil conditions of individual farmers and localities. On the whole, however, the furrow is kept open with as little soil cover on the seed piece as necessary to conserve moisture. Loose, shallow soil cover encourages deep seated stool formation. When covered deep, secondary shoots emerge from buds nearer to the surface possibly because of better aeration.

The first cultivation operation after planting is to shape the furrow made by the planter which could be vertical in moist conditions so that drying soil fall into the furrow. Rain after planting can also erode the furrow sides into the bottom creating too deep a soil cover. This is accomplished by a spinner-weeder or rotor chipper which throws soil in the furrow towards the ridge. In the process, it uproots emerging weeds. This is a precision job as too deep a cut could also uproot the cane seedling. To a certain extent, this can be accomplished with a cut-away unit which has discs or moldborads on either side of the plants that cut small ditches and throw the siol to the side of the furrow. A light rake over the plants loosens the soil which fall into the small ditches. This operation is sometimes deliberately used to multiply the primary shoot hence induce the emergence of secondary shoots – a process of early ratooning. This, however, is reportedly not widely practiced in Australia at present because keeping the soil loose has been found to encourage tillering and the primary stalk is saved.

It is also a common practice to throw all the soil into the furrow in one cultivation in order to bury and smother the weeds whick have grown in the row. Then most of the soil is thrown out again with a spinner weeder or cut-away unit when the weed seedlings are dead so as to encourage stooling.

When stooling is reasonably complete, the furrow is gradually filled-in with disc gangs and spring tine cultivators working on the inter-space until the field is level at harvest time. In the process, weeds are killed and the soil is kept loose to allow aeration and infiltration of rain water. Increased soil cover also conserves moisture in the root zone.

A light spring rake, called a multi-weeder or cleaner, uproots the weeds in the plant row wihout harming the emerging cane shoots. Narrow versions are also used to run over the row with discs and coil or spring-shank cultivators working in the inter-space. Fertilizer applicators for side dressing are likewise combined with cultivation at the appropriate stage of plant growth.

It is generally recommended that touching the soil should be kept minimal except to control weeds or to break the crust formed by rain drops or irrigation water as excessive soil disturbance and pruning is not conducive to vigorous root growth. If proper land preparation was initially performed, deep interrow cultivation is not necessary to further improve the soil tilth at the root zone level. In fact, constant tractor and cultivator points passages cause soil compaction and represent excess fuel and machine use.

The Manual of Cane-Growing used by Australian farmers cites the following reasons and tips:

a) To work in crop residues such as trash and green manure. This can be accomplished with disc gangs or a rotavator with

blades over the row removed and sometimes combined with front-mounted subsoiler tines in the interrow for ratoon cultivation.

b) To control weeds. It is best to control annually or biennially and seedlings of perennials with shallow working of the soil than with deeper tillage and as soon as the weed seedlings appear. If allowed to develop further or to reproduce, they become more difficult to eradicate. In addition, they use up soil nutrients and moisture.

c) To place fertilizer and insecticides in the soil as a side dressing, when required.

d) To make the soil surface more suitable for the entry of rain and irrigation water by breaking the crust caused by the impact of rain drops and irrigation water.

e) To help control pests by eliminating their hiding places and host plants as well as incorporating pesticides and mechanically chopping grubs with a rotavator.

f) To maintain a favorable soil structure to allow good aeration of the plant roots and encourage tillering.

Other tips on controlling weeds may be cited:

a) A fast growing legume used as green manure during the fallow period is effective in smothering weed seedlings and drastically reducing their population.

b) Deep plowing to bury weed seeds is not advisable as they can germinate years later when brought up. It is better to kill them at the surface. A farmer's adage says: "One year's seeding is seven years weeding."

c) When the soil is too wet for tractor cultivation which could cause compaction and a destruction of soil structure, herbicides applied manually or with a light tractor should be employed before weed growth becomes uncontrollable. If feasible, hand chipping of the cane row should be resorted to. These operations may also be necessary when the cane has grown too high and earlier cultivations failed to control the weeds sufficiently.

d) Implements and tractor wheels used in weed infested fields should be cleaned thoroughly to prevent dispersal of weed seeds and tubers clinging to them.

e) Headlands and drains should be kept clean by mowing, harrowing or herbicides to prevent weeds from spreading to other fields.

Flat vs. ridge culture. Except where furrow irrigation is practised or in some wet areas, the Australians have flat field at harvest time as against the hilled-up practice in the Philippines. Speculations on why hilling up as a final or closing operation is practised in the latter country may be cited as follows:

a) To support the stalks against strong winds. It does not seem possible for a 10 to 15 cm hill to support a 3 cm stalk thus the presence of lodged cane in typhoon-ravaged districts.

b) To kill the weeds in the rows. At closing time, sufficient cover from the cane would prevent emergence of weeds unless they were left uncontrolled during the growing stage.

c) To kill emerging "water shoots" which do not contain much sugar at harvest ime and consume plant nutrients.

d) For improved drainage. This is only true where deep tillage was performed and with wide row spacing such that excess water will be encouraged to infiltrate in the inter-space.

There are no evidences which buttress or disprove the foregoing "reasons". It has been observed, however, that sugar planters in Lipa consistently obtain higher yields than the rest of the Canlubang Mill District (neighboring areas in Southern Luzon, Philippines). It seems that all inputs and practices were similar except that Lipa farmers do not hill up their cane crops. One possible explanation is that 7.5 to 9 cm of millable stalks are covered by soil at harvest representing a loss of 3 to 6 piculs of sugar per ha. This explanation cannot be extended to the Austalian deep planting system because the stalks underground have developed into the root and reproductive system. Higher yields from a better established, heavy stool and better ratooning capability also make up for portions of the stalk left in the ground.

Shallow planting and hilling up could be partly responsible for lower yields in the Philippines, lodging cane and poor ratooning because their root systems are too close to the surface.

6) Harvesting – One hundred percent of Australia's sugarcane crop is now mechanically harvested with chopper-type machines which cut the cane tops, cut the stalks at ground level (commonly 5 cm below ground level), chops the stalks into billets 35 to 40 cm long, cleans the trash and dirt with extractor fans and through the feed rollers and deposits the cane into transport bins on trailers which are then transferred to rail cars or trucks/trailers for milling within 14 hours. These harvesters generally require that the field be burned prior to cutting to reduce the trash content as was practiced during the era when cane was still hand cut. Burning and chopping of the cane forced the industry to reduce the lead time from

harvesting to milling in order to minimize sugar losses.

Australia has gone through three stages of harvest mechanization. The first was mechanical loading of hand cut cane with front end loaders. The second was wholestick cutting which deposited the cane stalks in bundles back on the ground. Closely following were chopper harvesters which eliminated double handling and produced short billets which are more readily conveyed to transport bins and unloaded.

Because of wet conditions in Northern Queensland and environmentalists' concern on the effects of widespread burning, the harvesters are now being adopted to cut green or poorly burned cane.

It is necessary to stress that the prerequisite to the efficient employment of these types of mechanical harvesters is the installation of the entire cultural and field-to-mill systems used in Australia and other mechanized regions (or their efficient modifications). It is also essential to give due consideration to the labor displacement implications of these machines which replace the poorest rural inhabitants – the landless and small farm laborer, even if most of them are migrant. There are indications, however, that in some mill districts there already is a growing scarcity of labor willing to perform the arduous and unpleasant task of cutting and loading sugarcane. It would be wise for the industry to start investigating, preferably installing pilot projects, on this phase of operations so that it is ready to more fully mechanize when labor shortages and costs dictate it.

7) Ratooning – Since most of the cane is cut at ground or below ground level with mechanical harvesters, stubble shaving is seldom practised although implements are available to enable buds from the lower stalks to develop into healthy, deeper rooted crops.

The first operation on ratoons is ripping the interspace to cut old roots, correct the effects of compaction caused by the harvester and transport system, and encourage deep water percolation and root systems. This is then followed by a disc ratooner which prunes the side of the stools, cultivates the interspace and a light rake over the row uproot weeds and loosens the soil over the stool to encourage emergence of new tillers. These two operations are sometimes combined with a ripper-rotavator combination.

The ratoon is then sidedressed with fertilizer together with subsequent, but early, cultivations. Weeder rakes are used as a fast means of uprooting weed seedlings as they emerge in the row and between rows.

8) Trash conservation – Because of the general practice of preharvest burning, the Australian farmer gives little notice to conserving cane trash. Tops left by the harvester are in fact raked and burned because of the difficulty of burying them. Long term experiments have shown that there is little yield differences between trash farming and "clean" culture even if it is recognized that inceased humus from trash conservation improves moisture retention and soil structure. (Leaves and tops account for 35 % of the total cane plant weight.) This is possibly due to the practice of fallowing and green manuring which compensates for burning the trash. Trash left on the ground also prevent sunlight from reaching the soil to raise its temperature, a critical factor for germination in the colder areas.

It has been recently reported that trash incorporation is now getting some attention in Northern Queensland. Trash is chopped and incorporated into the soil with Rotavators or a new disc implement yet to be popularized.

Where feasible, filter mud, bagasse and even molasses are spread back into the field to improve organic matter and return soil nutrients.

9) Soil conservation – Australian farmers place great emphasis on coserving their meager top soil. Steep slopes are not planted to row crops which enhance erosion and difficult to mechanize. On rolling areas, contour plowing and row layouts, terracing and stip cropping are practised. Deep chiseling on the contour also encourages rain water percolation and minimizes runoff.

Benefits of the Australian Sugarcane Growing System

The following may be cited as the salient benefits which can be derived from adopting the Australian system of growing sugarcane:

1) A better established, deep rooted cane crop is developed to better withstand typhoons, drought and pest damage.

2) Moisture conservation is encouraged thus reducing reliance on supplemental irrigation. This is accomplished through deep tillage and proper soil cover on the germinating seedlings. The crop is also less vulnerable to waterlogging.

3) More efficient utilization of fertilizers and pesticides through accurate placement at proper rates.

4) More efficient, extended usage of tractors into more phases of the growing cycle and a reduction in herbicide and labor use in controlling weeds.

5) Better tillering and higher yields are obtained. Up to 25 % increases have been realized in the

already high yielding San Carlos (Central Philippines) district.

6) Higher yielding ratoons are possible because of the deeper, more vigorous stool. Since the ratoon crop is less expensive than the plant cane, the sugarcane farmer can improve his profitability as well as weather seasons of depressed sugar prices and fuel crises. This is considred by many as the most important benefit of the system.

The foregoing point to the desirability for the Filipino sugarcane farmer and the sugar industry to consider adopting the more efficient Austalian system in order to continue being a major sugar producer. Modifications may be necessary to suit our weather conditions, cane varieties and the socioeconomic situation at any given time frame. It is not possible to manualize a system which would apply to all districts, weather occurrences, and weed and pest infestations. In the ultimate analysis, the general Australian system and hardware will still be dependent on the farmer's management and attention. It has been said that: "The best fertilizer is the farmer's footprints in the field." A more contemporary saying is: TLC – Tender Loving Care – will make most anything bloom."

Addendum

Tillage – While the paper states that plowing follows ripping or subsoiling as generally practised in the Philippines, the Australian manual mentions that "grubbing" follows plowing in order to attain a deeper root zone. This was confirmed by an Australian farmer who claims that less power would be required when ripping plowed soil thus compensating for increased slippage on loose, plowed soil. Track-laying tractors or four wheel drives are more desirable for this operation. Another reasons for this sequence of oprations is that it is necessary to plow in the thick green manure crop at the flowering stage and the clods are left to weather before subsequent tillage work is done.

It is also worthy to mention that the rotavator has been found ideal for chopping up old stools thus are used prior to green manuring. The rotavator leaves a fine, level seedbed for the legume which could be seeded directly with a seed drill mounted on the rotavator.

Cultivation – The multi-weeder which merely scratches the soil is also ideal for breaking the surface crust caused by the beating of rain drops or irrigation water. More rigid cultivator points could cause compaction below their path which is evidenced by the presence of standing water in the slit formed by the cultivator after a rain.

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Thailand-Made Power Tiller Transmission System

by

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Abstract

A power tiller manufactured in Thailand was tested for its performance. A rope brake for measuring the input power to the power tiller axle was designed and fabricated. The tiller was mounted on a frame and one side of the axle was connected to the brake shaft by means of a flexible coupling. At full throttle setting the engine was loaded by placing weights on the brake hanger. The center distance between engine pulley and transmission pulley as well as the linkage setting of the clutch lever, and transmitted power for various possible combinations using two sets of belts were measured from the brake. For a particular configuration, power transmission was affected significantly by a change in belt tension. Sag (indicating belt tension) of 25 mm/m of center distance between the pulleys was found to transmit maximum power. For new belts ths sag was achieved at a center distance of 78 cm in which case the transmission efficiency was about 94 %.

Introduction

There has been a steady increase in the use of prime movers in Asian agriculture and tillage is the main operation for which they are usually employed. Farm tractors were first introduced into Thailand in 1951. Local manufacturing firms produced a small number of tractors during 1965-70. Many makes of tractors and power tillers are being used in Thailand which are either imported or locally manufactured. **Table 1** shows the trend and status of the tractor and power tiller industry in Thailand.

The locally manufactured power tillers are simplified versions of the imported ones. The imported engines are fitted into the locally manufactured frames. There is no transmission gear box and only a few makes have the hand steering

Table 1 Distribution of tractor used in Thailand

Year	Imported						Local make				
	Tractor				Power tiller		Tractor		Power tiller		Total
	Large > 34 kW	Percentage	Small < 34 kW	Percentage	Number	Percentage	Number < 34 kW	Percentage	Number	Percentage	
1974	912	3.29	50	0.18	150	0.53	2 324	8.23	24 808	87.83	28 244
1975	2 031	5.85	400	1.15	1 800	5.19	2 582	7.44	27 860	80.35	34 673
1976	2 357	5.93	500	1.25	2 400	6.00	2 914	7.29	31 766	79.57	39 937
1977	2 361	5.26	800	1.78	3 000	6.68	3 258	7.26	35 465	79.01	44 884
1978	1 898	3.97	900	1.89	1 500	3.15	3 808	7.99	39 568	83.00	47 674

Source: Tax Department, Royal Government of Thailand.

clutches. The operating speed is adjusted only by positioning the accelerator lever. The engagement or disengagement of power to be transmitted is done by means of an idler pulley. The power tillers are steadily gaining popularity mainly due to low initial cost. As energy from fossil fuel sources dwindles and subsequently becomes more expensive, the efficient utilization of energy resources becomes a major concern to the agricultural production system. The objective of this study was to evaluate the performance of the flexible power transmission system of a power tiller manufactured in Thailand[1].

The Power Tiller

The tiller has a locally manufactured frame and is equipped with an imported water cooled YANMAR diesel engine of 5.22 kW (continuous output) at 2 200 rpm. The unit has two hand steering clutches for ease of turning and uses two B section V-belts. The engine block is anchored unto a flattened C-shaped support member by means of three positioning blots. The block can slide freely by loosening these bolts such that the center distance between the transmission pulley and engine pulley can be varied if necessary. The transmission pulley has two grooves: the smaller one for higher speed on the road and the larger groove for field operations. At the time of receiving, the center distance between the two pulleys was 77.50 cm and the belts were set over the large diameter groove of the transmission pulley. Normally, two persons are required to start the engine: one to hold the steering clutch levers and the other to start the engine.

Power Measurement

In order to measure the input power to the tiller, a brake and a mounting frame were designed and fabricated[1]. The designed brake is an absorption type dynamometer and the frame is made of 'U' channels. The complete setup is shown in **Fig. 1**.

After removing the wheels the prime mover was mounted unto the supporting frame keeping the modified side of the axle towards the brake assembly. The axle was coupled with the brake shaft by means of flexible couplings. Before starting a test run, alignment was checked. After starting the engine the brake drum was energized and de-energized by engaging or disengaging the hand-steering clutch, respectively. Prior to energizing the drum, the hanger bottom was placed into a safety slot on the base member of the brake frame to avoid accident. By engaging the clutch the no-load speed of the drum was recorded initially. Throughout the experiment the engine was operated at full throttle setting. The weight was increased in increments of either 10 kg or 9.09 kg and for each piece of added weight the speed of the drum was measured by a tachometer. Tension in the slack side of the rope was also recorded. The load on the brake was then calculated from the algebraic summation of the tensions in the two sides of the rope. At higher loads, considerable stretching of the rope was noticed. To minimize this the attaching hook on the slack side was screwed down, thus shortening the length on the loading side. As the experiment progressed, after some time the brake drum became very hot. In order to cool it, water was poured frequently inside the drum surface, which removed the heat uniformly from the whole drum surface. Each test was repeated two times.

Two sets of belts were used in the experiment. At first the original pair of belts supplied by the manufacturer was used. The tests were repeated again using a newly-purchased pair of B-82 (locally manufactured) belts. During the direct coupling run (**Fig. 2**) the engine block was moved to its farthest permissible position on the mounting frame so that the power was transmitted directly from the flywheel to the transmission pulley. This was achieved by loosening the positioning bolts. The clutch (idler) was totally disengaged and the engagement or disengagement of the power transmission was achieved by means of the steering clutch lever. Using the old and new sets of belts, the experiment was conducted for the following seven combination settings:–

Fig. 1 Framework for mounting brake accessories and power tiller

1) Original setting – old belts, 2nd linkage setting
2) Original setting – old belts, 3rd linkage setting
3) Direct coupling – new belts, 2nd linkage setting
4) Original setting – new belts, 2nd linkage setting
5) At 78 cm center distance – old belts, 2nd setting
6) At 78 cm center distance – new belts, 2nd setting
7) At 78 cm center distance – new belts, 3rd setting.

Results and Discussion

Original Setting

The first experimental run was made with the original setting of the engine block anchorage and the existing belts. The center distance between transmission and engine sheaves was 77.50 cm and the linkage was set at the 2nd setting (counting from the handle side). During the test, only after 26 kg of load on the brake did the belts start to slip. With the addition of two more pieces of load, the brake drum stopped rotating. The experiment was repeated two times. It is clear from **Fig. 3** that the drum stopped while transmitting only 1.14 kW of power. The engine speed was reduced by only 17 percent of no-load speed. This indicates that the engine was not over-loaded. Instead, the transmission system of the power tiller was not working properly. After engaging the clutch, and the belts were pressed downwards, the sag on the light side was 44 mm, which amounts to a sag of 57 mm/m of center distance between the pulleys. The belts were too loose to maintain the proper initial tension and only a limited amount of power could be transmitted. The transmission efficiency was only 22 %.

Direct Coupling

In this setting the tests were conducted by directly coupling the transmission pulley with the engine fly wheel pulley as shwon in **Fig. 2**. This experiment was done to determine the maximum possible usable power from the engine by employing a minimum transmission facility. Results in **Fig. 4** show that a significant improvement can be achieved in this way. The plot follows the normal trend of an engine performance curve. The peak power at a brake load of 134.55 kg was 4.85 kW. It can also be seen that the power increased steadily upto a peak value and then decreased abruptly to a value far below the peak value. The no load speed was 120 rpm and with the increment of load the speed gradually decreased to 85 rpm. The curve AB for the governor shows a reduction of about 13 % in the overall speed. This indicates that the prime mover was equipped with a properly governed engine (YANMAR). After attaining the

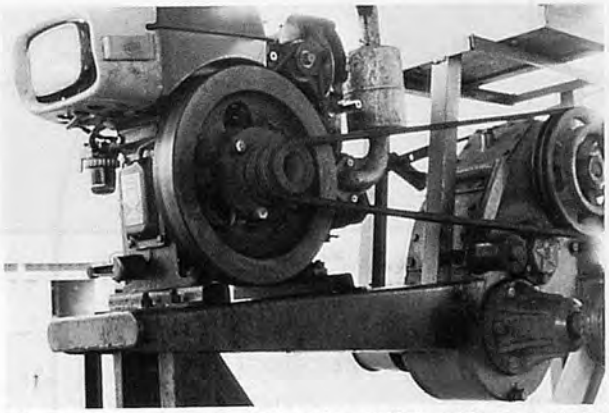

Fig. 2 Direct coupling of engine pulley with transmission pulley

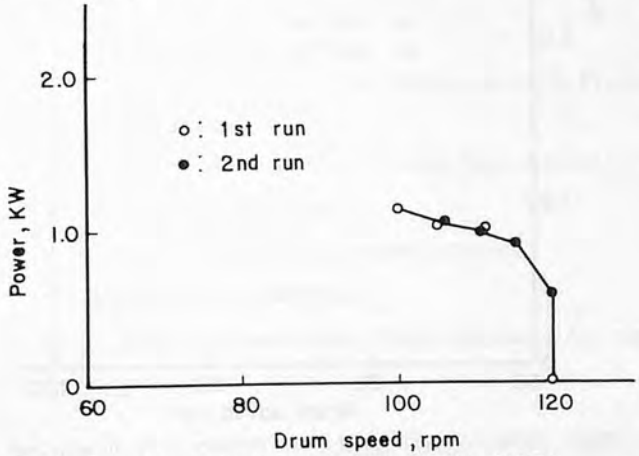

Fig. 3 Power transmitted at original setting with old belts

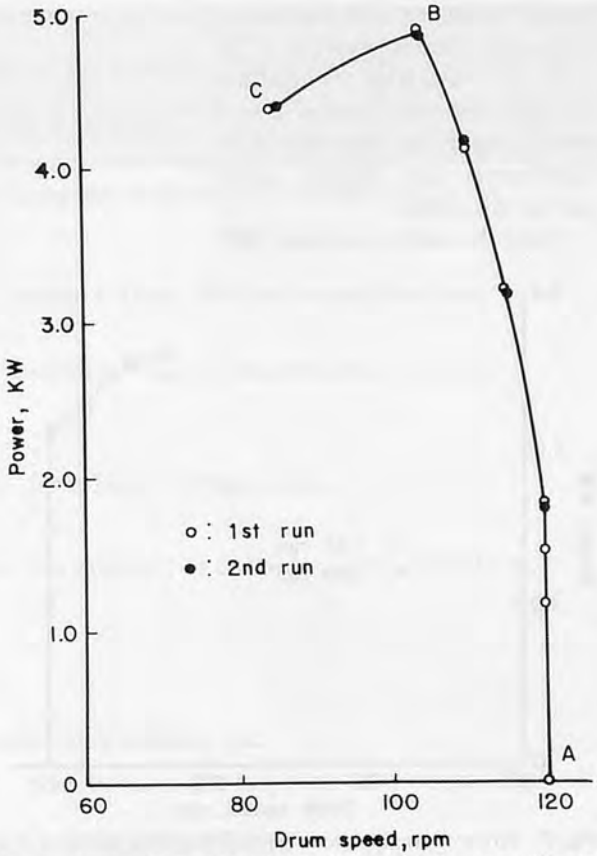

Fig. 4 Power transmitted during direct coupling run with old belts

peak value with the addition of the next piece of laod, the speed dropped abruptly due to overloading of the engine, which stopped within a very short time. Thus further recording of the speed was not possible. The overloading was easily noticed due to the dense black smoke coming out of the exhaust.

Clutch Engagement

There are four holes for setting the clutch linkage. In the 4th position of linkage setting (counting from the handle side) the belts were too slack and the initial tension was not sufficient for power transmission. Therefore, tests were not conducted for this setting.

The problem encountered with the first setting was that the belts became too tight to operate. With much difficulty, it was possible to engage the clutch with the original anchorage (center distance 77.50 cm). The belts were too tight and the excessive belt tension caused overheating of the belts. Hence, no experiments were likewise carried out for this setting.

Using the newly purchased B-82 (208.25 cm) belts and the anchorage at 77.50 cm, the linkage was changed to the second setting. After 52 kg of loading the engine speed started to reduce (**Fig. 5**). With the next three increments of load, although the engine was running, the belt slip reached almost 100 %. As another piece of load was added the transmission pulley stopped instantaneously, which time the transmitted power was 2.62 kW. The measured sag in the belts was 45 mm/m.

From **Figs. 3** and **5**, the output was 1.14 kW and 2.62 kW respectively. Both tests were made for the same center distance and linkage setting. This means that the initial tension of the old belts was less than that of the new ones. This may be due to the inequality in length of the two types of belt or to the fact that old belts might have stretched a little.

For the same linkage setting the center distance was changed to 78 cm. For this setting with the old belts, the useful power obtained was 4.52 kW. After that the belts started to slip. As further load was added the slip increased and the belts quickly became overheated and burnt before the power was disengaged. Sag in the belts for the setup was 30 mm/m of center distance. Keeping the same linkage setting and a center distance of 78 cm the belts were replaced by new ones. The sag was found to be 25 mm/m. The power at no-load speed of 120 rpm was 3.7 kW (**Fig. 6**) and peak power of 4.92 kW was measured at 105 rpm. With

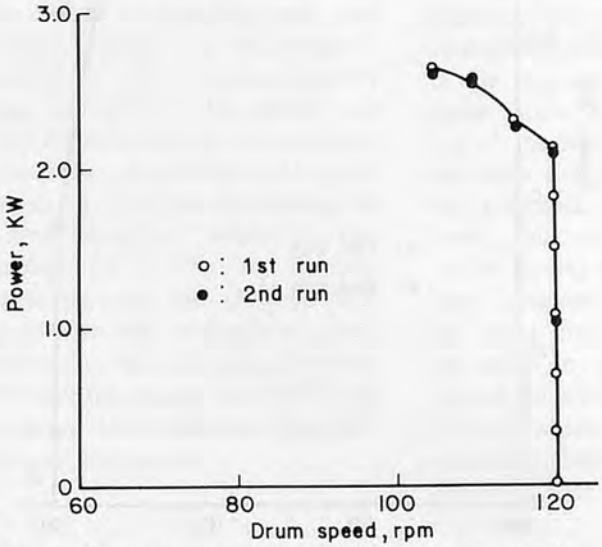

Fig. 5 Power transmitted at original setting with new belts

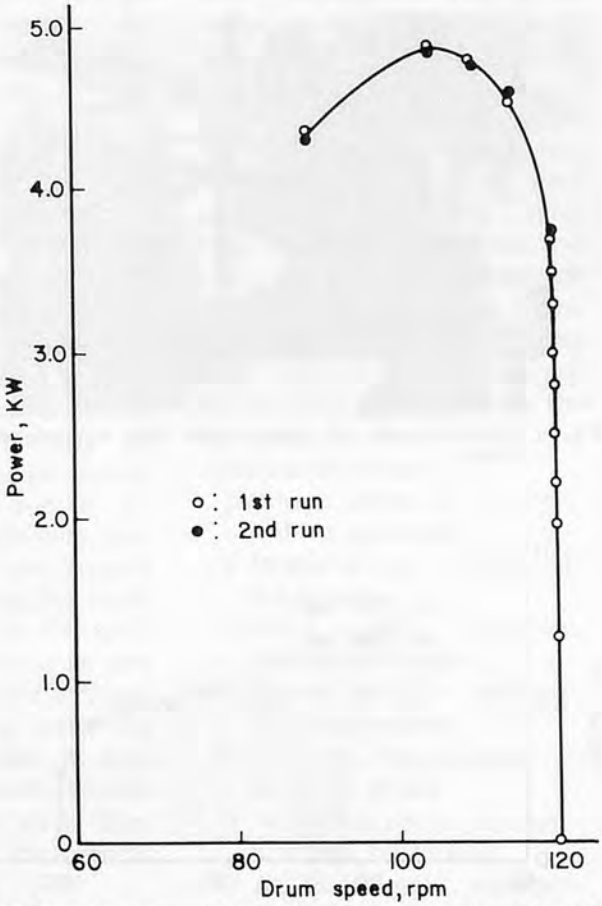

Fig. 6 Power transmitted at center distance of 78 cm with 2nd linkage setting and new belts

the addition of the next incremental load the engine became overloaded and there was a sharp decline in speed. Power transmitted at that time was 4.40 kW. The engine slowed down quickly and stopped within a very short period of time. For this setting the maximum transmission efficiency was 94.2 %.

Keeping all other settings as in the previous test, the linkage was changed to the third setting and the available power was measured. After several trials, it was observed that even at no-load on the hanger the belts slipped 100 %. The belts were too slack and the sag was 90 mm/m. The torque applied by the transmission system could not overcome the starting torque required by the brake assembly.

Conclusions

For the experimental unit, irrespective of linkage setting and anchorage position, transmitted power varied significantly with the amount of sag in the belts. When the sag was 57 mm/m the power transmitted was 1.14 kW. For the same setting with a new set of belts the sag was reduced to 45 mm/m and transmitted pwor increased to 2.26 kW. For the sag of 30 mm/m the transmitted power increased to 4.52 kW. For a center distance of 78 cm and 2nd linkage setting for the sag of 25 mm/m, the maximum power transmitted was 4.92 kW. When the linkage setting was changed to the 3rd position, the brake drum did not rotate as the transmitted power was not sufficient to overcome the initial starting torque. The sag in this case was 90 mm/m.

It can be concluded that for a particular configuration, power transmission is affected significantly by a change in the belt tension. For maximum power transmission using B-82 belts and the 2nd linkage setting on the test unit, the sag should be about 25 mm/m of center distance. For new blets this sag was achieved when the center distance between the pulleys was about 78 cm.

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Fabrication and Testing of Strain Gauge-Mounted Proving Ring Dynamometer for Tillage

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Introduction

The design and fabrication of the implement is one of the important factors which affects energy consumption and power use. Most of the equipments used in Indian agriculture were designed on the trial-and-error basis, specially for the measurement of draft forces where a sensitive and accurate dynamometer is required. For this study three types of dynamometers were used: mechanical, hydraulic and electrical. The mechanical dynamometer is good for measuring forces which do not vary frequently and is mostly used for static loading. The hydraulic dynamometers are generally used for measuring forces acting on the tillage tools which are hitched to the tractors.

The lack of sensitivity, leakage problem and inconvenience of attaching tillage tools were some of the limitations of these dynamometers. To avoid the above problems and power losses in tillage operations, strain gauge type dynamometers are most suited and have been developed for the study.

The disc harrow is a more popular implement among farmers than other tillage implements in India. About two-thirds of the tractors in India are equipped with different types of disc harrows which are mostly trailed types. For measuring the draft force required by the trailed type disc harrow, a strain gauge-mounted proving ring dynamometer has been fabricated and tested in actual field conditions. The study also determined the relaitonships among the gang angle, speed of operation and unit draft of the implement.

Buck and Beckwith described a strain gauge type ring transducer for calibrating the tensile testing machines and for the measuring large static loads. The capacity of the transducer varied between 150 and 150 000 kg. Radhey Lal studied a ring type dynamometer employing resistance strain gauges as secondary transducers. The strain gauges were mounted to the inner side of the ring at 90° spacing in the line and perpendicular to the load line. The ring was made of flat iron in rectangular cross-section. The material used was special alloy steel having a modulus of elasticity 2×10^6 kg/cm^2.

Constructional Details

Fig. 1 shows the strain gauge mounted proving ring dynamometer fabricated from mild steel bar having a modulus of elasticity 2×10^6 kg/cm^2. **Fig. 2** shows four strain gauges mounted on the ring surface. **Fig. 3** and **Photo 1** show a closed box measuring 160 x 160 x 76 mm made from 2 mm mild steel sheet to keep the ring fitted into it with lead wires soldered with strain gauges. The dynamometer measures 286 x 160 x 121 mm (L x W x T). The complete dynamometer assembly is shown in **Fig. 3.**

The steel ring was checked for its changes in diameter while loading by using the following equations:

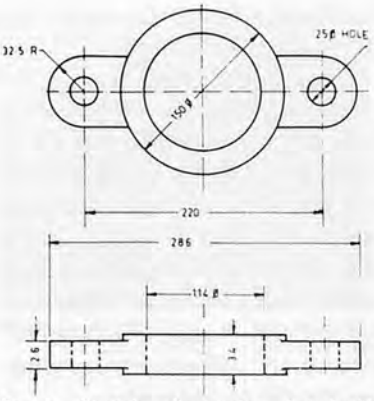

Fig. 1 Sketch of proving ring (unit: mm)

1) Increase in diameter along the load line $= 0.149\frac{PR^3}{EI}$

2) Decrease in diameter perpendicular to the load line $= 0.137\frac{PR^3}{EI}$

Where,

P = Load applied, kg; R = Mean radius of curvature of the ring, cm; E = Modulus of elasticity, kg/cm^2; I = Moment of inertia, cm^4

From the values obtained in the above equations it was found that there was a change in the diameter of ring about 0.1 mm at the maximum load of 3 000 kg. This value is neglegible.

Strain Gauge Mounting

The strain gauges were type SA-10 manufactured by M/S Rohits & Company (India). The resistance, gauge factor and length of the strain gauges were 117.1 ± 0.2 Ohms, 2.06 ± 2 % and 10 mm, respectively. The surface of the proving ring were made smooth through filing before mounting any strain gauge on it, but not highly polished in order to strengthen adhesion. With a surface of approximately the same degree of roughness, thorough cleaning was done by a volatile solvent, i.e. Rohits nitro solvent. After cleaning the surface, cementing material (nitro adhesive) was applied in two coatings on the ring surface and one

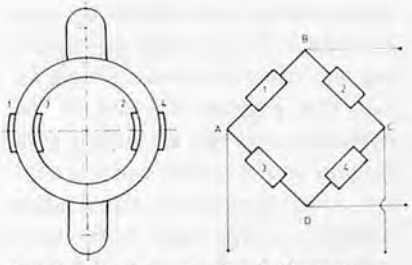

Fig. 2 Strain gauge circuit diagram

layer of adhesive on strain gauge cover paper. The bonded strain gauge was pressed for 12 hours keeping the blotting paper between it. The lead wire was soldered using noncorrosive flux after 12 hours of bonding the strain gauge on the test specimen. A small piece of insulating material was kept between the strain gauge lead and soldered lead joint which acts a shock absorber for the strain gauge, hence prevent short gauge circuit. This also eliminates external strains on the gauge. Water proofing compound was used on the bonded strain gauge.

The soldered lead wire was fixed to the testing material with the help of tape in order to avoid any disterbance to the strain gauge at the time of testing. Single lead copper wires of the size 1.0 mm were soldered to the strain gauge ribbon and connected to the strain indicator for reading the strains (**Photo 2**).

Strain Gauge Testing

The strain gauge resistance was checked with a multimeter before and after mounting on the proving ring. The strain gauges with the same resistance as supplied by the manufacturer were mounted on the test specimen and again tested. If the resistance differs after bonding from the tested value, it means that it has been damaged during the process of bonding and it should be discarded. The mounting and checking process was repeated until

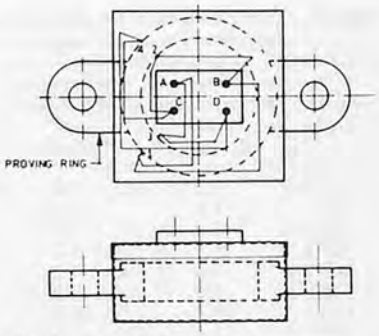

Fig. 3 Strain gauge mounted proving ring dynamometer

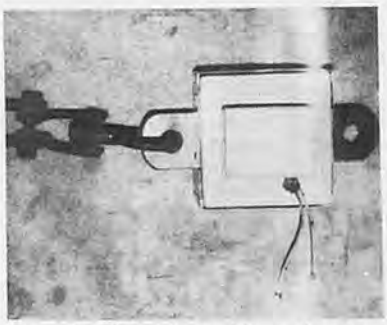

Photo 1 Closed box with proving ring

Photo 2 Proving ring with strain gauge mounting

it gave the correct value. In this process the strain gauge was pressed lightly with an eraser and the deviations on the strain indicator were noted. After releasing the load the needle approached the same zero position as before which means that the strain gauge was perfectly bonded. If it fails to return to zero position it means that the strain gauge is either imperfectly bonded or damaged. This process was repeated for all the four strain gauges mounted on the proving ring.

The static calibration of the

Table 1 Calibration chart for the dynamometer at low loads

Load (kg)	Deflection at increasing load (Division)	Deflection at decreasing load (Division)
0	0.0	0.0
25	1.8	1.8
50	3.6	3.6
75	5.4	5.2
100	7.0	7.2
125	9.0	9.0
150	10.8	10.8
175	12.6	12.6
200	14.4	14.4
225	16.2	16.0
250	17.8	18.0
275	19.8	19.8
300	21.6	21.6

Table 2 Calibration chart for the dynamometer at high load

Load (kg)	Deflection at increasing load (Division)	Deflection at decreasing load (Division)
0	0.0	0.0
500	3.6	3.6
1 000	7.2	7.2
1 500	10.8	11.2
2 000	14.0	14.4
2 500	18.0	18.0
3 000	21.6	21.6

dynamometer was done by suspending a 20 kg weight in increasing and decreasing order (**Table 1**). For this purpose one end of the dynamometer was suspended with support and the other end was kept free for suspending the known weights. The lead wires were connected to the strain indicator for reading the strains at all loads applied or removed. The calibration curve was plotted between the load applied and deflection (division) read from indicator (**Fig. 4**). A linear relationship existed between load and deflection. By decreasing the loads in the order they were applied, the deflection showed no change, which indicates that there was no hysteresis effect. The calibration was also done on the Universal Testing Machine (UTM) for high capacity loading of 500 kg in increasing and decreasing order up to a maximum load 3 000 kg (**Table 2**). From this observation, the curve was plotted which exhibited a linear relationship between load and deflection (**Fig. 5**).

Testing of Dynamometer – The testing was done on the University farm in a 2 ha plot selected for the study. The soil under study was silty-clay-loam with an average moisture content of 12.21 % at the time of testing. The average bulk density and cone index values were 1.437 g/cm^3 and 10.0 kg/cm^2 respectively. The draft was measured by the dynamometer.

Experimental Procedure – The dynamometer was connected by clamps between the drawbar of the tractor and hitch point of disc harrow (**Photo 3**). The drawbar was lowered to such height that the dynamometer may assume a horizontal plane. The lead wires of the dynamometer were connected to a battery operated strain indicator which was held by a person sitting on the mudgaurd of the tractor and utmost care was taken to mimimize vibrations. The draft of the imple-

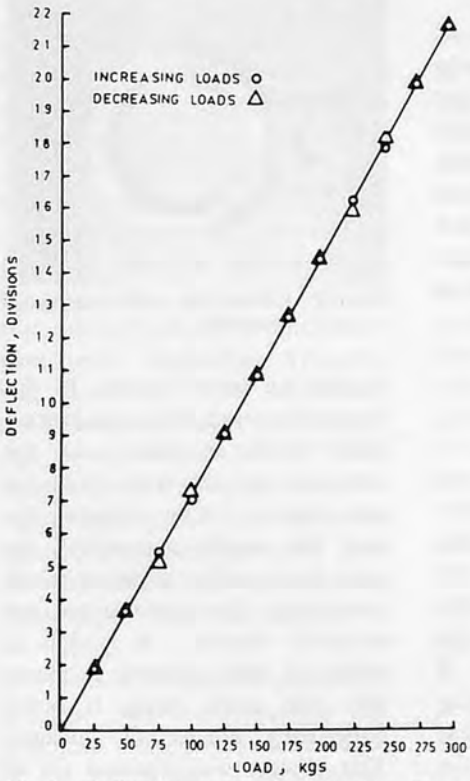

Fig. 4 Calibration curve of strain gauge type proving ring dynamometer for low capacity

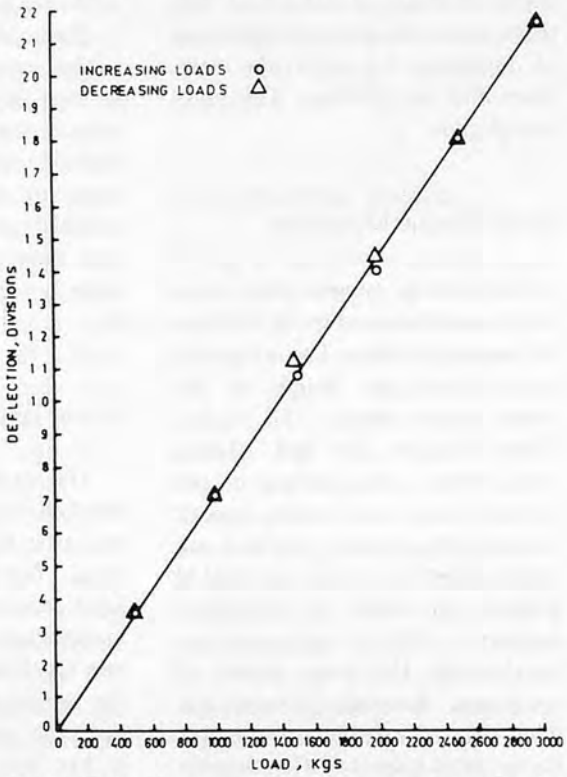

Fig. 5 Calibration curve of strain gauge type proving ring dynamometer for high capacity

Photo 3 Connection of proving ring dynamometer between tractor and disc harrow

ment was recorded after running the tractor for a while and bringing the needle of the indicator to a steady condition.

The speed of travel was noted simulteneously by measuring the time to travel a particular marked distance in the field with the help of stop watch. For every replication the width and depth of cut was also measured for the calculation of cross-sectional area.

Table 3 Variation of unit draft with speed and gang angle

Gang angle (degrees)	Speed (m/s)	Draft (kg)	Cross-sectional area (cm^2)	Unit draft (kg/cm^2)
13.5	0.868	147.64	1 278.88	0.115
	1.076	193.95	1 121.93	0.173
	1.740	254.29	1 157.63	0.220
	2.251	265.08	1 151.38	0.230
26.5	0.868	303.85	1 701.56	0.190
	1.076	318.93	1 385.93	0.230
	1.740	365.57	1 343.93	0.271
	2.251	364.19	1 260.76	0.292
32.5	0.868	365.41	1 645.41	0.222
	1.076	377.60	1 480.71	0.256
	1.740	424.16	1 431.22	0.296
	2.251	428.06	1 362.91	0.314
35	0.868	405.36	1 379.74	0.237
	1.076	396.24	1 446.60	0.270
	1.740	439.24	1 446.65	0.306
	2.252	448.24	1 385.89	0.326
40	0.868	495.65	1 898.20	0.264
	1.076	558.14	1 922.93	0.290
	1.740	637.87	1 990.17	0.326
	2.251	702.53	2 021.10	0.348

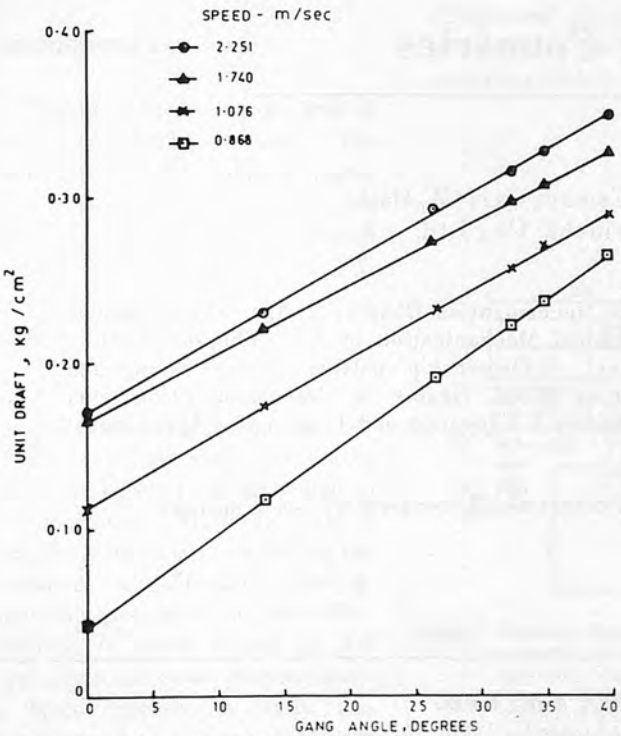

Fig. 6 Variation of unit draft with gang angle

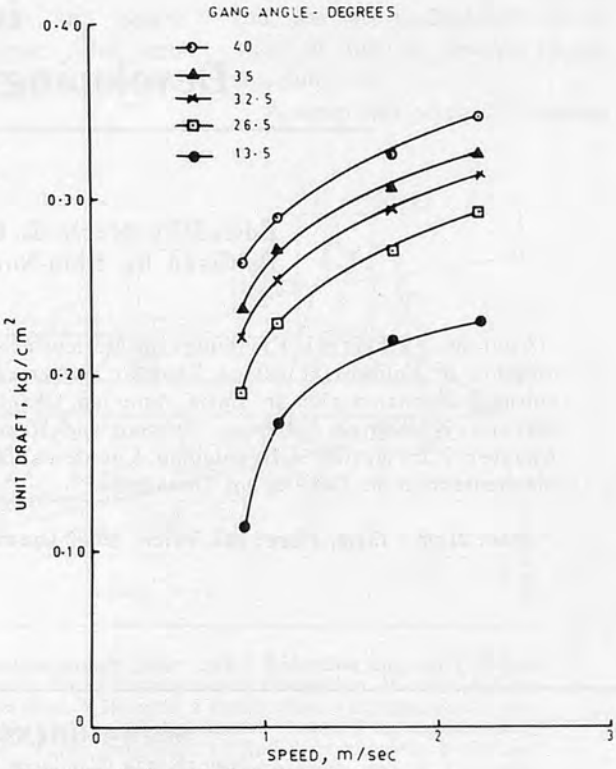

Fig. 7 Variation of unit draft with speed

Results

The dynamometer can measure the draft up to 3 000 kg with zero hysterisis effect and no error found at any stage.

The correlation of different parameters with unit draft were studied separately.

Effect of gang angle on Unit draft – The effect of gang angle and unit draft at various speeds is shown in **Table 3** and **Fig. 6**. At speeds of 0.868, 1.076, 1.740, 2.251 m/s the relationship between the gang angle and unit draft were studied. The unit draft increased linearly as the gang angle increased. The lowest unit draft of 0.115 kg/cm^2 was at the gang angle of 13.5° and the maximum unit draft of 0.348 kg/cm^2 was found at the gang angle of 40°.

Effect of speed on unit draft – The relationship between the unit draft of the disc harrow and speed of operation was plotted (**Fig. 7**). The rate of increase in unit draft was greater at lower speeds, i.e. 18.3 % compared with the higher speed of 3.54 %. The unit draft of 0.115 kg/cm^2 was lowest at the speed of 0.868 m/s and the greatest draft of 0.348 kg/cm^2 was at the speed of 2.251 m/s.

Conclusion

1. The dynamometer has a maximum capacity of 3 000 kg.
2. There was no hysterisis effect while decreasing or increasing the loads up to the designed capacity, hence no error.
3. The unit draft of the disc harrow tested increased linearly with the gang angle when the speed of operation and other parameters were kept constant.
4. The unit draft increased with an increase in the speed but with curvilenear relation when the gang angle and other parameters are kept constant.

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Agricultural Mechanization in Developing Countries

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Soil Separation by and Power Requirement of a Potato Elevator Digger

by

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Abstract

The present study was carried out to determine the soil separation by and power requirement of a potato elevator digger equipped with oscillating and non-oscillating blades. The performance of the digger fitted with oscillating and non-oscillating blades was compared.

Introduction

Potato is grown on an area of about 650 000 ha in India. The two main labour intensive operations of potato cultivation are planting and harvesting which utilize about 50 % and 33 %, respectively, of the total labour requirement of the crop.

There has been some recent progress in the mechanisation of potato harvesting in the country. Tractor-mounted single-row potato elevator diggers have been used in some regions. However, there is very little information regarding the influence of different soil-crop-machine parameters on the effectiveness of these diggers on soil separation and power requirements.

More recently, a study was initiated on oscillating tools for tillage and root crop harvesting. The main advantages offered by oscillating tools include reduction in draft, better soil fragmentation and lower energy requirement for achieving the desired soil conditions.

The present study was carried out to investigate the influence of selected parameters like length and speed of the elevating conveyor and forward speed of the machine on soil separation and power requirement of diggers fitted with conventional (non-oscillating) and oscillating blades.

Methods and Materials

Field conditions were simulated in the soil bin at Indian Institute of Technology, Kharagpur. Tests were carried out at a soil moisture content of 8.5 %. Potato density in the ridge was kept at 1 kg/m. The average bulk density of the soil was 1.7 g/cc. The ridge had 35 cm base width and 18 cm height and was left undisturbed for 24 hours in order to develop its soil structure.

A setup was prepared as shwon

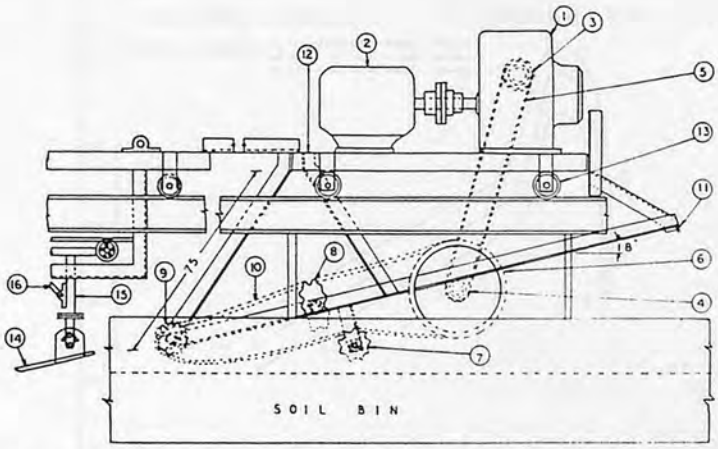

Fig. 1 Elevator conveyor trolley (Unit: cm) 1 Reduction unit, 40:1, 2 A.C. induction motor, 5hp. 3 Chain sprocket, 11 cm diam. 19 teeth, 4 Chain sprocket, 9 cm diam. x 15 teeth. 5 Roller chain. 6 Driving gear for conveyor, 19 teeth. 7 Idle gear, 11 cm diam. x 9 teeth. 8 Agitator sprocket, 16x9, 10 teeth. 9 Idler gear front. 10 Rod chain conveyor, 1 cm diam. 11 Conveyor frame angle iron. 12 Conveyor trolly channel. 13 Trolley roller, 9 cm diam. 14 Digger tool. 15 Tool standard. 16 Connecting rod.

in Fig. 1. Two trolleys were fabricated for mounting the digging blades and conveyor chain separately. Both trolleys were hitched together at the time of operation. The power to oscillate the digging blade and to rotate the conveyor chain was supplied by separate motors. The tool was 55 cm wide, 25 cm long and 0.5 cm thick. It was inclined at an angle of 20 degrees. The frequency and amplitude of oscillations were 7.8 cycles /s and 15 mm respectively. The mode of oscillation was horizontal and paralled to the direction of the motion. The width and pitch of the conveyor was 58 cm and 30 mm, respectively. The forward speed of the machine and peripheral speed of the conveyor were varied during the study. The values of these parameters are shown in Table 1. The inclination of the conveyor was kept 18 degrees.

Table 1 Test parameters and values

Conveyor length:	1, 1.28 & 1.55 m
Conveyor speed:	26.2 & 54.3 m/min
Forward speed:	11.7, 23.7 & 30 m/min

Some dimensionless groups were made by dimensional analysis. One group was named 'Conveyor Speed Index' which is the ratio of the peripheral speed of the conveyor to the forward speed of the machine. The other group was conveyor length to the pitch ratio.

Results and Discussions

The results obtained during the study are presented graphically in Figs. 2 through 5. The soil separation increased with the increase in

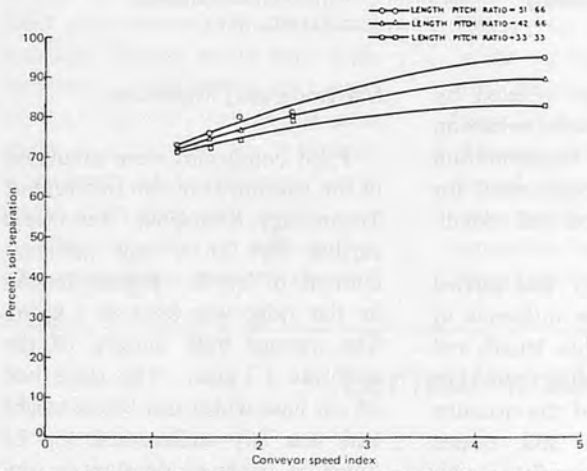

Fig.2 Relationship between conveyor speed indices and % soil separation for potato elevator digger with oscillating blade.

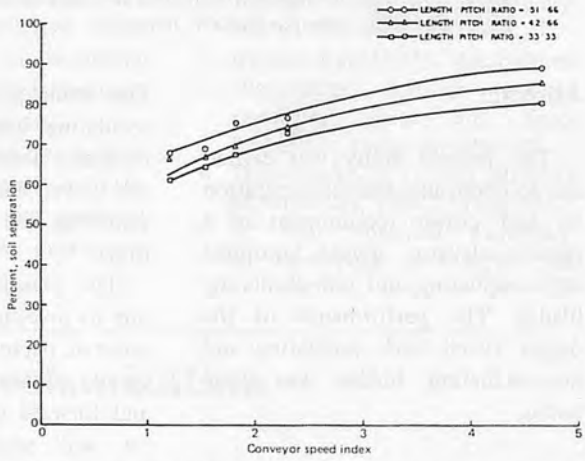

Fig. 3 Relationship between conveyor speed indices and % soil separation for potato elevator digger with non-oscillating blade at different conveyor length-ratios.

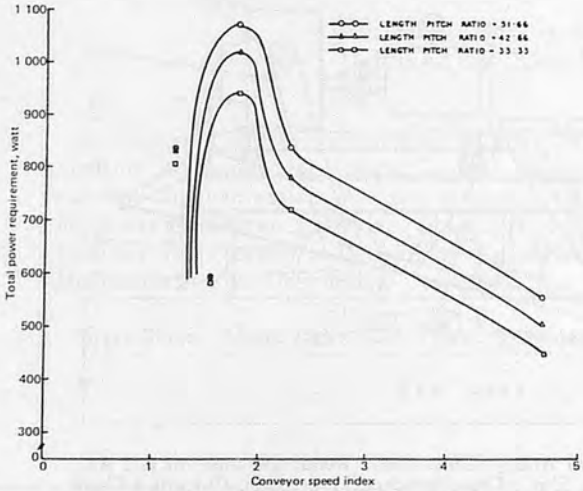

Fig. 4 Relationship between conveyor speed index and total power required for potato elevator digger with non-oscillating blade.

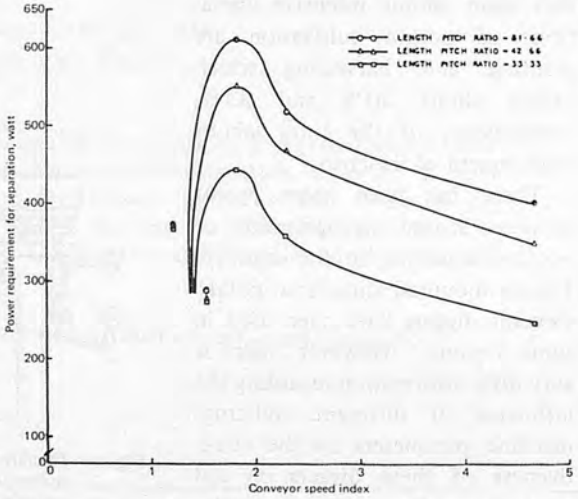

Fig. 5 Relationship between conveyor speed index and power required for separation for potato elevator digger with oscillating blade.

conveyor speed index for all the conveyor length pitch ratios and for both non-oscillating and oscillating blade. This indicates that either at a slow forward speed or at higher conveyor speed there is better soil separation. This is because at lower conveyor speed indices, the quantity of soil handled by the conveyor per unit time is less.

At a given conveyor speed index, and length pitch ratio soil separation was better for the oscillating blade. The increase in soil separation with the use of an oscillating blade ranged between 3.1 and 10.4 %. This increase in soil separation was due to better breakup of the soil by the blade at the point of splitting the ridge.

For a given pitch of the conveyor, as the length of the conveyor is increased, the soil separation also increased for both types of blades. For the non-oscillating blade, the soil separation increased from 1 to 1.55 %. The increase in case of oscillating blade was 12 %.

The power requirement for soil separation was computed by combining the draft as well as the driving power for the elevator conveyor.

The power requirement for separation increased with the conveyor speed indices up to a limit and then it decreased for both oscillating and non-oscillating blades. This was true for all the conveyor length-pitch ratios studied. It indicates that there is a critical combination of the conveyor speed and the forward speed of the machine corresponding to which the combined driving and the draft power of the conveyor exceeded the conveyor speed indices on either sides. It is, however, interesting to note that the power requirement for separation in case of oscillating blade is comparatively lower for all the length pitch ratios. This difference, however, was reduced progressively for higher length pitch ratios.

Although the power requirement for separation was lower for an oscillating blade, the total power requirement was comparatively higher. The reason was that though the oscillating blade reduces the draft, it requires additional power to oscillate the blade. The maximum and minimum difference in the total power requirement for oscillating and non-oscillating blades were 6.5 and 4 % for the length pitch ratios of 51.66 and 33.33, respectively.

The power required for separation and the total power requirement were high for higher length pitch ratios for both the oscillating and non-oscillating blades.

Conclusion

The use of an oscillating blade in a potato elevator digger reduces the conveyor length and better soil separation can be achieved without much increase in the power requirement.

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Energy Input-Output Relationship in Traditional and Mechanized Rice Cultivation in Bangladesh

by

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Introduction

Agricultural activities in Bangadesh are mostly traditional. Some basic production resources are lacking in these traditional systems. Self-sufficiency in food production for the country's vast population is an understandable goal. The achievement of that self-sufficiency should be through prudent use of available energy resources, a steady supply of commercial energy inputs at reasonable prices, and the development of production systems that will fully utilize all production resources. Commercial energy inputs on farms such as petroleum, irrigation water, chemical fertilizer, machinery, pesticides, and herbicides are indispensable parts of modern agriculture. For many developing countries, full supply of commercial energy inputs on farms is not possible due to many inherent factors, but a slight increase in the energy in-flow often results in a significant response in food production.

A complete mechanization of agriculture in Bangladesh under so many economical, social and political constraints is not realistic. But selective or partial mechanization programme is suitable in order to improve the food and fibre production under the present socio-economic conditions. Energy is one of the basic production resources for any sort of mechanization. No on-field reliable research data is yet available in Bangladesh to justify the introduction of either partial or full mechanization. However, some fragmented research results are available for partially mechanized cultivation of a particular crop such as the effect of irrigation frequencies on yield of a particular crop.

Since no systematic study on energy input-output relationship has been undertaken for a complete selective mechanized cultivation in the country, total assessment of energy use on the farm is lacking. An on-field study of energy input and output for both traditional and selected mechanized cultivation of the Boro crop has been performed in the Bangladesh Agricultural University Agronomy Farm in 1979 with the following objectives:

1) Study the suitability of selective mechanization over traditional practices.

2) Compare the yield of selective mechanized cultivation with that of traditional cultivation.

3) Study the energy input requirement on different stages of cultivation for both systesm.

4) Compare the energy input-output nature for both the systems of cultivation.

5) Suggest measures for improvement of traditional practices.

Solar energy at the rate of 1 %

Acknowledgements: The authors are grateful to Mr. A. Hannan Khan, Farm Superintendent, Bangladesh Agricultural University Farm for providing land for the study and his valuable suggestions during the experimentation. The assistance extended by Department and Farm staff are gratefully acknowledged.

of the total incident radiation is included in the calculation for both the systems.

Experimental Procedure

Two acres of agricultural land of mostly loamy soil with moderate moisture content was selected for this study. The area was divided into four equal-sized plots: two plots for traditional cultivation and two others for selective mechanized cultivation. Both traditional and selective mechanized cultivations were performed simultaneously to study the effect of practices on yield. The land preparation activities were started in April, 1979 with BR-3, high yeilding varieties of paddy. The implements used for traditional cultivation were country plough, ladder and other traditional equipments. The power sources in this system were bullock and human power. For the selective mechanized cultivation, the implements used were offset disc harrow, country plow for puddling, rotavator for finer clods, traditional ladder for levelling, and a Japanese weeder. The power sources for this system were tractor, bullock and human power. The operations

Table 1 Distribution of Energy Inputs, Traditional Farming Method

Operations	Traditional cultivation No. 1						Traditional cultivation No. 2					
	Animal		Human		Mechanical or chemical	Total	Animal		Human		Mechanical or chemical	Total
	Bullock -h	kcal	Man-h	kcal	kcal	kcal	Bullock -h	kcal	Man-h	kcal	kcal	kcal
Land preparation	72.6	5 778.04	36.31	1 161.97	–	6 940.01	77.00	5 902.32	38.50	1 234.02	–	7 136.34
Irrigation	–	–	6.5	208.35	4 808.25	5 016.60	–	–	5.5	192.30	4 808.25	5 000.55
Fertilizer	–	–	3.0	96.16	884.00	980.16	–	–	3.0	96.16	884.00	980.16
Insect & pest control	–	–	1.0	32.05	40.57	72.62	–	–	1.0	32.05	40.57	72.62
Inter-cultural operations	–	–	84.75	2 716.66	–	2 716.66	–	–	86.83	2 783.39	–	2 783.39
Harvesting & threshing	–	–	160	5 128.80	–	5 128.80	–	–	160	5 128.80	–	5 128.80
Total	72.63	5 778.04	291.56	9 343.99	5 732.82	20 854.85	77.00	5 902.32	294.83	9 466.72	5 732.82	21 101.86

Table 2 Distribution of Energy Inputs, Traditional Farming Method

Operations	Mechanized cultivation No. 1						Mechanized cultivation No. 2					
	Animal		Human		Mechanical or chemical	Total	Animal		Human		Mechanical or chemical	Total
	Bullock -h	kcal	Man-h	kcal	kcal	kcal	Bullick -h	kcal	Man-h	kcal	kcal	kcal
Land preparation	17.6	1 266.23	10.17	348.31	5 031.85	6 646.39	15.83	1 129.11	9.19	289.47	5 305.11	6 723.69
Irrigation	–	–	6.50	208.35	4 808.25	5 016.60	–	–	6.50	208.35	4 808.25	5 016.60
Fertilizer	–	–	3.00	96.16	884.00	980.16	–	–	2.00	64.11	884.00	948.11
Insect & pest control	–	–	1.00	32.05	40.57	72.62	–	–	1.00	32.05	40.57	72.62
Inter-cultural operations	–	–	84.65	2 713.45	–	2 713.45	–	–	73.83	2 366.69	–	2 366.69
Harvesting & threshing	–	–	192.00	6 154.56	–	6 154.56	–	–	192.00	6 154.56	–	6 154.56
Total	17.6	1 266.23	297.32	9 552.88	10 764.67	21 583.78	15.83	1 129.11	284.52	9 115.23	11 037.93	21 282.27

The calculations are based on 1) human power 0.05 hp/man, 2) Production energy of nitrogen fertilizer, 19 093 cal/kg. 3) Production energy of phosphate fertilizer, 3 341 cal/kg. 4) Production energy of potassium fertilizer, 2 148 cal/kg. 5) Production energy of pesticide 23 866 cal/kg. Energy inputs are calculated for 0.5 acre of land. Source: Kiamco and McMennamy, AMA, Vol. IX, No. 2, 1979, pp 12-13.

Table 3 Comparative energy output

Output Materials	TC_1		TC_2		MC_1		MC_2	
	Amount kg	Energy kcal	Amount kg	Energy kcal	Amount kg	Energy kcal	Amount kg	Energy kcal
Rice (14 % wb)	573.75	21 228.75	565.83	20 935.71	669.12	24 757.44	656.51	24 290.87
Straw (dry)	786.10	2 672.74	704.93	2 396.76	859.27	2 921.52	810.47	2 755.60
Rice hull & chaff (dry)	283.66	964.44	276.09	938.70	338.84	1 152.05	330.07	1 122.24
Total	1 643.51	24 865.93	1 546.85	24 271.17	1 867.23	28 831.01	1 797.05	28 168.71

Food energy content of rice: 37 kcal/kg. Energy content of rice hull and chaff, based on heating value as 3.4 kcal/kg. Energy outputs are calculated for 0.5 acre of land. Source: Kiamco and McMennamy, AMA, Vol. IX, No. 2, 1979, pp 12-13.

for puddling, fertilizing, irrigation and application of insecticides were kept uniform for both systems of cultivation. The total energy inputs were calculated in kilocalories (**Tables 1** and 2) for both systems. The total energy output were recorded in kilocalories from the yield of rice, straw, husk, residues, etc (**Table 3**). Quantities of irrigation water, fertilizers and insecticides were kept constant for all the plots.

Results and Discussion

From the results presented in **Tables 1** and 2, it appears that selective mechanized cultivation uses only a vary small amount of higher energy (less than 5 % in this case) than the traditional system (**Fig. 1**). On the other hand energy output in mechanized system is 25 % higher than traditional systems (**Fig. 2**). It is also interesting to note from **Fig. 1** that the energy inputs in land preparation for mechanized cultivation (MC) were less than traditional cultivation (TC). Higher yields of paddy mainly contributed for the increased energy output in mechanized cultivation. The energy contribution by paddy residues was calculated at its dry condition. Immediately before harvest a sudden attack of insect pests caused a significant amount of loss in output.

Conclusion and Suggestions

On the basis of the study, the following conclusions may be drawn:

1) In selective mechanization demands for energy inputs are not so high and within a reasonable limit.

2) A small increase in energy input results in a significant response in yield.

3) Considering all the factors of production, the mixed mechanized cultivation systems seem suitable for increasing the agricultural production under Bangladesh condition.

Higher yield from selective mechanized cultivation will generate enough capital for small farmers to supply them with increased energy inputs, through power tillers and tractors. Significant increase in output can be obtained through small energy inputs by farmers in various farm operations. It can be recommended from this study that selective mechanization of some operations, particularly that of land preparation activities, be practised without delay through government help to attain self sufficiency in food production.

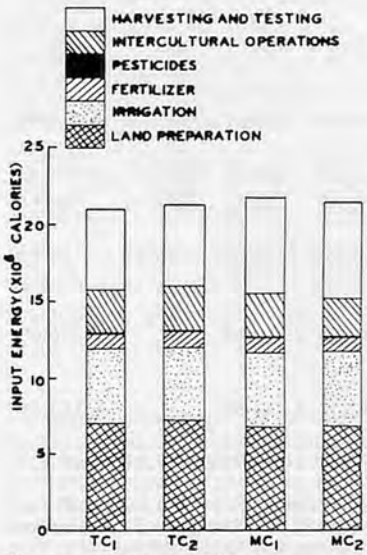

Fig. 1 Distribution of input energy

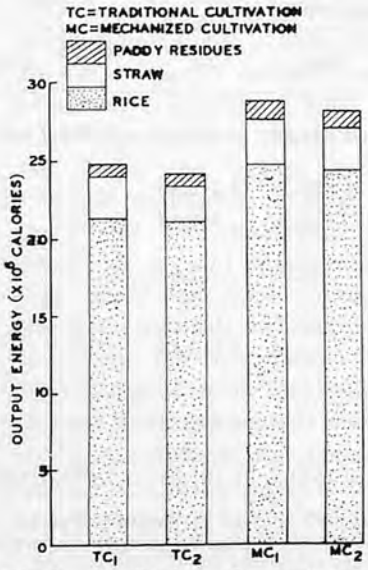

Fig. 2 Distribution of output energy

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Performance of Tillage Implement Combinations

by

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Abstract

Draft, field speed and work performance for plow-combinations of mouldboard plow + plow packer, mouldboard plow + subsurface packer, and mouldboard plow + spring-tooth harrow and a mouldboard plow separately were measured on chernozem (Black soil). A D-4k, 90 hp, diesel tractor was used to power these combinations and the mouldboard plow. The results indicate that different combinations have varying effect on soil preparation and workability.

Introduction

Repeated passes of tillage machines for preparing seedbed can be very much damaging to soil structure and porosity. Traditionally, the seedbed preparation involves a chain of field operations of plowing, harrowing, disking, soil packing and so on which eventually cause severe soil compaction. Tractor wheels may pass over almost 100 % of the soil surface, or, repeatedly over a field during the preparation of seedbed. Twenty percent crop yield in addition to saving of cost and time might be expected from the land without wheel traffic compared to land which received normal treatment (3).

Considerable work has been done in the past (1, 2, 8, 10) to develop suitable tillage combinations for growing different crops. This interest had grown out of the concern for soil structural deterioration, high tillage costs, delayed seeding and yield reductions as a result of excessive tillage.

Farming now is a business rather than a way of life. An efficient management is the key to staying in business as never before. Operations that are wasteful of time and destructive to soil can be eliminated. The farmers become increasingly aware of the need for minimum tillage and to minimize the use of machines from the view point of both soil conservation and economics of crop production. Field operations can be achieved with various implement combinations which result in economic use of energy and time.

The present study was undertaken to design and test tillage-combinations of mounted farm machines attached to mouldboard plow and the plow separately to produce suitable seedbed in one pass without undue disturbance to the soil and to improve the physical properties providing congenial root environment to the plants. The properties of a suitable seedbed must ensure uniform soil loosening and crumbling ensuring proper land grading with no tracks visible (4). The designed tillage combinations were in tandem with the mouldboard plow and mounted. The

Table 1 Implement specification

Implement	Weight kg	Width m	Depth cm	Design features
Mouldboard plow	450	1.05	23	3-bottom width 0.35 m each.
Mouldboard plow + Packer	685	1.05	24	3-section with 3-rollers in each with v-shaped rims of 22 cm, diam.
Mouldboard plow + Subsurface packer	733	1.05	23	3-section with 3 v-shaped wheels of 60 cm diam.
Mouldboard plow + Spring-tooth harrow	577	1.05	24	3-section with 11 spring-tooth in 2-rows

implement combinations were separately compared with the mouldboard plow operation to evaluate the work quality performance and draft requirements.

Farm Machines

The implement combinations used for once-over seedbed prepration are presented in **Table 1**. A three-bottom, 35 cm, mounted mouldboard plow was used with three seedbed refining tillage implement combinations for evaluating the power requirement and work performance. All the three types of implements for plow-combination were designed and constructed at the University of Agricultural Sciences, Godollo.

The mouldboard plow and its combinations were powered by a D-4k, 90 hp, diesel tractor. The design features of the combinations were based on the criteria that the implement combinations were easily accessible, had improved functional performance and efficiency, required single pass operation to prepare seedbed, had the provision of testing more tillage combinations, and which created a level, uniform and trash free seedbed.

The implement mounting tool bar made possible the easy and quick attachment and detachment of the plow combinations which assured smooth operation, working depth and pressure adjustments. The implements attached to the plow are shown in **Photos 1**, 2 and 3.

Instruments

Draft was determined by transducers and mounting the plow and its combinations on the tubular frame. The frame was strong enough for measuring forces up to 4 000 kg. The Honeywell visicorder 1706 and oscillograph along with other instruments of recording van plotted the forces. The same data recorded during the operation were fed to the computer.

The field speed was determined for a distance of 100 m with stop watch for each observation. The depth of work was determined from the bottom of the furrow to the surface level of the soil. The work width was measured from the furrow wall to the total tilled area. The condition of the furrow and the maximum lateral soil transporting effect were also determined. All the above measurements were made by a meter scale at 0.5 cm accuracy. The soil inversion angle was recorded by using the sextant, while, the soil loosening effect of plow and plow-combinations was determined by relief meter (5, 6, 7) before and after each operation.

The soil crumbling effect was determined by collecting the furrow slice from a piece of plot 40 x 30 cm after each operation. The crumb size distribution was determined by using different sized sieves (9). The clods so measured were in the range of 10-20 cm, 5-10 cm, 1-5 cm and less than 0.5 cm. The relative distribution of all clod sizes was recorded in percent to the total soil sieved for each operation.

Photo 1 Plow-packer combination with moldboard plow for once-over seedbed preparation

Photo 2 Subsurface-packer combination with moldboard plow for once-over seedbed preparation

Photo 3 Spring-tooth harrow combination with moldboard plow for once-over seedbed preparation

Soil friability was calculated for the clod sizes below 5 cm. A simple formula assuming 82.5 % efficiency was used for calculating the field capacity of the implement combinations.

The soil worked by the tillage treatments was calculated by multiplying the field capacity and depth of operation of the machines.

Chernozem soil had mechanical components of 71.5 % sand, 11.3 % silt and 17.2 % clay with 9 % soil moisture and a pH value of 5.4. The mean soil strength recorded

by penetrometer was 2.68 kg/cm^2.

The barley crop was grown during the preceding season and the land was left in fairly smooth condition. Ground cover consisted of previous crop stubbles of 12 to 18 cm long estimated at 5 250 kg/ha.

All the observations of draft requirement and work performance of plow and plow combinations at three different speeds were taken in accordance with the standards of MGI 2-003 and 2-004 (Farm Machinery Research Institute, Godollo) in an area of 24 ha. Ten replications were taken in all cases for each speed. The observations were taken only after the tractor reached to operating speed with the implements functioning properly.

Table 2 Field capacity and power requirement of mouldboard plow and its combinations

Tillage practices	Field speed km/h	Depth cm	Width cm	Field capacity ha/h	Specific draft kg/cm^2
Speed-I					
Mouldboard plow	4.44	23.0	108.3	0.397	0.35
Mouldboard plow + Packer	4.24	25.5	105.4	0.369	0.41
Mouldboard plow + Subsurface packer	4.11	22.7	108.6	0.368	0.43
Mouldboard plow + Spring-tooth harrow	4.06	23.7	108.8	0.364	0.46
Speed-II					
Mouldboard plow	5.96	24.2	111.3	0.547	0.37
Mouldboard plow + Packer	5.80	22.9	108.3	0.518	0.50
Mouldboard plow + Subsurface packer	5.80	22.3	110.1	0.527	0.47
Mouldboard plow + Spring-tooth harrow	5.85	23.6	109.0	0.526	0.51
Speed-III					
Mouldboard plow	8.65	24.1	114.1	0.814	0.41
Mouldboard plow + Packer	8.18	22.3	110.1	0.743	0.57
Mouldboard plow + Subsurface packer	8.37	22.0	110.4	0.762	0.58
Mouldboard plow + Spring-tooth harrow	8.63	23.6	108.4	0.772	0.59

Results and Discussion

It is clear from **Table 2** that with the change in speed, the draft force changed. Amongst the once-over operations the lowest draft recorded was for the plow-packer combination.

Table 3 shows the loosening, inversion, transport and volume of soil worked by the plow and once-over tillage operations. The soil loosening effect under the plow was highest but the plots were left unpacked and cloddy as xompared to once-over tillage treatments.

The soil friability is reported in **Table 4**. For all three speeds, the highest friability was obtained by tilling the soil with once-over operation of the plow-packer combination which pulverized and optimally packed the soil leaving the surface in good condition.

Table 3 Soil loosening, soil inversion, soil side transport and volume of soil worked by plow and its combinations

Tillage treatments	Soil loosening %	Soil inversion angle degrees	Soil side transport cm	Soil worked cu. m /h
Speed-I				
Mouldboard plow	34.76	51.4	163.5	913.10
Mouldboard plow + Packer	31.45	51.0	168.1	940.95
Mouldboard plow + Subsurface packer	25.90	51.7	169.4	835.36
Mouldboard plow + Spring-tooth harrow	31.30	51.6	180.5	862.68
Speed-II				
Mouldboard plow	43.68	50.1	172.8	1 323.74
Mouldboard plow + Packer	38.18	52.4	194.4	1 186.22
Mouldboard plow + Subsurface packer	27.40	53.4	189.5	1 175.21
Mouldboard plow + Spring-tooth harrow	44.30	53.7	193.5	1 241.36
Speed-III				
Mouldboard plow	70.50	50.5	202.5	1 961.74
Mouldboard plow + Packer	43.49	52.7	205.5	1 656.89
Mouldboard plow + Subsurface packer	39.80	52.1	200.7	1 676.40
Mouldboard plow + Spring-tooth harrow	68.30	51.8	184.8	1 821.92

Conclusions

The research results are summarized in **Tables 2, 3** and **4** indicating that once-over tillage operations improved the soil properties such as soil friability and loosening with optimum compaction. With reference to soil characteristics, the once-over tillage operation by combining the packer with the mouldboard plow was considered as a suitable once-over tillage operation. It is suggested that the possibility of designing the once-over tillage combinations for large-sized plows may be designed and tested to popularize the use of time and money saving once-over operations.

Table 4 Soil crumbling effect by plow and its combinations

Tillage combinations	Soil crumbles (%)					Soil crumbling (%)
	10–20 cm	5–10 cm	1–5 cm	0.5–1 cm	< 0.5 cm	
Speed-I						
Mouldboard plow	29.8	6.80	18.20	13.60	31.60	63.40
Mouldboard plow + Pakcer	–	10.29	26.96	19.60	43.15	89.71
Mouldboard plow + Subsurface packer	6.15	24.10	25.11	16.11	28.53	77.26
Mouldboard plow + Spring-tooth harrow	–	13.24	23.31	26.65	36.80	85.76
Speed-II						
Mouldboard plow	15.8	12.85	21.63	19.61	30.11	71.35
Mouldboard plow + Packer	–	19.79	27.34	17.99	34.88	80.21
Mouldboard plow + Subsurface packer	6.37	17.37	24.15	17.79	34.32	69.75
Mouldboard plow + Spring-tooth harrow	–	29.62	28.85	18.81	22.72	70.38
Speed-III						
Mouldboard plow	23.17	13.98	29.15	14.32	19.38	72.85
Mouldboard plow + Packer	–	17.22	31.94	16.38	34.46	75.78
Mouldboard plow + Subsurface packer	9.71	26.43	23.34	15.41	25.11	63.86
Mouldboard plow + Spring-tooth harrow	17.91	18.37	18.12	18.12	27.48	65.44

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Simulation of Paddy Drying under Tropical Conditions

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Abstract

A series of thin-layer drying tests were performed in a controlled temperature laboratory-type dryer within the temperature and relative humidity ranging from 26.6 to 43.3°C and 25 to 95%, respectively. A second order drying equation was fitted into experimental data to represent the drying behavior. The parameters of the developed thin-layer drying equation were related to the air temperature, relative humidity and the initial moisture content. A simulation model was developed to predict the drying in a deep bed of paddy consisting of a number of thin layers stacked upon each other. The experimental results from the multilayer drying tests were compared with the simulated results based on the model. The predicted drying rates were higher than the experimantal drying rates. The experimentally observed and the predicted air temperatures in between the layers of the deep bed differed markedly.

Introduction

Drying of paddy is becoming more important with the increasing demand for food and the increase in production rate. Paddy is dried mostly in the traditional way on sunfloors in Southeast Asia. Because of inappropriate drying facilities a considerable percentage of produced food grains are being damaged every year. Except Japan, in most parts of the Southeast Asia, the mechanical or artificial methods of drying paddy are not common. This is mainly due to the inappropriate drying technology for the tropical conditions and comparatively high cost involved with mechanical methods of drying. Therefore, the reduction of drying cost is very important for the development of appropriate mechanical drying.

Drying of grains with unheated air or naturally heated air and the storage of grains at high moisture content with naturally heated minimum possible air circulation through the grain storage are the possible ways of cost reduction in drying operations. Before implementing these methods it is important to optimize the system for maximum allowable grain moisture content, depth of grain in the storage and minimum air flow rate based on the air temperature and relative humidity. With this in view, a research attempt has been performed on paddy drying in the Agricultural and Food Engineering Division, Asian Institute of Technology, Bangkok. The purpose of this study is to investigate the drying characteristics of paddy at various drying air temperatures and relative humidity, initial moisture content of grain, air flow rate and for various depth of grain layers. The ultimate aim was to develop a simulation model to optimize the natural air-circulated paddy drying system.

Simulation is a method whereby the performance of systems or processes can be predicted through the use of a mathematical model. With this method, answers can be obtained that would be difficult if not impossible to solve experimentally. However, it is not so easy to obtain deep-bed drying results experimentally. Therefore, the usual practice is to predict deep bed drying results by developing a simulation model based on thin layer drying equation. In this study the basic approach used to describe the continuous drying process is to divide the system into many small processes and simulate them by consecutively calculating the changes that occur during the short increment of time with the deep bed consisting of a number of thin layers.

In deep bed, drying air evaporates moisture from the grain and carries it away. As the air absorbs moisture its temperature decreases and its ability to pick up more moisture decreases (Thompson,

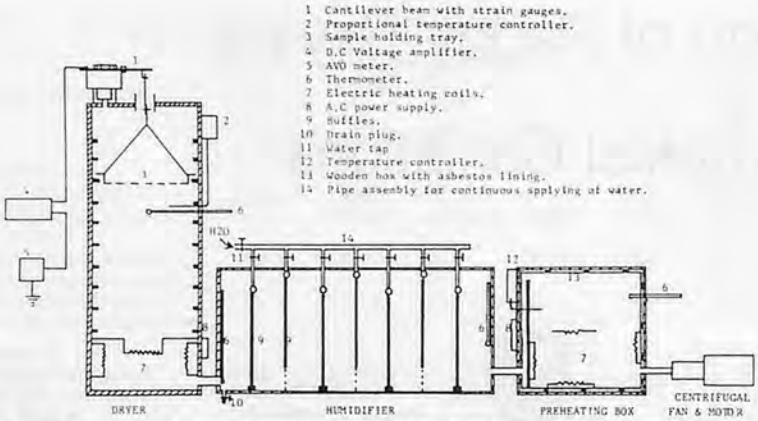

Fig. 1 Schematic diagram of vertical fixed bed dryer with humidifier and preheating box

1970). In an attempt to reduce the moisture difference across the grain column, Thompson proposed a grain dryer in which the flow direction through grain column was reversed midway through the drying section. Paulsen and Thompson (1973) developed a mathematical drying model from Thompson's cross flow deep bed drying model to simulate this reversal of air flow in a continuous cross flow dryer. This model introduced a reversal air flow stage between the initial drying and cooling stage, which simulated the drying of grain with air entering from the opposite side of the grain column. Schroeder and Peart (1967) used dynamic programming to determine optimal air flow distribution patterns to maximize the rate of moisture removal from grain with a given air flow. The results indicated that higher air flow rates were required by the wettest grain, near the grain inlet.

Boyce (1965) described the general procedure to calculate the changes in air temperature and grain moisture content in deep beds and their predicted results were reasonably well. Thompson et al (1968) developed a mathematical simulation model for drying corn in deep beds. They used a thin layer drying equation to calculate moisture changes in the layers based on the following assumptions: 1) Initial grain temperature is equal to the surrounding air temperature; 2) Drying takes place at an arbitrary equilibrium temperature which would fall between the initial and final air temperatures. They did not consider the evaporative cooling in the calculation of equilibrium temperature. Flood and Sabbah (1972) also used a thin layer drying equation to simulate the natural air drying of corn.

Simulation Model of Drying

A deep bed simulation model was developed following the basic approach by Thompson et al (1968). Drying air at temperature T °C and absolute humidity H was passed through a thin layer of paddy (M % moisture content and G°C temperature) for a drying time interval Δt. During this time the interval ΔM % moisture content was evaporated from the paddy into the air, increasing its absolute humidity to $H + \Delta H$ during which the temperature of the drying air decreased by ΔT °C in proportion to the temperature increase the paddy by ΔG°C and evaporative cooling accompanying the moisture evaporation. The amount of drying performed would be calculated by a thin layer drying equation with constants depending on the air temperature, relative humidity and initial moisture content. Complete heat balances were used to calculate the final air temperature and grain temperature consistent with evaporative cooling accompanying the moisture evaporation. The model considered the changes that occur in the paddy and drying as shown in **Fig. 2A**.

To simulate paddy drying characteristics several modifications were made to the Thompson's deep bed drying model. The following information in required for the modifications: a thin layer drying equation for paddy; an equation for the equilibrium moisture content of paddy; the specific heat equation of paddy; equation of bulk density of paddy and an equation for the latent heat of vaporization of moisture of paddy.

Most of the basic thin layer drying equations for grains orginate from the equation reported by Hukill (1947):

$$dM/dt = -K(M - M_e)$$

Where, M = Moisture content of the kernel, % (DB); M_e = equilibrium moisture content, % (DB);

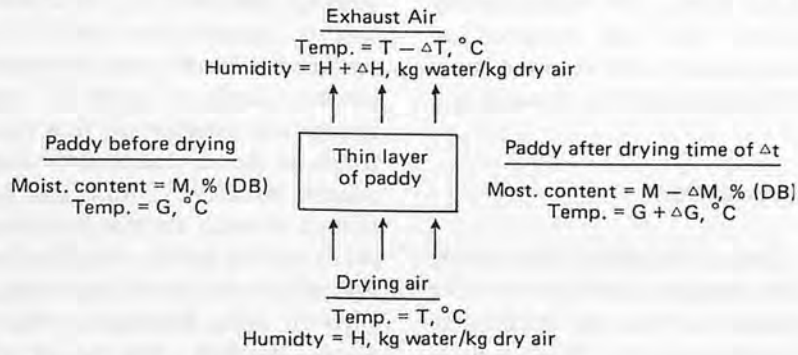

Fig. 2A Schematic diagram of basic simulation approach

t = drying time, hr; k = drying constant.

This equation states that the rate of moisture removal is proportional to the amount of moisture available to be removed.

Thompson et al (1968) found that the following second order equation involving time and natural logarithm of moisture ratio adequately represented drying characteristics of shelled corn:

$$t = A\,Ln(MR) + B[Ln(MR)]^2$$

The coefficients A and B are described as functions of drying air temperature.

Thin Layer Drying Equation

A series of thin layer drying tests were performed in a laboratory-type electrically heated air dryer, at various drying air temperature, relative humidity and initial moisture content. About 1 000 g paddy sample was spread in a 30 cm square screen-bottomed tray placed inside an insulated drying chamber. The tray was suspended by a cantilever beam which was mounted on a strain gage bridge circuit. Therefore, the grain sample was measured without disturbing them throughout the drying period. Drying air temperature ranging from 26.6 to 43.3°C and relative humidity ranging from 25 to 95% were investigated. The drying air temperature and relative humidity were maintained constant throughout the drying period by means of an air preheater and humidifier units. The air flow rate was 17 to 119m^3/h and the initial moisture content of paddy was 23 to 45% (DB). The higher initial moisture content was obtained by remoistening the paddy.

For the fully exposed thin layer of paddy drying no appreciable difference in drying rates could be detected when air rate was increased from 17 to 119 m^3/h, but reasonable difference in drying rate was observed for different initial moisture content of paddy.

Multiple regression analysis was used to determine the first and second order drying equation. The second order logarithmic drying equation fitted adequately with all the drying data with correlation coefficient of 0.98 or better in all cases. The coefficients for the second order drying equation, A was the function of drying air temperature and relative humidity while B was the function of drying air temperature and inital moisture content. Summarized thin layer equation which best represent the drying characteristics of paddy was as follows:

$$t = A\,Ln(MR) + B[Ln(MR)]^2$$

$$\text{where, } A = a_1 + a_2\frac{1}{T} + a_3\,(T^2/RH) + a_4/[\log\{\log(T^{2.3}).\log(RH^{2.3})\}.\log(RH^3)]$$

$$Log(B) = b_1 + b_2/M_i + b_3\log(T)/T$$

$a_1 = -1.3404$
$a_2 = -3\,733.5544$
$a_3 = -0.0399$
$a_4 = 268.842$
$b_1 = -3.3892$
$b_2 = 53.4392$
$b_3 = 124.1254$

$MR = (M - M_e)/(M_i - M_e)$ = moisture ratio

M = moisture content of paddy, % (DB)
M_i = initial moisture content of paddy, % (DB)
M_e = equilibrium moisture content, % (DB)
T = drying air temperature, °C
RH = relative humidity, %
t = drying time, hr

Other Equations Used in Simulation Model

An equation was needed to calculate the equilibrium moisture content of paddy at various relative humidities and temperatures. The equation derived by Henderson (1952) exhibits a very small response to change in air temperature. Pfost et al (1976) modified Henderson's equilibrium moisture equation and the constants for paddy to better represent the effect of temperature on the equilibrium moisture contents at various relative humidities and temperatures. The temperature term was used in degrees C and a constant "b" was added to the term. The paddy following equation and constants based on experimental paddy equilibrium moisture data was determined:

$$1 - RH = \exp[-C(T+b)M_e^n]$$

Where, Rh = relative humidity, decimal; c = 1.9187 x 10^{-5}; n = 2.4451; b = 51.16

The latent heat of vaporization was needed in heat balance equation. The following equation of latent heat of vaoprization of paddy was determined by Duggal (1978):

$$L = k\,(1\,075.8966 - 0.56983\,T)$$

$$k = 1.315 - 0.0156\,M + 0.681 \times 10^{-4}M^2 + 0.3383 \times 10^{-5}M^3$$

where, L = latent heat of paddy, J/kg

Thus, the latent heat of vaporization of paddy above that requried for free water is

$$L_v = (1\,075.8966 - 0.56983\,T)(k - 1)$$

The specific heat of paddy was needed in heat balance equation. For heat balance equation specific heat of paddy was converted to J/kg of dry air/°C. Wratten and Pool (1969) reported the following equation for determing the specific heat of paddy:

$$Sp = 0.22008 + 0.01301\,M_W$$

$$C = (0.22008 + 0.01301\,M_W)/R$$

where, Sp = specific heat of paddy, J/kg of paddy °C, C = specific heat of paddy, J/kg of air °C, M_W = moisture content of paddy, % (wb), R = air to grain ratio, kg of air/kg of grain.

The bulk density of paddy was also essential for determining the

bulk volume of paddy at different moisture content. The equation of bulk density for paddy was determined by Wratten and Pool (1969):

Bulk density, BD = 31.195 + 0.52 M_W

The relative humidity of air was determined by the following equation:

RH = Patm H/[(H + 0.622) (Exp 54.63 – 12 301.69/Tabs – 5.17 Ln Tabs)]

where, Patm = atmospheric pressure, kg/m^2; Tabs = absolute temperature, °K; H = absolute humidity, kg of water/kg of dry air

Using these components a computer simulation model was developed for paddy following the Thompson's deep-bed simulation model for corn drying. The flow chart of simulation model is shown in **Fig. 2B** (See Thompson et al (1968) for more detailed information on the deep-bed drying model).

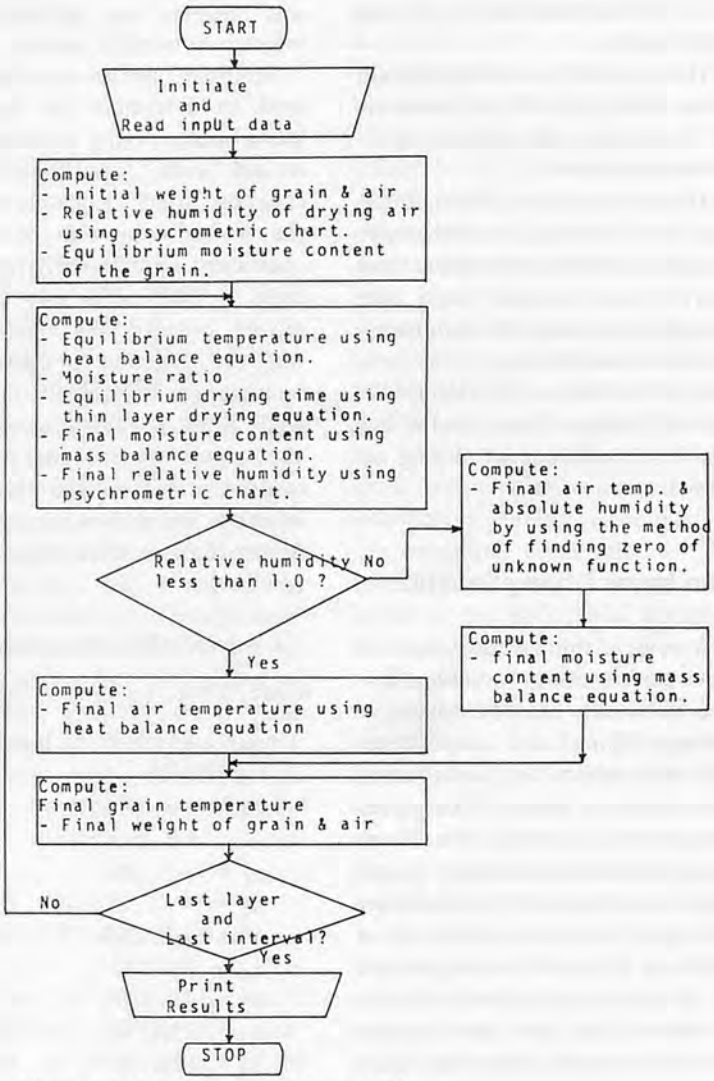

Fig. 2B Flow chart of deep bed simulation model

Multilayer Drying Tests and Simulated Results

Multilayer drying tests were performed in a vertical fixed bed dryer for the following different drying conditions:

	Drying air temperature	Relative humidity	Air flow rate
1	43.3°C	55 %	34 m^3/h
2	39.5°C	60 %	34 m^3/h
3	60.0°C	10 %	34 m^3/h

Eight trays were loaded with 1 200 g fresh paddy of initial moisture content 26 % (DB), and stacked upon each other into a vertical insulated dryer. The moisture loss from each tray was determined periodically, by picking up 15 to 20 g of sample from each tray, and determining the moisture contnet of the samples by air oven method. The air temperatures in between the layers were also recorded by mercury bulb thermometer as the drying progressed. Air leaks by the sides of the tray were sealed.

The computed results based on the simulation model were compared with the experimental results obtained from the multilayer drying tests. The predicted moisture removal rates were higher than that of experimentally observed (**Figs. 3** and **4**). The air temperature in between the layers predicted by the simulation model were also compared against air temperatures observed in multilayer drying tests, which differed markedly (**Figs 5** and **6**). This possibly led to the higher drying rates computed by simulation model.

Conclusions and Recommendations

The plots of moisture content versus drying time (**Figs. 3** and **4**) indicate that when the average grain moisture content reaches 16 % (DB), part of the grains remains underdried and part is overdried. However, due to the high relative humidity and low temperature of drying air the equilibrium moisture content of the grain would not be very low due to which the level of overdrying would not be much below than the desired final moisture content. Only a longer drying time would be required to reach the desired

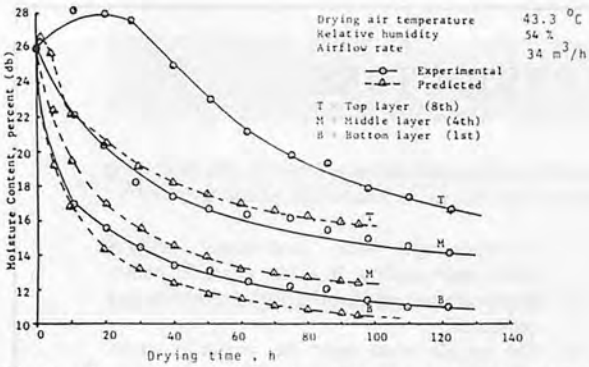

Fig. 3 Comparison of experimental and predicted moisture removal rate

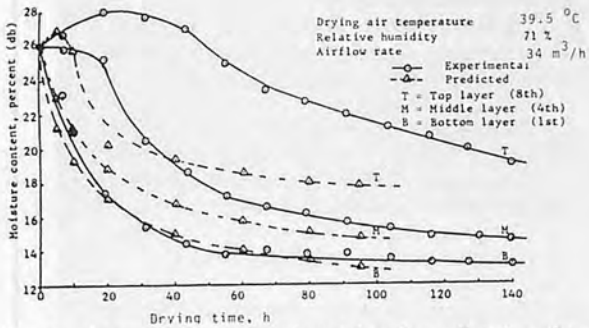

Fig. 4 Comparison of experimental and predicted moisture removal rate

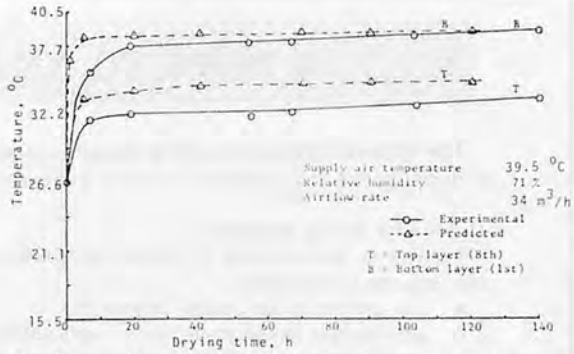

Fig. 5 Comparison of experimental and predicted drying air temperature

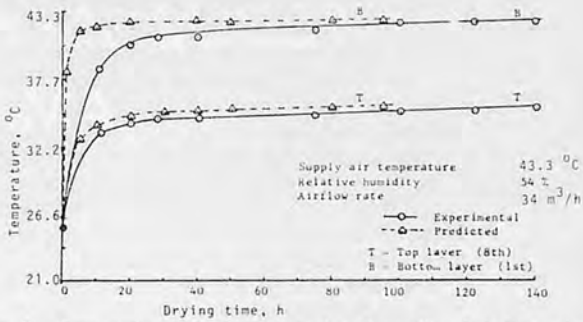

Fig. 6 Comparison of experimental and predicted drying air temperature

moisture content level of the underdried grain.

Predicted and experimental results for multilayer drying tests were compared. The predicted drying rates were faster than the experimentally observed drying rates. The air temperatures in between the layers predicted by the simulation model were higher than the experimentally recorded temperatures. This has obviously resulted in the higher drying rates.

Future research may be recommended to verify predicted drying air temperature in the simulation model. The assumption of final absolute humidity in the simulation model for the computation of final air temperature using the final heat balance equation, always overestimates the final absolute humidity than the actual moisture in the air.

The equations for the coefficients A and B of the second order drying equation may further be verified for low temperature and high humidity drying of paddy.

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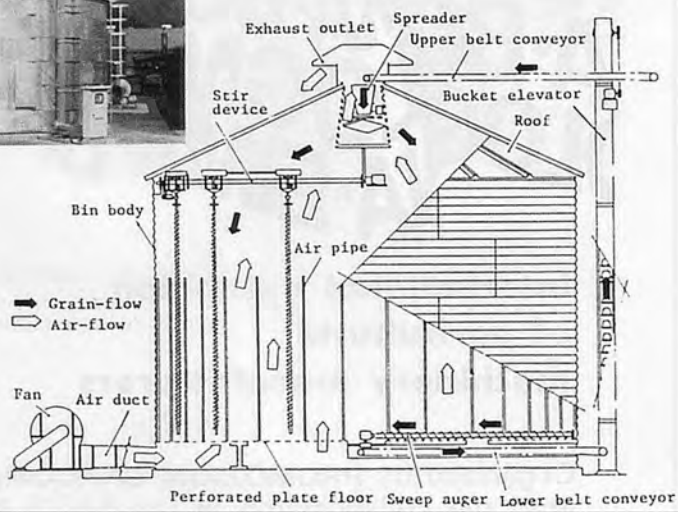

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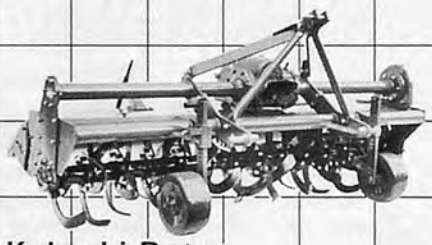

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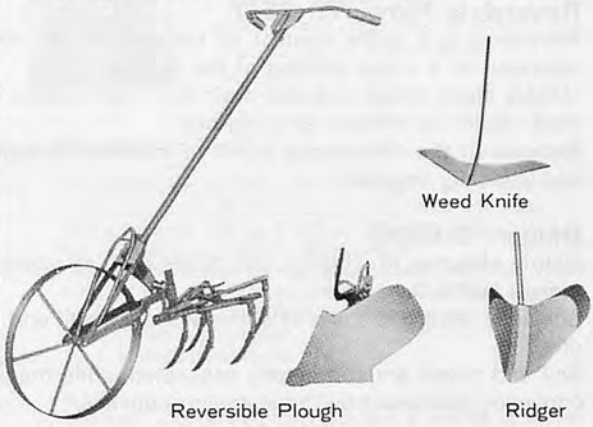

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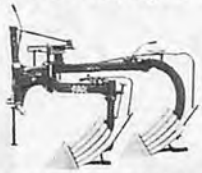

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Aspects of Cardamom Drying in Nepal

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Nepal

Introduction

The vast majority of the hill population in Nepal is engaged in subsistence farming. Traditionally, farmers have produced grains mainly, plus a few vegetables primarily for their own household consumption. Nearby forests have provided fuel and fodder in addition to a variety of wild tubers, fruits, spices and medicinal herbs. Some of these farm and forest products may be brought to local markets where they are bartered or sold to augment the farm family income (**Table 1**). Cardamom (*Amomum subulatum*, in Nepali, "alainchi") is one such product of marginal lands. Cardamom is one of the major cash crops of the eastern hill districts that has been cultivated and traded in Nepal for many decades. The cardamom seeds, used whole or powdered, are enjoyed locally as a flavoring for sauces, curries and sweetmeats and as a masticatory. In addition, Nepali cardamom, also known as "large" or "false" cardamom and enters the international spice trade largely as a substitute for "true" cardamom (*Elettaria cardamomum*, "sukmel"). Historically, the bulk of the Nepalese cardamom has been exported to India. Until very recently most of the harvest has been sent to Singapore for further grading before worldwide distribution. Final destinations include Hong Kong, Pakistan and the Middle East.

Table 1 Some features of hill agriculture, Nepal

Total geographical area	: 141 000 sq km of which 80 % is considered as hill area.
Total population	: 12.5 million of which 66 % are living in the hill area.
Elevation	: Hill area from 750 to 4 000 m. Regions above 4 000 m are of limited agricultural significance.
Rainfall	: From 2 000 mm in the east to less than 1 000 mm in the west. Large fluctuations (minimum about 200 mm and maximum 5 000 mm) occur, however, are associated mainly with topography.
Agricultural employment	: 93 % of total labor force.
Share of agriculture in gross domestic product	: 67 %.
Per capita income	: National average US$ 110-120, but it can be as low as US$ 24 in the hill areas.
Population density of cultivated land	Mountain region: 1 174/km² : Hill region : 1 002/km² Plains (Terai) : 336/km²
Farm size	: 82 % of the farms in the hills are less than one bigha (0.67 ha).

In 1970, total cardamom production in Nepal amounted only to about 400 tons. An increase in demand and subsequent increase in price has encouraged a growth in production, estimated to be almost 700 tons in 1979. This increase in demand for "large" cardamom has been the result of shortages of the preferred "true" cardamom in recent years, probably only a temporary phenomenon. Nevertheless, in light of the improved market conditions and good export potential, the Nepali government Ministry of Agriculture decided that cardamom would be a suitable crop for promotion and development in the hill areas. Thus, in 1975, the government established a Cardamom Research Farm at Phikkal in the far eastern district of Ilam.

Cardamom Production

A herbaceous perennial of the Zingiberaceae family, cardamom grows in Nepal's eastern hill region between the altitudes of 700 and 2 000 m. As a moisture-loving plant, it thrives in the damp, but well-drained soils of the mountain ravines. The species is intolerant of direct sunlight hence, does best under light shade or on north-facing slopes. Propagated vegetatively, cardamom begins producing fruit in its third year, reaching maximum production (about 400 kg of dried cardamom per ha) by the 7th year. Undemanding in its fertility requirements, cardamom does not compete with any other crop for land area or labor. Where grown under a tree crop, most commonly, alder (Alnus nepalensis, "utis"), carda-

* A.G. Rijk was assigned to the UNDP/FAO-assisted Hill Agriculture Development Project from January 1977 through March 1979. Affiliated with the Research Centre for Applied Science and Technology in Kathmandu, D.G. Donovan has been investigating the utilization of wood fuel in small-scale industry and agricultural processing in Nepal since March 1979.

Fig. 1 Gardamom planted under alder in eastern Nepal

Fig. 2 Traditional "bhatti" dryer

mom can be an effective agent of soil stabilization, an important consideration in steep hill areas (Fig. 1).

From mid-February through mid-March, the cardamom plant flowers and produces a large almond-size fruit containing a sweet pulp and some 40 to 50 camphorous seeds. The fruit matures during the humid summer monsoon period, and is harvested in August and September. Freshly picked cardamom must be dried immediately after harvesting to avoid deterioration through mold growth. Although a portion of the cardamom crop is sun-dried in the open air, the bulk of the harvest, and especially that from the misty hills of Ilam district, is dried over open wood fires.

Small producers may hang their crop to dry over the household cooking fire, but most of the harvest is dried in simple dryers of mud and stone. Traditional drying methods use a substantial amount of wood fuel and often produce a product of rather poor quality. A conservative estimate of total wood fuel consumption by cardamom processors would be roughly 2 800 to 8 400 t of firewood annually, equivalent to the fuel needs of some 4 000 to 14 000 villagers.

Traditional Drying Practices

The commonly used cardamom batch dryer, locally known as a "bhatti", is a square or rectangular structure (roughly 225 cm by 245 cm) about 170 cm high (Fig. 2). Its stone walls, mortared and plastered with mud, are approximately 25 cm thick. On one wall is an opening, about 60 cm by 80 cm to permit the feeding of firewood. The dryer is protected from the rain by a thatch roof standing some 20 cm above the top of the stone walls. Cardamom fruits are spread in a layer of about 20 cm thick on a loosely woven bamboo mat which is placed some 150 cm above the fire. The heated air and smoke from the fire then must pass through this bamboo screen, thus heating and drying its cardamom contents. As a result of placement directly over the fire, heating is often very rapid and uneven and, consequently, much of the fruit becomes scorched and split. Moreover, it acquires a smoky odor and flavor which reduces the product's quality and market value.

Estimates of firewood consumption for cardamom drying varies considerably, from one to three or more kg of wood/kg of wet cardamom. Factors such as wood moisture content, form and species of wood used, distance from the drying screen to the fire, thickness of the layer of cardamom fruit in the dryer and the attentiveness of the operator would all affect drying time and the quantity of fuel used. Although workers at the government Cardamom Reserach Farm professed to use firewood which had been collected some six months before the harvest and drying period, most farmers burn wet, green wood gathered just at the time it is needed Currently, the fuel used in cardamom drying is collected freely from the farmers own land or adjacent forests by farm workers or by hired labor. Consequently, lower fuel consumption is viewed in terms of labor savings and therefore of marginal interest given the present very low wage rates in rural Nepal.

People living in the hill region of Nepal are almost wholly dependent on firewood for cooking and heating purposes. Commercial enterprises, such as tea houses and inns, and small-scale rural industry, such as bakeries, and blacksmiths and brickworks, also use wood fuel. The recent extension of tea plantation in the cardamom producing areas portend very heavy demands for firewood in this region in the not too distant future. As the firewood demands of the growing population and small-scale industry increase, the farmer will find that his fuelwood will fetch an attractive price in the local bazaar. Then the consumption of firewood for the cardamom dryer will have a cost beyond that of the wages of collection. Foresters working in the community forestry project in Ilam district report recent requests from local farmers for suggestions on how to make their cardamom dryers more fuel efficient.

Development of New Cardamom Dryers

Early in 1977, the farm manager of the government Cardamom Research Farm at Phikkal requested the assistance of the Agricultural Engineering Division (AED) of the Department of Agriculture and the UNDP/FAO Hill Agricultural Development (HADP) in the development of a better cardamom dryer. During the previous year the government's Food Research Division (FRD) had developed a tray-type batch dryer with a firebox constructued of a single oildrum

plus a chimney. The cardamom fruits are dried in wire mesh trays (two stacks of seven trays each) positioned directly above the metal firebox; two dryers of this design were constructed in eastern Nepal.

In their attempts to develop an improved dryer, the AED/HADP engineers focused on increasing dryer capacity and lowering construction costs. Two models, one (Type A) a modification of the FRD design and the other (Type B) a modification of the local "bhatti" dryer, were constructed.

Type A – This tray-type batch dryer uses two oildrums, one as a firebox and the other as a heat exchange unit (**Figs. 3A, 3B**). Additional modifications on the FRD design included:

- ventilation openings in the front wall at either side of the firebox opening, rather than in the side walls
- the dryer was positioned with its firebox opening facing the prevailing wind direction (east) to improve natural ventilation
- two stacks of five trays (each 8 cm deep) instead of two stacks of seven trays
- bamboo poles replacing the iron rods used to support the trays
- a corrugated metal sheet suspended above the firebox to equalize heat distribution

In October 1977, the cost of construction, including materials and labour, were as follows (US$ 1 = Rps 12):

– Labour and supervision for stone masonry and roof (material provided by the farm)	Rs. 700
– Carpenter (including wood) for trays and doors	350
– Two oildrums, each Rs. 150	300
– Chimney, grate and welding of firebox	600
– Wire mesh for trays (8 mesh x 22 gauge)	50
– Nails, screws, hinges, etc. (approximately)	50
– Scrap iron sheet (approximately)	50
Total cost (excluding stones and roofing material)	Rs. 2 300

Fig. 3A Type A dryer under construction

Fig. 3B Type A dryer with two trays placed in the dryer

Construction of the modified tray batch dryer (Type A) took five days. With a single tray containing up to 30 kg of wet cardamom, 300 kg of cardamom can be dried in one operation. By using trays, the lower layers of a batch can be removed and the upper layers lowered to speed the drying process.

Type B – The AED/HADP engineers also experimented with a low cost modification of the cardamom dryer currently used by local farmers. An enclosed firebox and a chimney was added to the traditional mud and stone "bhatti". This new design (**Figs. 4A, 4B**) has the advantage of costing not more than Rs. 900 for the farmer already in possession of the traditional dryer. Moreover, no special construction skills are required to make the modifications. A substitution of galvanized wire mesh screen (8 mesh x 22 gauge) for the trandi-tional bamboo mat drying tray improved the natural ventilation, but also increased the cost by an additional Rs. 100.

Fig. 4A Firebox placed in a traditional dryer

Comparative Performance Trails

During the 1977 harvest season, comparative performance trials were conducted with the three dryers: Type A, Tray type. Type B, The modified local dryer (with wire mesh screen) and Type C, Traditional dryer ("Bhatti")

Due to insufficient quantities of raw cardamom and dry firewood, inadequate testing equipment and limited manpower, no conclusive data was obtained at that time. Cardamom dried in the tray-type and modified local dryer, however,

Fig. 4B Top view of improved traditional dryer with firebox and metal sheet suspended above the firebox. Wire mesh screen is not yet installed

showed better color and appeared to lack the smoky odor and flavor characteristic of fruits dried by traditional methods. The newly designed dryers, however, proved to require more firewood and a longer drying period.

In October 1978, further trials were carried out with these three types of dryers. Due to local holidays, only one run per dryer could be made. Later, an additional batch was run through type B at a lower maximum temperature (90° C). A small, gas-heated drying stove and single-beam balance (to 0.1 g accuracy) were used for gravimetric moisture content determination. If properly operated, this field equipment can record with an accuracy of within 0.5 % moisture content. Temperature registration was hampered by the fact that mercury and dial thermometers were employed in the measurement rather than the multiple point recording thermometer, which was under repair at the time of the tests.

The basic data regarding the various trials conducted by local researchers are summarized in Table 2.

Table 2 Comparative Performance of Dryers

Feature	Type A	Type B	Type C
Cardamon fruit load	200 kg wet fruit (10 trays)	160 kg	160 kg
Fuel used	200 kg firewood	155 kg firewood	135 kg firewood
Drying time	21 hrs., max., top trays	17 hrs.	9 hrs.
Maximum recorded air temperature	190°C	130°C	155°C
Air temperature (top trays)	65°C, max.	–	
Weight of dried cardamon (kg)	42	32	31
Moisture content of wet cardamon(%)	80	82	80
Moisture content of dried cardamon(%)	13	18	11

*The cardam on fruits were harvested 10 and 15 days before being dried, and the two samples being kept separately.

In each of the trials ambient air temperature was about 21° C (day time); relative humidity registered 80–85 % (day time).

Laboratory Analysis of Trial Products

Following the field trials with these dryers in 1978, 10 kg of fresh cardamom were brought to Kathmandu and dried in an electrically heated and ventilated drying cabinet and maximum temperature reached 65° C. Subsequently, samples of the cardamom dried by the four different methods: electric oven, tray-type dryer, modified local dryer, and traditional dryer were sent to the Tropical Products Institute (TPI) London, England for analysis of their various aspects (sample No. S(78) 54). Among the characteristics investigated were physical appearance and condition, moisture content, volatile oil content and composition of volatile oils. A summary of the results of the analysis are presented in Table 3 and briefly summarized as follows:

Physical state – Those samples

Table 3 Cardamom Drying Trying Trial Sample Preparations and Results

Drying Method	Sample Preparation				Dried Sample Characteristics*					
	Interval between harvest and drying	Drying temp.	Drying time	Fuelwood consumption / kg water evaporated	Moisture content	Volatile oil		Split fruit content	Debris content	Appearance
						as received	moisture free basis			
	days	°C	h	kg	%	%	%	%	%	
Electrical dryer	5	65 max.	–	–	9.94	2.16	2.40	6.60	1.60	Purple, mold-free pods.
Type A: Tray dryer	10	65 max.	21 max.	1.29	12.25	1.97	2.25	4.30	0.30	Purple pods with some light charring
Type A: Tray dryer	15	190 max. 140 avg.	–	–	12.75	2.11	2.40	16.40	0.20	Shrivelled, gray-brown purple tinged pods Mold free.
Type B: Modified local dryer	7	130 max. 110 avg.	16.	1.27	18.80	1.79	2.20	5.50	0.20	Spongy pods with mold contamination. Mold-free pods were purplish in color
Type C: Traditional dryer	4	155 max.	9	1.08	13.20	1.93	2.22	27.00	1.20	Very brittle, brown pods with considerable charring
Type B: Modified local dryer	10	90 max.	–	–	17.90	1.70	2.06	4.40	0.20	Spongy pods with mold contamination. Mold-free pods purplish color.

*Analysis by the Tropical Products Institute, London, U.K.; Sample No. S(78) 54.

that had been dried at low temperatures had retained a strong purple hue. Samples dried at higher temperatures appeared brownish and somewhat charred. The latter group also contained a higher proportion of split fruits. Samples 4 and 6 from the modified local dryer were found to be moldy upon receipt at TPI.

Mositure content – Assessment of moisture content of samples 4 and 6 confirmed that they had been insufficiently dried. Mold formation tends to occur in a specimen with a moisture content of more than 13 %.

Volatile oils – Volatile oil content on a moisture free basis did not show a marked difference (13 % maximum) between the various samples. Very little difference in composition was noted between the six cardamom oil samples; 8-cineole was the major constituent (73–77 %). The high cineole content contributes to the somewhat harsh flavor, rendering large cardamom comparable more with eucalyptus than "true" cardamom.

Conclusions and Recommendations

Very little information is available in Nepal regarding proper drying techniques for cardamom. During the experiments described above, no special instructions regarding temperature limits were given to local researches. Consequently, kiln temperatures were allowed to rise as high as possible in order to speed the drying process and reduce drying time. As seen from the damaged, charred fruits that resulted, the drying temperatures clearly were far too high. The drying trials have confirmed that the relatively low temperatures (up to 65° C) yield a product of better color and with lower incidence of fruit splitting and scorching.

The TPI analysis shows, rather surprisingly, that relatively little volatile oil was lost in the sample dried at the higher temperatures. Indeed, volatile oil composition was virtually identical in all samples. Apart from noticing a slight smoky taste in the product of the traditional drier, the consumer would not be expected to comment on any appreciable difference in flavor or flavor strength among samples 1, 2, 3, or 5.

Various literature mention that the cardamom fruit should be harvested just before they fully ripen in order to prevent the fruit from splitting during the drying process. The high moisture content of the wet cardamom (roughly 80 %) plus a high drying temperature results in a steep moisture gradient from the core to the periphery of the fruit. This, in turn, causes the fruit to split open. To avoid this phenomenon drying temperatures probably should not reach much above 45° C, with a maximum temperature of 65° C, at the final stage of drying. The moisture gradient within the fruit can be expected to exist for more than 24 h. By dividing the drying process into two stages (for example, in the first stage reducing fruit moisture content to 20 % and a few days later to a final moisture content of approximately 12 %), the producer could probably reduce substantially the percentage of split fruits.

Newly harvested cardamom can not be kept long without deterioration and quality loss. Wet samples exhibited decay after only five days. The trial samples showed a clear difference in quality between those of 10 days and those of 15 days time lag between harvesting and drying. Cardamom should be dried to a moisture content not exceeding 12 %. Samples of 18 % moisture content showed rapid deterioration due to mold growth during storage.

Given the wet weather conditions prevailing in most of the cardamom growing areas during the harvest season, possibilities for sun drying the crop are very limited. Consequently, the majority of farmers dry their harvest in the traditional wood-fired dryer or "bhattis". Having their own dryers, the farmers generally do not suffer the problems of time lag between harvesting and drying that created some difficulties for the trial units.

The experiments point out that the traditional "bhatti" gives faster drying speed with less fuel consumption than either of the newly designed dryers. This is logical since average temperatures in the local dryers tend to be higher. Moreover, a portion of the heat generated in the new dryers is lost through the chimney. Modifications of the new design, however, could reduce both fuel requirements and drying time. Enlarging the drying surface and adding two more oildrums would increase capacity and efficiency by providing a larger heat exchange surface. To regulate draught and improve fire control, a manually adjustable valve should be installed.

The grate of the firebox had been fabricated of carbon steel, which is unsuited for this purpose, cast iron would be a better material. The Agricultural Tools Factory at Birgunj produces cast iron parts (grates and doors) for tobacco kilns. These pieces may be suitable for installation in the cardamom dryers as well.

It may be noted that the performance of the modified local dryer (Type B) was better than that of the tray dryer (Type A). In addition, Type B is cheaper and easier to construct and to operate. Moreover, existing traditional dryers may be easily and inexpensively modified to include the improved design elements. Therefore, it is recommended that future research and development efforts concent-

rate on further improving the Type B dryer.

A partial solution to fuel scarcity would be the intensive interplanting of cardamom with fast growing tree species, such as alder (*Alnus nepalensis,* "utis") and albizia (*Albiza lebbek,* "siris"), which could be pruned to provide firewood. Moreover, using dry wood, instead of green logs as is currently the practice, would greatly enhance fuel efficiency. Approximately 20% more wood is required to produce a given amount of heat if wet rather than dry wood is burned. Farmers should be encouraged to collect firewood requirements during the slack season (winter) and to store it in a dry area. Stacked against the walls of the dryer, or even within the temporarily unused dryer itself, the firewood would be protected from the spring and summer rains by the dryer's thatched roof.

Continuous use through the harvest period would also increase the operational efficiency of the dryer. Considerable heat energy is lost in the heating up and cooling down periods. The cardamom shrinks substantially during the drying process. Maintaining a uniformly loaded drying floor prevents leakage of hot air.

Summary

As a means of increasing farm family incomes and diversifying production in the rural areas, cardamom cultivation offers several advantages. Easily grown on marginal lands, the cardamom plant is a relatively long-lived perennial with few labor requirements. Moreover, the high value to weight ratio of the final product is very desirable in a country where the rugged terrain and rudimentary road system renders the transport and distribution of often bulky agricultural products extremely difficult. The market position for Nepali "large" cardamom is somewhat precarious, however, given its popularity mainly as a substitute for the scarcer "true" cardamom. With the substantially lower price of the former, though, a better quality Nepali product may possibly strengthen its competitive edge in the international market.

Better drying practices could both improve the appearance of the final product and reduce losses due to fruit splitting, in addition to lowering fuel consumption. It is not altogether clear, however, that an improved product would bring a better price to the farmer. Unless a better quality product is favored with a higher market price, it will be difficult to interest the farmer in adopting the new technology. In order to make investment in improved drying facilities more financially feasible, one dryer should serve several farmers. Cardamom growers should organize themselves in order to obtain credit to finance improved dryers and storage facilities. In addition, an organized producer group could push for a stronger position in marketing negotiations.

If the depletion of the forests continues at the present rapid rate, engineers will find the farmers willing to pay increasingly more attention to fuel efficiency. As wood available for fuel purposes becomes scarcer and more distant from the source of demand, collection costs will increase. Moreover, the farmer will find that selling his firewood in the local market will be more profitable than profligate burning in cardamom dryers.

Recent research efforts of Development Consultant Services (DCS) at Butwal in the Terai have focused on the development of a mechanical heat generator coupled to a mini-hydro turbine. Such technology may offer in the future a partial solution to the energy problems facing agro-processing industry in Nepal's hill districts. Nevertheless, in the near term wood fuel will continue to be the cheapest and most readily available energy source for the majority of the Nepal's hill farmers. Improved cardamom dryers could contribute greatly to economizing on wood-fuel consumption.

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Thermal Disinfestation of Wheat with Solid Heat Transfer Medium

by

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Abstract

The influence of wheat drying with hot silica sand on the survival of adults and immatures of *Cryptolestes ferrungineus* was investigated, employing a batch and a continuous flow dryer. The effects of different sand to grain mass ratio, initial sand temperature, and residence time were also studied. No adult survived in any treatment using any dryer, whereas the average survival of adults in the untreated samples were 27.3 and 22.2 using the batch and the continuous flow dryer, respectively. Results showed the possibility of thermal disinfestation by heating infested wheat with sand at 105°C for one minute using a sand to grain mass ratio of 4.5 : 1 in the batch dryer. The effectiveness of solid medium drying in controlling insert populations was demonstrated.

Introduction

Hot and cold temperatures are not extensively used for disinfecting cereals and cereal products. Cold arrests the activity of insects but does not kill them unless the temperature is very low or the time of exposure is very long. It is possible to kill any insect quickly by heating. This principle is used effectively in hot climates on a small scale by spreading a thin layer of grain to dry in the sun. Some species of insects are more heat tolerant than others. The humidity also influences the lethal effects of a particular temperature. Exposure to 60° C for 10 min or 49° C for 20 min in practice can be relied on to provide 100 % control (Kent and Amos 1967). Russian investigators (Gerzhoi et al 1961) indicated the minimum temperature at which several insects and their larvae perished. For grain pests they found these temperatures in the range of 45° to 60°C.

Trisvyatskii (1966) found in trials of gas dryers that the grain temperature changed at a rate of 30° to 40° C/s and lethal conditions for cereal pests were reached in 1.0 to 1.5 s after the grain was placed in the dryer. Observations have shown that the eggs of both the granary and rice weevils were killed within 1 to 2 min at these conditions. Mortality of mites or weevils depended mainly on the temperature at which the grain was exposed and on the length of exposure time at this temperature. According to Gerzhoi et al (1961) complete disinfestation of mites (flour, elongated hairy) in all stages of development except the hypopus stage can be achieved by heating wheat to 45° C for 55 min.

Disienfestation of cereal grains by heating is limited in application not only by economic and mechanical difficulties but also because of the small difference between the heating necessary to achieve control and that which will damage the commodity. For example, it has been demonstrated by Trisvyatskii (1966) that heating above 60° C for any length of time may damage the baking quality of wheat. Experiments have also shown that the disinfestation of dry seed grain from cereal crops (at 12 to 13 % moisture content (wet basis)) did not cause loss of seed viability.

The results of the thermal disinfestation will depend on, the uniformity of the grain heating and the

residence time of grain in the drying chamber. Numerous investigations (Trisvyatskii 1966) have shown that thermal drying of batches of grain in thermal dryers under regimes in use at the present time did not result in a large reduction of insects and microorganisms.

This paper discusses the influence of wheat drying with hot sand on the survival of adults and immatures of *Cryptolestes ferrugineus*. The effects of different sand to grain mass ratio, initial sand temperature, and residence time were also investigated.

Methods and Material

Batch Dryer

A model batch dryer was used in this investigation. The main component of the model was an aluminium drying bucket 29.3 cm inside diamter and 22.9 cm deep. The bucket was equipped with a removable lid. The entire bucket was enclosed with a 5.1 cm thickness of asbestos insulation. Quick release clamps were installed on the outside of the bucket to facilitate rapid placement and removal of the lid during the tests. Two 1.3 cm diameter vents were provided in the lid to permit the escape of moisture. This assembly was mounted on a supporting yoke with angular adjustments. A 186 W gear head electric motor transmitting power through a matched pair of pulleys provided different rotating speeds (Lapp et al 1976).

Parameters and Procedures

Silica sand having a 13–30 texture (0.59 to 1.65 mm particle size) was used. Sand having a 12–30 texture means grain sizes which pass a 12-mesh screen (12 openings/2.54 cm length) and retained on a 30 mesh screen. The Neepawa wheat (a hard, red spring variety) initially conditioned to about 17 to 17.5 % moisture content (wet basis) and a rotating drum speed of 24 rpm were employed.

Grain infested with adults and larvae of *Cryptolestes ferrugineus* (Stephens) was supplied by the Winnipeg Research Station, Agriculture Canada. Each 500 g sample, composed of 50 g of infested grain mixed with 450 g of moist grain was treated with hot sand. The predetermined mass of sand was poured into an enamel tray and heated in an electric oven to the required temperature. The drying bucket was preheated to the desired temperature using a small propane torch prior to each set of drying trials. The wheat and the sand were put into the bucket while the bucket top was in a vertical position. The mixture of sand and wheat was emptied from the bucket when the desired time had elapsed.

Five treatments, as shown in **Table 1**, were used, and each treatment was replicated three times. A randomized experimental design was employed.

Continuous Flow Dryer

The prototype dryer used for this investigation consisted of a rotating drum 3.05 m long with 43.2 cm inside diameter. The length was divided into a 1.22 m insulated drying section, a 0.61 m screened separating section and a 1.22 m cooling and delivery section. The cylinder was driven by a small gear meshing with a large gear fitted to the rotating cylinder. The feed rates of grain and sand, the rotational speed of the drum, and the angle of inclination of drum were adjustable. A fan of 17 cubic m/min capacity was installed at the end of the cooling section. The details are given by Lapp et al (1977).

The wheat samples of 50 g infested with adults and larvae of *Cryptolestes ferrugineus* were placed in cloth bags which were then sealed. These bags were placed at the inlet of the drying section while the dryer was in operation. Moist grain mixed with hot sand was also introduced at the same time into the drying section through a metering device. The treatments applied to each of six samples is presented in **Table 2**. Treatments 1, 5 and 6 were subjected to two stages of drying,

Table 1 Comparative Treatment for Therman Disinfestation, Batch Dryer

Treatment No.	Sand to grain mass ratio	Initial sand temp. °C	Residence time min.	Stages of drying	Initial grain temp. °C	Initial grain moisture content %wb	Final grain moisture content %wb
1	4:1	99.7	2	one	24.0	17.5	15.2
2	4.5:1	106.0	1	one	28.0	17.3	14.8
3	4:1	91.0	2	two	29.3	17.4	14.0
4	4:1	99.3	2	four	30.0	17.2	11.5
5	4:1	99.3	2	two	28.3	17.4	13.5

Table 2 Comparative Treatment for Thermal Disinfestation, Continuous Flow Dryer

Treatment No.	Sand to grain mass ratio	Initial sand temp. %	Grain moisture content %wb		Stages of drying
			Initial	Final	
1	4.5:1	105	17.3	12.9	two
2	4.5:1	105	16.9	14.5	one
3	4:1	115	17.1	13.6	one
4	4:1	105	17.4	13.2	two
5	4:1	105	17.2	13.2	two
6	4:1	105	17.2	13.4	two

*At grain flow rate of 3 kg/min, and residence time of 1 min.

while in other treatments one stage drying was employed.

Results and Discussion

Batch Dryer

Adult insect survival was determined 24 h after the treatment and survival of immatures was determined from the number of adults found at weekly examinations of each sample. The results of the analysis are recorded in Table 3. No adult survived in the treatments, whereas the average survival of adults in the untreated samples was 27.3. No survival of immature insects was found in treatments 2, 4 and 5. However, one immature survived in one of the samples in treatment 1, probably an egg. The other two samples had no survivors. Treatment 3 was not as effective as the other treatments because a total of four immatures survived (probably one small larva and three eggs).

Results showed the possibility of thermal disinfestation by heating infested wheat with sand at 105° C for one minute using a sand-to-grain mass ratio of 4.5 : 1. No significant improvement was obtained by heating wheat in four stages since two stages using sand at 100°C for 2 min and a sand to grain mass ratio of 4 : 1 was equally effective.

Continuous Flow Dryer

Treated samples were analysed and the results are recorded in Table 4. No adult survived in any treatment, while in the untreated samples the average number of live adults per sample was 22.2. The average number of dead adults in each treatment was 17.8, whereas in the untreated samples the average number of dead adults was 1.8. These results confirm the feasibility of destroying adult insects by heating with hot sand. The temperature of the sand used for drying was sufficient to kill them in 1 to 2 min.

Observations were also recorded on the survival of the immature stages in grain. Results indicate that treatments 2 and 4 were not effective in killing insects that were inside the kernels of wheat. A total of 392 and 489 live insects, respectively, were recorded while in the untreated samples the average population of insects was 552. The treatments in which either two-stage drying (1, 5 and 6) or higher sand temperature (3) was used, were more effective. In treatments 1, 5 and 6 the total number of live insects was 14, 23 and 25, respectively, as compared to the average in the control samples of 552. In treatment three, 29 live immature insects were recorded.

These results show the effective-

Table 3 Survival of Adult and Immature *Cryptolestes ferrugineus* after Thermal Disinfestation in Batch Dryer (3 replications per treatment)

Treatment number	Adult survival/replicate		Survival of immatures/replicate					
	Treated	Untreated	Treated					Untreated
			Weeks after treatment					
			1 (Pupae)	2 (large larvae)	3 (medium larvae)	4 (small larvae)	5 (eggs)	Average of all stages
1	0	14.0	0	0	0	0	0.3	30.8
2	0	18.7	0	0	0	0	0	33.1
3	0	23.7	0	0	0	0.3	1.0	33.1
4	0	36.0	0	0	0	0	0	33.1
5	0	44.0	0	0	0	0	0	28.8

Table 4 Survival at Different Stages of *Cryptolestes ferrugineus* after Thermal Disinfestation in Continuous Flow Dryer

Weeks after treatment	Survival in differnt treatments													
	1		2		3		4		5		6		Average of six untreated samples	
	L*	D*	L	D	L	D	L	D	L	D	L	D	L	D
0 (adult)	0	16	0	15	0	18	0	34	0	14	0	10	22.2	1.8
1 (pupae)	1	0	7	2	11	1	11	1	3	1	13	1	19.0	1.0
2 (large larvae)	3	0	32	1	5	1	51	0	7	2	8	1	68.2	0.3
3 (medium larvae)	1	0	160	0	6	1	194	0	4	1	0	0	182.5	0.5
4 (small larvae)	3	0	141	0	3	0	152	0	5	0	1	0	173.3	1.0
5 (eggs)	6	0	52	0	4	0	81	0	4	0	3	0	103.7	0.0
Total	14	16	392	18	29	21	489	35	23	18	25	12	552.2	4.2
Mean	2.3	2.7	65.3	3.0	4.8	3.5	81.5	5.8	3.8	3.0	4.2	2.0	92.0	0.7

*L: Live, D: Dead

ness of solid medium drying in controlling insect populations. Because the infested grain was contained in bags, it was not mixed thoroughly with the hot sand as was the case in the batch dryer. Since a large amount of infested grain would require considerable time and labor to examine, only small samples of infested grain were used. Thus each sample was enclosed in a bag. It was observed thtat the grain in the bags was not as hot as the free flowing grain. The layer of sand in the rotating cylinder was shallow, and therefore the sample bags were not covered completely by the sand. This resulted in less effective heating. Free flowing grain reached a higher temperature and would probably result in a lower survival of insects.

It was concluded that one stage heating of wheat was effective for killing adult insects but not the immature ones. At least two-stage heating was required for a significant reduction of the immature insects. A more efficient method would be to increase the residence time in the drying section. One-stage heating with sand at 115° C was as effective as the two-stage heating at 105° C. Possibly two-stage heating at 115° C would give complete disinfestation of adult and immature *Cryptolestes ferrungineus.*

Conclusions

Studies employing the batch dryer showed that complete thermal disinfestation of *Cryptolestes ferrugineus* was accomplished during the solid heat transfer medium drying process. Samples of infested wheat in cloth bags passed through the continuous flow dryer also demonstrated the feasibility of thermal disinfestation.

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Production and Analysis of White Ash

by

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Abstract

This study examines various methods of white ash produced from rice husk by burning the latter under different conditions. The physico-chemical nature, structure and crystallization of silica in ash thus obtained at temperatures varying from 400–1 300° C has been analyzed through various techniques, viz., differential thermal analysis, thermogravimetric analysis, x-ray analysis and scanning electron microscopy. The results indicate that the ash contains considerable amount of amorphous and active silica mixed with activated carbon, and that it is possible to reduce this silica at lower temperatures compared to the mixture of quartz and graphite.

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Introduction

The world's paddy production is estimated at about 350 million t, one fifth of which is husk. In India, rice husk production is approximately 16 million t, which can yield 3.2 million t of silica. No other agricultural residue contains the amount of silica found in rice husk; i.e. 20 %, in very finely divided and dispersed form and constitutes an unique source of high grade silica. The amount of harmful contaminants such as boron, arsenic and tin are generally very low as compared with other cheap sources of ash such as sand, bentonite and diatomaceous earth.

The silicon in rice husk is of the hydrated amorphous form. The silicon is taken up and transported in the plant during its vegetative growth as mono-silicic acid moving to the outer surfaces where it becomes concentrated through evaporation and polymerized to form cellulose silica membrane.

Although various reserach work is going on in the use of white ash as source of silica for making cement, insulators, ceramics, and solar grade silicon for use in solar cells, the analysis of white ash itself has been the most neglected phase of research. Unless, this is thoroughly investigated, it may ultimately prove to be futile to carry out studies on its use. For example, in making solar grade silicon, it is important to have the ash as white as possible and to maintain it in amorphous state for reducing the silica content. Even in cement manufacture, there are stringent requirements on the physico-chemical nature of white ash. Hence it is important the different states of physical that and chemical existence of rice husk ash are well defined and understood. In order to prepare the fosterite ceramics dielectric materials and high frequency insulators from white ash, it is imperative to develop efficient techniques to produce white ash commercially.

As a first step in using silica from rice husk, the study analyzed the content of minor impurities in ash and its nature and structure with the use of different methods.

This lays down the necessary base for further studying the utilization of rice husk ash in the manufacture of industrial products.

Production of White Ash

In all kinds of furnaces, i.e., grate, cyclone and suspension type, the refuse (ash) is black-gray colour, containing 8–15 % carbon. It is rather difficult to manufacture white ash in industrial furnaces due to its inherent resistance to burning. Therefore, the following methods were used:

1) Burning in piles in open atmosphere – Atmospheric burning is not necessarily the ideal condition. If the pile is very thin and there is some air blanket turbulence such as on an open field, true burning will occur, as in an air-suspended furnace or burner. However, as soon as the unburnt mass is brought up to a temperature of about 350° C, decomposition begins and the volatile matter of the husk distills off and will flare if ignited. If purely amorphous silica is the desired product, the pile configuration must be such that internal temperatures do not rise about 750° C, a temperature at which amorphous silica changes to crystalline phase. The radiation and convection from the mass must balance the rate of heat released from the decomposition to hold the temperature in balance. The ideal pile atmospheric process is more similar to the pyrolysis rather than the burning process. The temperaure in such a pile goes up to 850° C at the centre of the pile. In general, the mixture of amorphous and crystalline silica is obtained in such a process. It takes about 60 h for a complete combustion of the pile. However, this method suffers from the disadvantage of getting soaked in rains or blown off in heavy wind.

2) Burning in a closed area – In this type of burning, it is possible to control the input, and with that the whole activity within the walls. There is no disturbance of the inert blanket covering the pile. For the present study a chamber of the size 1.5 x 1.5 x 1.5 m was constructed with bricks and wire mesh (**Fig. 1**). Two openings were provided at one side of the chamber so that the atmospheric air can enter below the wire mesh and help in creating natural thermal convection currents which create a slight draft through the openings and maintain the temperature at any desired level. A small blower may also be fitted into the openings for converting black ash into white ash through a recombustion process.

Experiments were conducted for burning rice husk and reburning of black ash obtained from the boiler ashpit. The complete combustion of husk and black ash was achieved in 30–35 h resulting in a completely white ash. In this situation, the temperature inside the ash bed went up to 900° C which yielded a mixture of amorphous and crystalline product. In comparison it took 48–60 h to produce white ash in atmospheric pile system of burning.

3) Burning in an electirc furnace – The electric muffle furnace (0–1 400° C) having silicon carbide rods as heating elements, was used for the experiments. Burning of rice husk in an electric furnace has never been a commercial process. However, in order to produce white ash under controlled conditions for further studies on white ash, the electric furnace is generally used.

The experiments were conducted by firing a 10 g sample of rice husk at different temperatures varying from 400° to 1 000° C. The time of firing was also varied. The results are shown in **Table 1**. The samples were analysed under x-ray diffraction for crystalline property.

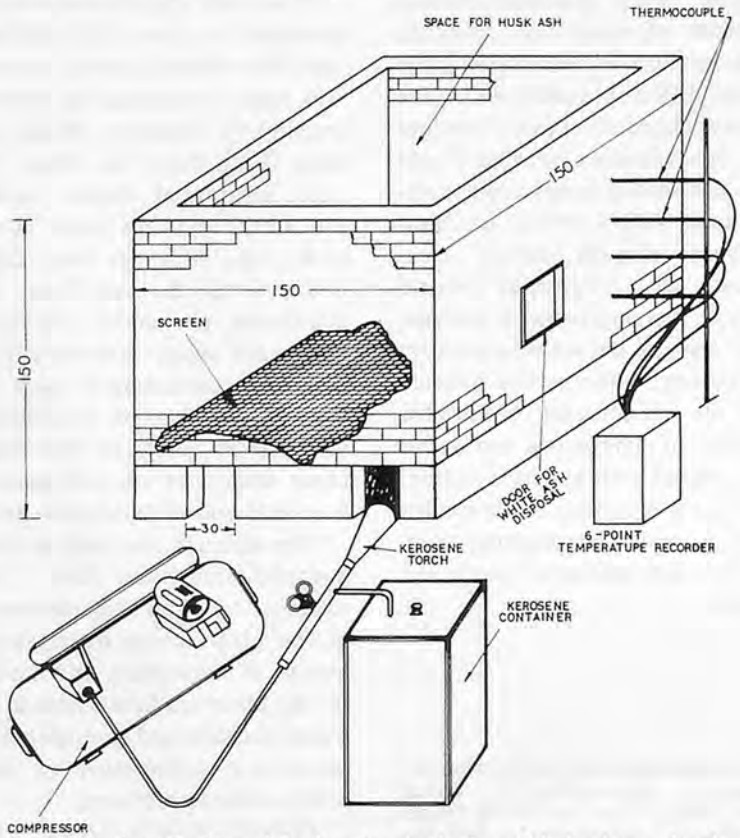

Fig. 1 Production of white ash by burning rice husk and black ash in a closed chamber (Unit: cm)

Table 1 Burning of 10g rice husk in electric muffle furnace

Temperature of firing °C	Time of firing h-min	Weight of ash g	Colour of ash	Crystalline/ non-crystalline
400	15	2.72	Black	Non-crystalline
"	30	2.33	"	"
"	1–0	2.21	"	"
"	3–0	2.15	"	"
500	15	2.16	Black	"
"	30	2.06	Gray	"
"	1–0	2.04	"	"
"	3–0	2.02	"	"
600	15	2.23	Gray	"
"	30	2.20	"	"
"	1–0	2.03	"	"
"	3–0	2.01	"	"
700	15	2.13	White	"
"	30	2.02	"	"
"	1–0	2.02	"	Crystalline
"	3–0	2.00	"	"
800	15	2.03	"	"
"	30	2.01	"	"
"	1–0	2.00	"	"
"	3–0	1.85	"	"
900	15	2.02	White	"
"	30	2.00	"	"
"	1–0	1.95	"	"
"	3–0	1.85	"	"
1000	15	2.01	White	"
"	30	2.00	"	"
"	1–0	1.85	"	"
"	3–0	1,85	"	"

It is a slow burning process and as a result, complete carbon and other volatile matter were burnt out. At 600° C it took 3 h to turn the rice husk into completely white ash and the silica obtained remains in amorphous state as verified by x-ray studies. Firing at 700° C for 15 min is the optimum condition for converting a thin layer of rice husk into white ash. Under higher temperatures, over 750° C, the ash changed to crystalline state. **Table 2** shows the composition of white ash in % and ppm.

Analysis of Rice Husk Ash

The physico-chemical nature, structure and crystallization of silica in ash obtained by firing rice husk at different temperatures varying from 400°–1 300° C were analyzed by various techniques, viz., differential thermal analysis, thermogravimetric analysis, x-ray analysis and scanning electron microscopy.

1) Differential thermal analysis (DTA) – DTA is convenient in making mineralogical analysis. It involves measuring and graphing the difference in temperatures between the sample being examined and an inert substance (alumina) as the two are heated rapidly. The temperature of the sample during a test was influenced by the reaction taking place in this unknown sample. The ash samples were finely ground up to the size of 350 mesh. The ash samples were prepared by burning rice husk at temperatures, viz., 400, 500, 600, 700, 750, 800, 900, 1 000, 1 100, 1 200 and 1 300° C. The ash samples and inert material alumina were placed in separate cells side by side inside a furnace and were heated rapidly. The DTA apparatus was connected to a X-Y recorder which plotted the difference in temperature of the white ash and alumina as the ordinate against the temperature of the crucible as the abscissa. The DTA apparatus is shown in **Fig. 2**.

Table 2 Composition of white ash (IR-8 Rice Husk, W.B.)

Constituent	%	Constituent	ppm
Sio_2	94.50	Cd	0.40
K_2O	1.10	Ni	2.40
Na_2O	0.70	Zn	76.00
P_2O_5	0.23	Fe	256.00
MgO	0.23	Cr	1.33
CaO	0.25	B	15.00
SO_3	1.13		

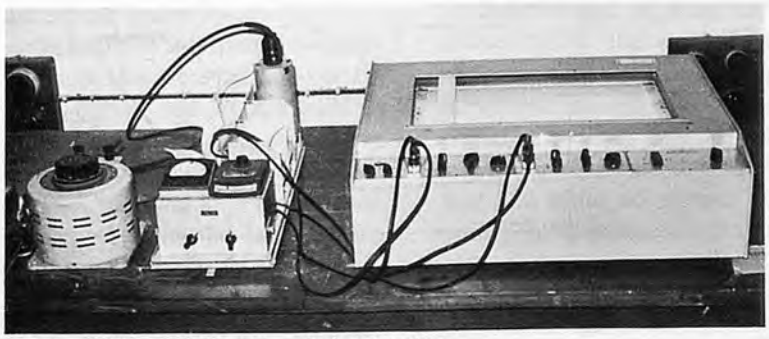

Fig. 2 Differential thermal analysis apparatus

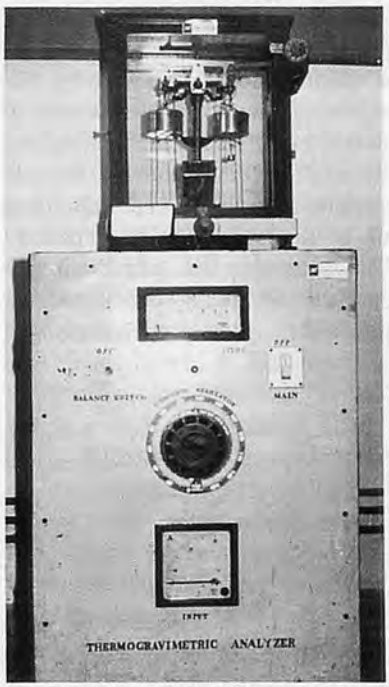

Fig. 3 Thermogravimetric analyzer

2) Thermogravimetric analysis (TGA) – A small quantity (0.5 g) of finely ground rice husk was taken in a small platinum container and was hung from the bottom of the pan of a chemical balance placed over an electrically heated furnace. The temperature of the furnace was raised (200° C/h) upto 800° C and the weight of the husk was recorded at 3-minute intervals. The thermogravimetric analysis apparatus is shown in **Fig. 3**.

3) X-ray diffraction – An x-ray analysis has been carried out for all the samples of white ash fired at different temperatures varying from 400° to 1 300° C in order to determine the crystalline and non-crystalline structures of silica.

4) Photographic power technique (Hull-Debye-Scherrer Method) – The white ash specimen was prepared by firing rice husk at different temperatures, viz., 600, 750, 800, 900 and 1 000° C. The ashes were finely ground. The x-ray photographs were taken by the Debye-Scherrer Technique. The small amount of sample powder (as little as 0.1 mg) was required for each specimen.

5) Scanning electron microscopy (SEM) – The main requirement of a specimen for examination by the scanning electron microscopy is that it be of a size small enough to fit into the SEM chamber. The ash samples were spread in powder form. on to the surfaces of brass pallets. The aqua daq was pasted on the surfaces of brass pallets which adhered the silica particles strongly on the surface. The conductive carbon coating was then made. The white ash samples prepared at 1 000° C for 1 hr were examined by the SEM under different magnifications, viz., 500, 1 000, 5 000 and 10 000 x.

Results and Discussion

The results of differential thermal analysis plots are shown in **Figs. 4** to **9**. Differential thermal analysis of rice husk as given in **Fig. 4** indicates some endothermic and exothermic peaks in curve (b) whereas curve (a) is flat. Peak I occurring at about 100° C and representing endothermic reaction may be attributed to the removal of moisture from the husk. Peak II which is also an endothermic one and occurring at 200° C is probably due to chemical decomposition of the organic compounds present in rice husk. At about 420° C the curve slowly rises indicating a slow exothermic reaction (Peak III) which is believed to be due to the gradual change in the structure of silica which, in turn, may be due to the crystallization of amorphous silica or to the rapid reduction in surface area.

The white ash samples, prepared at temperatures from 400 to 700°C in an electric furnace, did not show any exothermic peak in DTA plots as shown in **Fig. 5** which suggests the presence of silica in amorphous state. On the other hand, all the white ash samples prepared at higher temperatures ranging from 750 to 1 300° C showed an endothermic peak with temperatures ranging from 100–110° C for the evaporation of water and an exothermic peak ranging from 410 to 430° C as illustrated in **Figs. 6** to **9**. Within this temperature range crystallization of amorphous silica occurs, which gives rise to exothermic reaction resulting in the evolution of heat in the system. Peak III indicates the gradual evolution of heat due to the sintering of silica particles.

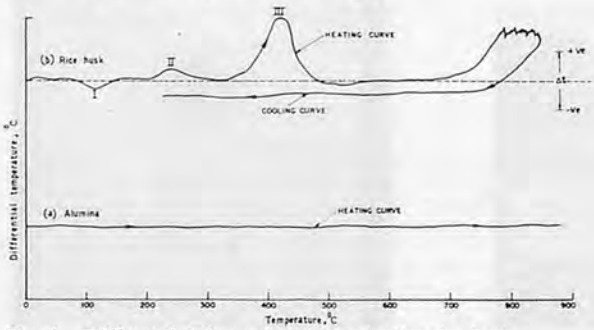

Fig. 4 Differential thermal analysis plot for rice husk

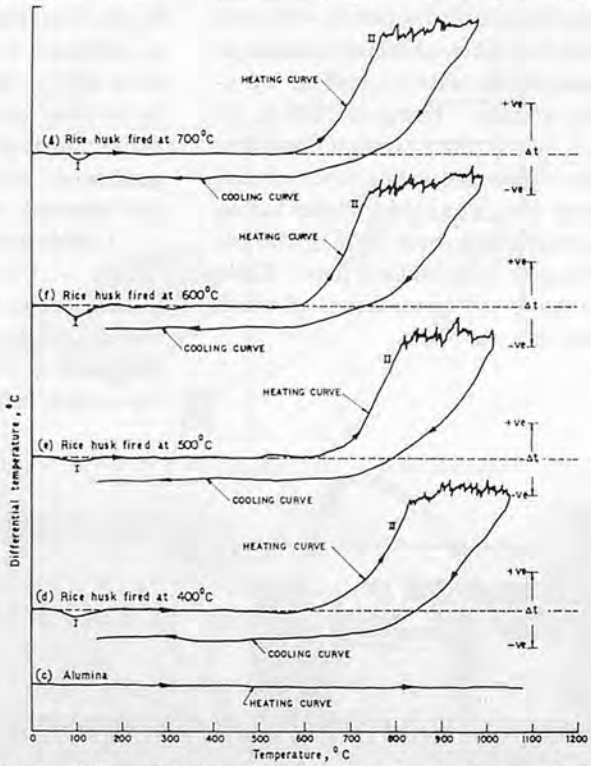

Fig. 5 Differential thermal analysis plot for rice husk ash fired at 400°C, 500°C, 600°C and 700°C

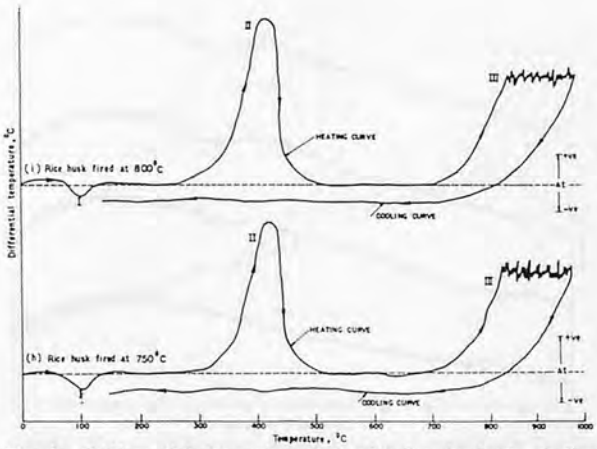

Fig. 6 Differential thermal analysis plot for rice husk ash fired at 750°C and 800°C

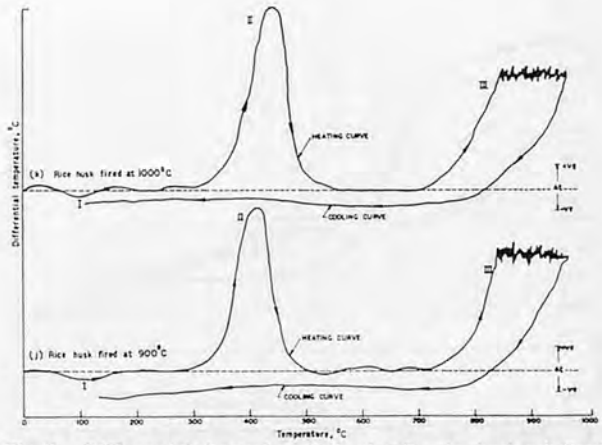

Fig. 7 Differential thermal analysis plot for rice husk ash fired at 900°C and 1 000°C

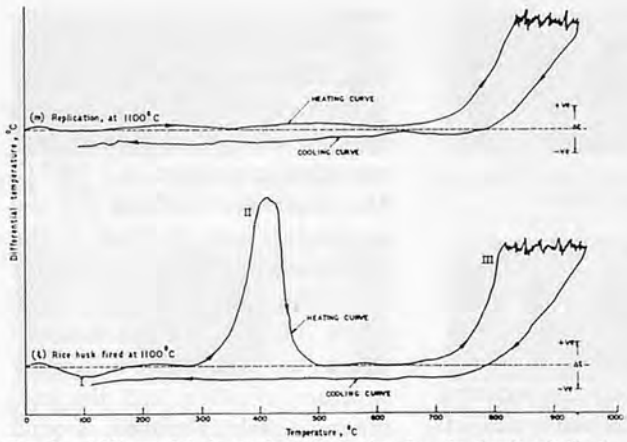

Fig. 8 Differential thermal analysis plot for rice husk ash fired at 1 100°C

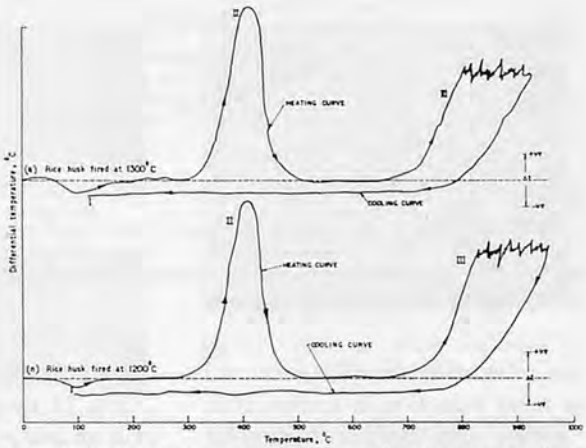

Fig. 9 Differential thermal analysis plot for rice husk ash fired at 1 200°C and 1 300°C

Fig. 8 also shows the two successive DTA runs on ash sample prepared at 1 100° C. The plot (m) of Fig. 8 does not exhibit any exothermic or endothermic peak except sintering characteristics at about 850° C. This type of behaviour of white ash shows that complete transformation of silica structure had taken place during the first heating of the ash sample (curve 1).

In order to interpret the various reactions that were indicated on the DTA curves, the TGA studies of white ash samples were carried out. The rate of heating of the sample in TGA runs was kept almost identical level as in the DTA studies.

It may be observed from Fig. 10 curve (a) that the loss in weight of the husk takes place in two distinct steps, one occurring between 50 and 200° C while the other occurs between 200° to 400° C. It may be suggested that the former was due to the removal of moisture and the latter due to the decomposition and subsequent removal of the other compounds. While much of the loss took place under 400° C, it continued slowly beyond 400° C. This later stage may be attributed to the removal of fixed carbon. Above 500° C the weight remains almost constant and corresponds to the carbon free ash which is mostly silica. The curves b, c, d, e and f in Fig. 10 represent the results of gray and white ash samples which were fired at temperatures of 900, 750, 600, 500 and 300° C for 0.5 h in electric muffle furnace. There is no weight loss in the white ash sample fired at 900° C as evidenced from more or less straight line in curve (b). Gray ash samples have some carbon inside silica particles which burn during heating in controlled conditions in TGA and, therefore, the weight loss occurs as evidenced from curve c, d, e and f (Fig. 10). However, the fired white ash samples have a strong exothermic peak in DTA at 420° C as shown in Figs. 4 to 7. As no weight loss is observed at this temperature in TGA studies, it may be suggested that there is some kind of transformation occurring at around this temperature region which is not of the nature of oxidation or reduction. This behaviour of silica occurring in the rice husk ash is comparable to that obtained in ferric oxide gels. This exothermic peak may be due to the crystalliza-

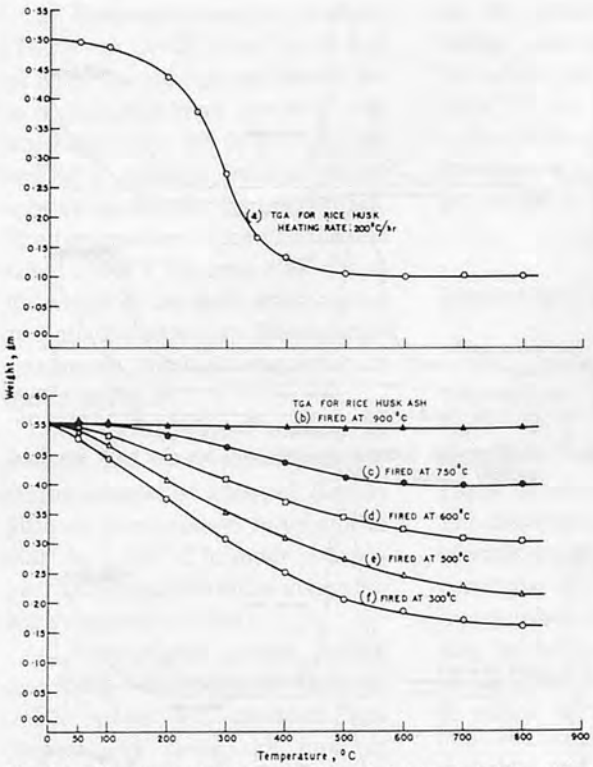

Fig. 10 Thermogravimetric analysis of rice husk, white and gray ash

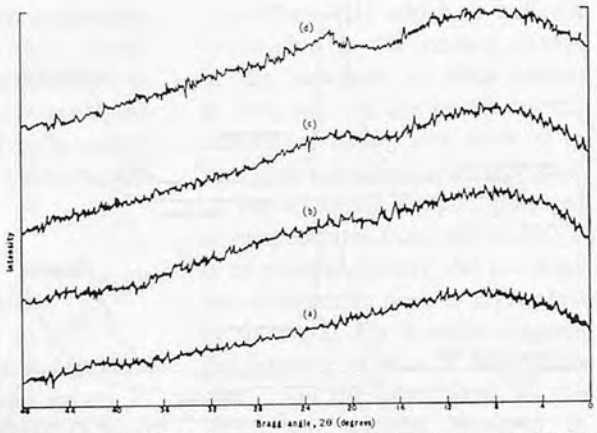

Fig. 11 X-ray diffraction of white ash fired at (a) 400°C, (b) 500°C, (c) 600°C and (d) 700°C

tion of virtually amorphous material or rapid reduction in surface area.

After this rapid reduction in surface area, there was a slow rise of the DTA curve which is possibly again due to slow sintering and further reduction in surface area. In order to further analyse the structure of silica in ash, x-ray studies were carried out.

X-ray diffraction analysis

Fig. 11 shows only the presence of large hump in the plot typical of amorphous structures. This shows that the silica in rice husk ash exists as amorphous silica up to the firing temperature of 700° C. Crystallization of silica begins at 750° C as revealed by the peak at 22° (2θ). This peak remains and increases in intensity with increase in temperature above 750° C as evidenced from Figs. 12 to 15. The humps on x-ray plots show that a fraction of silica exists in amorphous form even at very high temperatures of 1 300° C. This study also confirms that the exothermic peak observed in the DTA studies of white ash obtained after firing rice husk ash at temperature 700° C is not due to amorphous to crystalline change of structure of silica, and the exothermic peak observed around 420° C is due to rapid reduction in surface area.

Photographic powder technique

There is no sharp dividing line between crystalline and the amorphous materials. As the crystalline

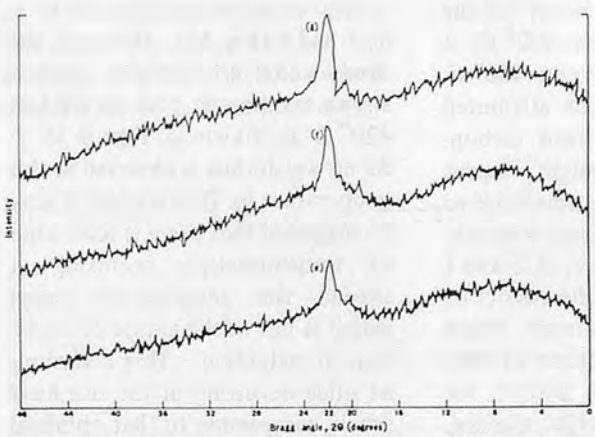

Fig. 12 X-ray diffraction pattern of rice husk ash fired at (e) 750°C, (f) 800°C and (g) 900°C

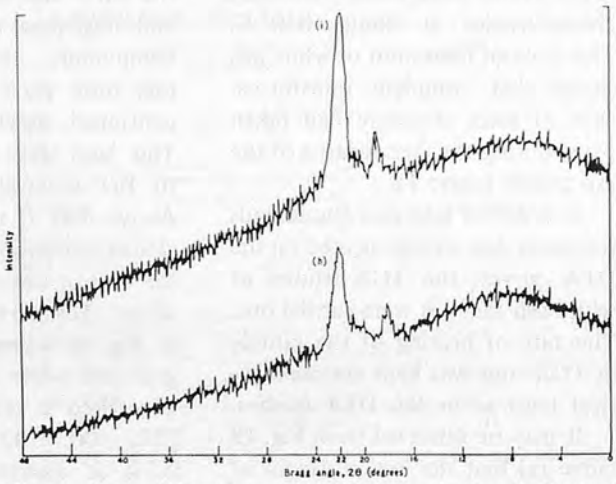

Fig. 13 X-ray diffraction pattern of rice husk ash fired at (h) 1 000°C and (i) 1 100°C

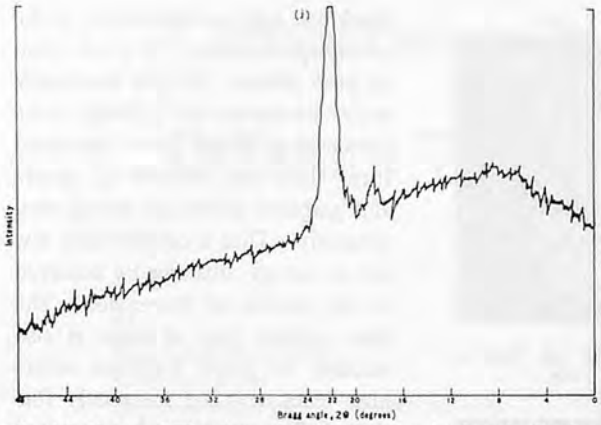

Fig. 14 X-ray diffraction pattern of rice husk ash fired at (j) 1 200°C

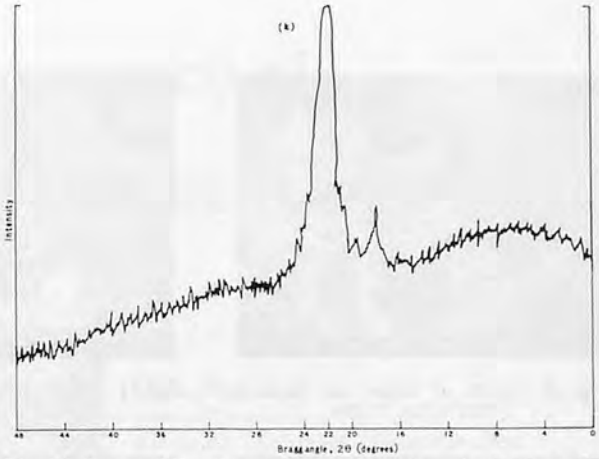

Fig. 15 X-ray diffraction pattern of white ash fired at (k) 1 300°C

Fig. 16A X-ray photo of white ash fired at 600°C/1h – CuK_α rad.

Fig. 16B X-ray photo of white ash fired at 750°C/0.5h – CuK_α rad.

Fig. 16C X-ray photo of white ash fired at 800°C/1h – Cuk_α rad.

Fig. 16D X-ray photo of white ash fired at 800°C/2h – CuK_α rad.

Fig. 16E X-ray photo of white ash fired at 900°C/1h – CuK_α rad.

Fig. 16F X-ray photo of white ash fired at 1 000°C/1h – CuK_α rad.

size diminished, the width of the lines composing the powder diagram increased until the fainter lines were not discernible and the stronger lines assume the diffuse character that is typical of non-crystalline substances.

Patterns A and B (**Fig. 16**) do not show sharp, clear rings and reflect the diffuse character that silica is non-crystalline. Pattern C in **Fig. 16** shows that the width of the lines is decreasing which indicate that firing at 750° C for 0.5 h, silica still exists as amorphous to some extent. Pattern D and E (**Fig. 16**) were obtained from the sample fired at 800° C for 2 h and 800° C for 6 h, which show the crystallinity of silica.

The x-ray photograph of the ash sample prepared at 1 000° C for 1 h (Pattern F) in **Fig. 16** illustrates extremely sharp, narrow lines showing sufficient quantity of crystalline material.

Scanning electron microscopy (SEM)

The SEM of white ash samples at different magnifications are shown in **Figs. 17** to **22** which show that low magnifications (500 and 1 000 x) does not indicate much details about the size and shape of silica particles and the burning of organic materials. The SEM (**Figs. 19, 20** and **21**) examined at higher magnifications (5 000 to 10 000 x) for the husk fired at 1 000° C for 1 h show complete and deep burning of carbon and other organic matter. It is evident from these micrographs that the white ash contains silica in very finely divided and dispersed form. The SEM micrograph (**Fig. 22**) illustrates that firing the rice husk at lower temperature (500–600° C) the carbon

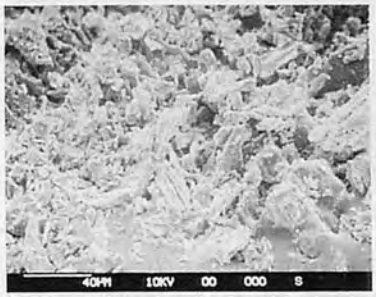

Fig. 17 SEM of white ash fired at 1 000°C/1h, 500x

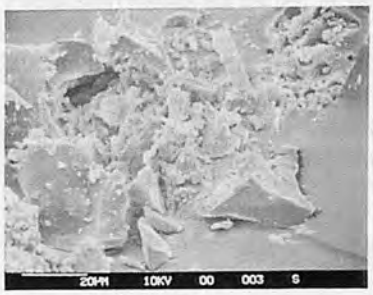

Fig. 18 SEM of white ash fired at 1 000°C/1h, 1 000x

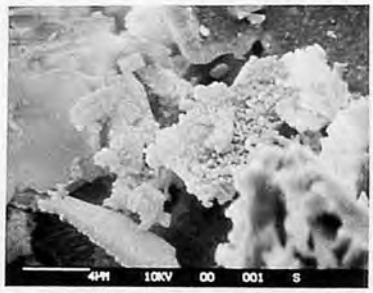

Fig. 19 SEM of white ash fired at 1 000°C/1h, 5 000x

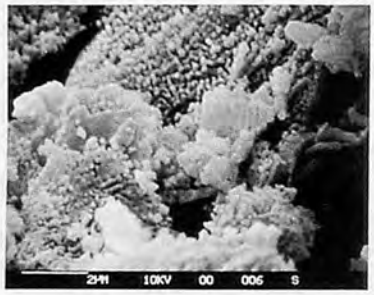

Fig. 21 SEM of white ash fired at 1 000°C/1h, 10 00x

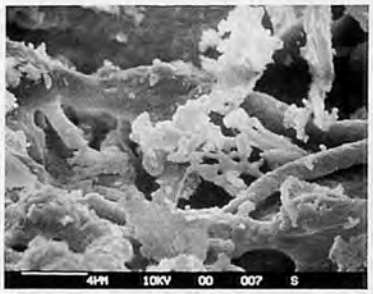

Fig. 20 SEM of white ash fired at 1 000°C/1h, 5 000x

Fig. 22 SEM of rice husk ash fired at 500–600°C/1h, 150x

had not burnt out completely and remains inside the silica matrix. It can be seen that the rice husk fired at higher temperature (1 000° C) and in the air for longer time shows complete and deep burning of carbon and other organic materials. The photographs clearly show the porous nature of silica in white ash indicating high surface area.

Conclusions

Rice husk is a unique agricultural waste product. Its special nature is high ash and silica (SiO_2) content. The results of firing rice husk in electric furnace indicated that at 700° C for 15 min is the optimum condition for converting a thin layer of husk into white ash. The SEM studies indicated that silica in ash is in finely divided and dispersed form and constitutes a unique source of high grade silica. The x-ray studies show that the silica in ash exists in amorphous state and is highly active when fired up to 750°C. At higher temperatures. of 750° C, it changes to crystalline state.

The intimate mixture of active silica and carbon available in the black ash may be considered as the potential source for the production of pure silicon. It is a chemically active substance and is likely to be activated at much lower temperatures than the mixture of quartz and graphite which are being used presently. Thus a considerable saving in energy also can be acheived in the process of conversion. The large surface area of silica is also suitable for other products where high reactivity and extremely fine size of silica in white ash is required as the cement manufacture.

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Comparative Performance of Different Types of Manual Pumps

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Abstract

Manually operated low lift pumps are still the main irrigation machinery used by Bangladesh farmers. Although the use of power pumps, shallow and deep tube-wells, is increasing, the rate is still very slow due to users' low buying capacity, fragmented plots, socio-economic constraints, lack of spare parts, repair and maintenance facilities, etc. For small scale irrigation projects, manually operated pumps are still the most appropriate machinery. The present study comprises the collection of different types of manually operated pumps, comparison of their performance in terms of capacity, total lifting head, ergonomics, cost-benefit ratio and maintenance characteristics. On the basis of performance, the best pump has been selected and recommendation have been made regarding its use and manufacture.

Introduction

Irrigation is one of the most important factors required for increasing food production which is the number one programme during the second five year plan in Bangladesh. To achieve this goal HYV of rice, wheat and other crops must be introduced in the cropping systems. Adequate irrigation requirement is the main characteristic of these high yielding varieties. At present only 14 % of total paddy acreage is under irrigation (Statistical Pocket Book of Bangladesh, 1978). Irrigation is done mainly by manually operated low lift pumps, shallow tube-wells (STW), deep tube-wells (DTW), power pumps etc. Sixty percent of the total irrigation is still done by manual pumping devices from surface sources of water. On the basis of the available manufacturing facilities, cost, socio-economic conditions, repair and maintenance facilities and sources of water, manually operated pumps are still considered as the main machineries for irrigation. Therefore, due emphasis must be given to them in studying their performance, costs and production potentials.

There are quite a good number of traditional manually operated pumping devices available in the country. But all of them can work only within 1.5–2.0 m of suction heads. In neighbouring countries, attempts have been made to develop the manually operated pumps having more discharge at higher operating heads. But no systemaic study has yet been made in Bangladesh to compare their performance with respect to discharge, total pumping head, ergonomic characteristics, etc.

In this study, seven manually operated pumps were collected and tested in the pump testing bed on their performance at different suction heads created artificially by a pressure regulator designed locally. In addition, the performance tests of 'Done' and 'Swing basket' were also studied to evaluate the performance.

Objectives

The objective of the study were:

1) Collect some prototype pumps for testing.

2) Design a pressure regulator.

3) Measure the discharge of the pumps at different suction heads (viz. 3, 4.5, 6 & 7.5 m).

4) Determine the ease in operation at different heads.

5) Study the cost involved in

manufacturing and maintenance.

6) Select the best pump after evaluation of their performance and finally to recommend its use in Bangladesh.

Materials and Methodology

The most critical part of the experiment was to regulate the pressure equivalent to different suction heads. To attain the purpose, a pressure regulator to adjust the heads was designed which eliminated the necessity of lifting the pumps from the water surface to the heights of 3, 4.5, 6.0 and 7.5 m. The regulator was constructed with a 0.32 m M.S. pipe provided with a system to hold weights for different suction heads and a device to fix a vacuum gauge in reading the desired suction heads with the predetermined weights.

Since it was previously decided that the pumps were to be tested successively at 3.0, 4.5, 6.0 and 7.5 m of suction heads, the weights were designed accordingly. The weights were made from a 15.24 cm dia. M.S.bar.

A vacuum gauge was used to make a thorough checking of suction heads and pressure regulator. The pressure regulator was immersed vertically into water up to its neck. To simulate the momentum in the suction pipe of a tube-well, two numbers of 3.81 cm dia. 6 m long G.I. pipe, kept on the ground in a U-shape, were fitted between the pressure regulator and the pump. Before pumping, the selected pumps were fitted to the free end of the G.I. pipe and the whole system was checked for airtight thoroughly. A drum of 50 gallons capacity was used to measure the discharge.

Description of Pumps

Rower pump – This is a reciprocating piston pump with 2 inch PVC pipe as the cylinder. This cylinder is inclined at an angle of 30° to the horizontal line and an operator pushes and pulls directly on a 'T' shaped handle at the end of the piston rod. The pump is operated with a rowing action, hence the name "Rower" (**Fig. 1**).

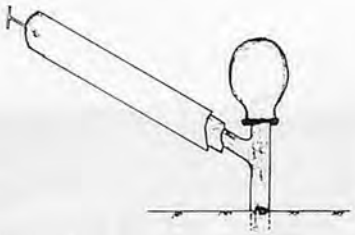

Fig. 1 Rower pump

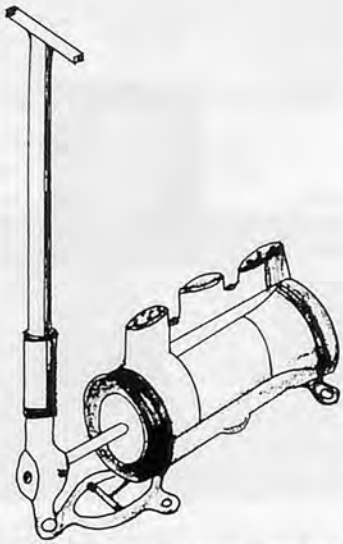

Fig. 2 Single man operated gardening pump

Single-man operated gardening pumb – It is a cast iron pump working in a reciprocating action. The cylinder of the pump is in a horizontal position. Alternate pulling and pushing mechanism is done with a 'T' shaped handle hinged to the driving piston (**Fig. 2**).

Two-men operated gardening pump – The pump is similar to the singleman-operated gardening pump except that it is operated by two persons standing on two opposite sides of the pump facing each other (**Fig. 3**).

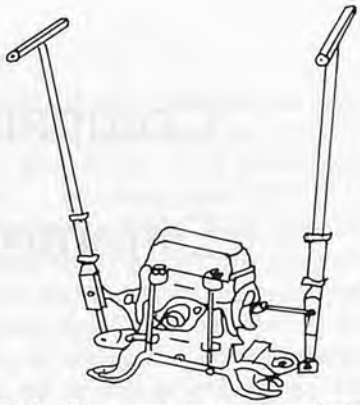

Fig. 3 Two men operated gardening pump

Diaphragm pump – The body of this pump is an irregular shaped cast iron vessel having a rubber flap which is the most important element. One man operates it with a long lever which raises and lowers the rubber flap to create vacuum (**Fig. 4**).

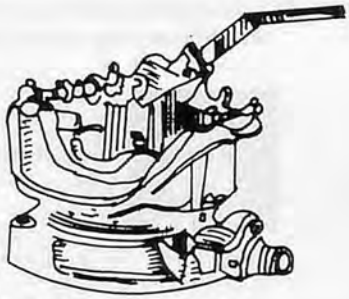

Fig. 4 Diaphragm pump

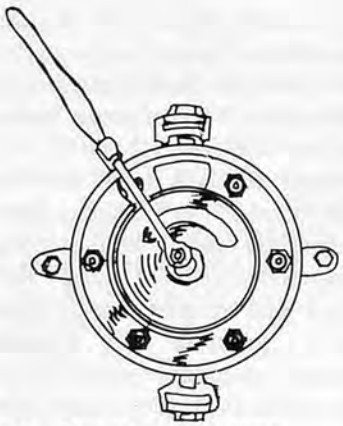

Fig. 5 Semi-rotary hand pump

Semi-rotary hand pump – It has two impellers inside a cast iron body. Each impeller is rotated by 90° to create vacuum. A'V' shaped wooden handle is rotated by two persons for operating the pump (**Fig. 5**).

Y-pump – This is made of two 8.9 cm diameter cast iron cylinder fixed to a 3.8 cm pipe making a Y-shaped structure. The open ends of the pipe serve as the delivery of the pump. This pedal-operated

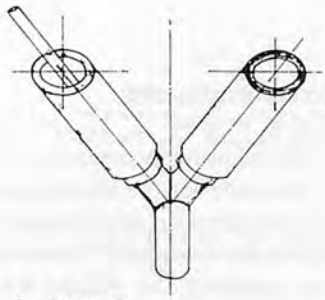

Fig. 6 Y-pump

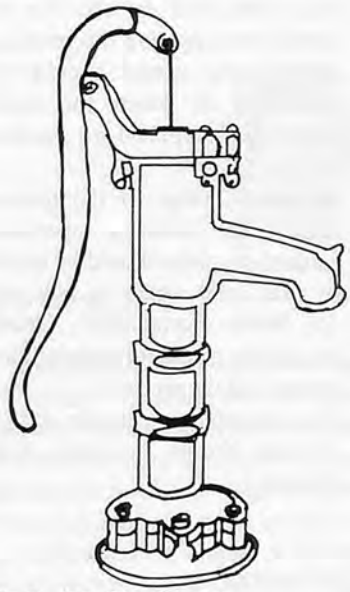

Fig. 7 No. 6 hand pump

Fig. 8 Done

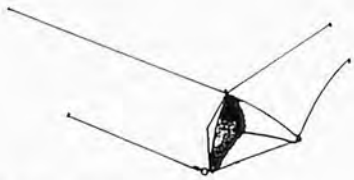

Fig. 9 Swing

pump requires a complicated operating mechanism (**Fig. 6**).

No. 6 hand pump – This pump is generally used in rural areas for lifting drinking water. The cylinder has an internal diameter of 10.16 cm and the water chamber which is just above the pump cylinder is 12.70 cm diameter. The piston of the pump is connected to a hand lever (**Fig. 7**).

"Done" – This traditional pump has been used in Bangladesh for many years. Its shape is like a mini-boat acting on a fulcrum (**Fig. 8**). It is very suitable for lifting surface water from a depth not exceeding 2.25 m. The discharge at 90 cm head is 378 ℓ/min and at 1.5 m is 117 ℓ/min. The discharge may be increased by setting the pump at double stages.

Swing basket – This is also an old and widely-used device. A basket is operated by two persons standing at two ends of two ropes fitted to the basket (**Fig. 9**). The discharge is 227 ℓ/min at 90 cm head and can lift water only within 2.25 m suction head.

Test of Pumps

All of the above mentioned pumps were tested with different arrangements suitable for individual pump in the pump test bed. First, a pump was fitted to the free end of the G.I. pipe and was placed on a platform so as to make it convenient to discharge water into the drum. The system was tested to check any leakage and a specific suction head was maintained by placing required weights on the plunger shaft of the pressure regulator. Time to fill the drum and time loss betweeen two consecutive readings were noted. All pumps were tested at 3.0 m, 4.5 m, 6.0 m and 7.5 m suction head.

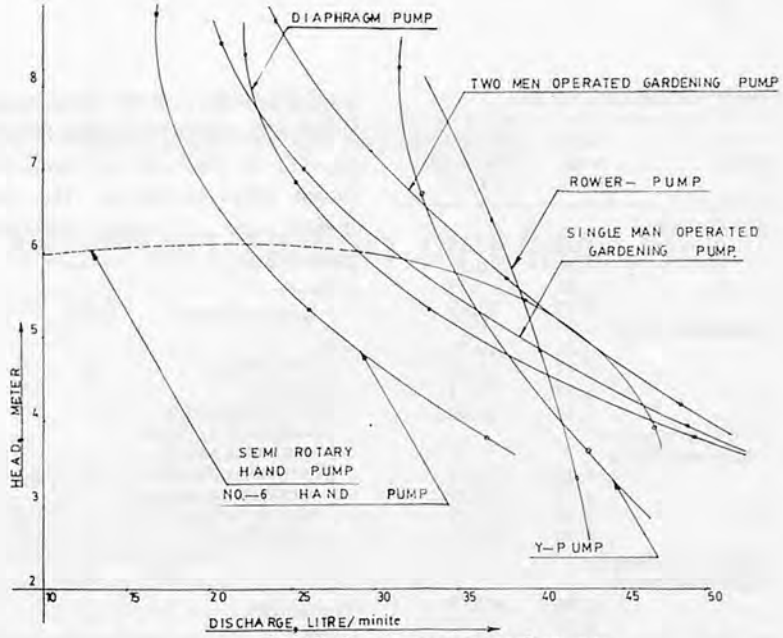

Fig. 10 Graph on pump performance

Results and Discussion

Graphs were plotted with the net average discharge (ℓ/min) as abscissa and the total head (m) as ordinate (**Fig. 10**). Average discharge was obtained by dividing the quantity of water discharged by pumping time.

Discharge of pumps

The performance of different types of pumps can be obtained from the test data in **Table 1**. For all pumps it was observed that with the increase of suction head, the discharge decreased. From the performance curves it is evident that at lower suction heads, diaphragm, single man and twomen operated gardening and rotary pumps show good results. At higher heads, the Rower and Y-pumps had better results. The diaphragm pump gave the best result (52ℓ/min) at 3.5m suction head. At a suction head ranging from 3.66m to 5.5m, the double acting gardening pump

Table 1 Performance test data

Item	Total head (m)	Net average discharge (ℓ/min.)
Rower pump		
	3.35	42.32
	4.88	40.31
	6.40	37.43
	7.92	33.69
Diaphragm pump		
	3.81	49.70
	5.33	33.76
	6.88	25.51
	8.38	22.60
Two-men operated gardening pump		
	4.22	47.62
	5.74	38.23
	7.26	31.38
	8.79	24.15
Signle-man operated gardening pump		
	3.96	47.19
	5.49	30.43
	7.01	25.81
	8.53	20.88
Y-pump		
	3.66	42.98
	5.18	36.04
	6.71	33.17
	8.23	31.71
No. 6 hand pump		
	3.81	36.96
	5.33	26.00
	6.86	22.80
	8.83	16.86
Semi-rotary pump		
	3.96	47.00
	5.49	39.16
	7.01	Cavitation

serves the best (52 to 40ℓmin.) The rower pump had the best output ranging from 40 to 32ℓ/min at suction heads between 5.5 and 7.5m. It also gave satisfactory results at lower heads.

Ergonomics in operation

This affects greatly the discharge of a manual pump. A machine should be such that an operator can operate it continuously for a considerable span of time with ease. During operation it was found that the operators were not so tired with the Rower pump even for a suction head of 7.5 m. The Y-pump being pedal operated, the operators could take the advantage of pumping it for a considerably long time. The single and double acting gardening pumps were easy to operate up to a sunction head of 3.5 m.

Cost of operation

In practice, farmers who possess a small holding look for the cheapest pump that can provide a satisfactory amount of discharge at heads between 2.5 m to 6.0 m. The estimated costs of pumps tested are given below.

Name of pump	Approximate cost.
Power pump	Tk. 220
Y-pump	325
No. 6 hand pump	325
Single-man operated gardening pump	1160
Two-men operated gardening pump	1500
Diagram pump	1600
Rotary pump	3425

Portability

The diaphragm, rotary, single and two-men operated gardening pumps were too heavy to carry from one place to another. The rower and Y-pumps are light and easily portable. The following chart shows the estimated approximate weight of the pumps.

Name of pump	Weight (kg)
Power pump	4
Y-pump	18
No. 6 hand pump	25
Single-man operated gardening pump	50
Two-men operated gardening pump	85
Diaphragm pump	98
Rotary pump	100

Operating mechanism

The operating mechanisms of these pumps were simple and only the Y-pump required a complicated bamboo structure. The diaphragm and rotary pumps needed a heavy platform to mount on. The single and two-men operated gardening pumps required only a base support to which the pumps were screwed.

Durability

No test for durability was made during the test of the pumps. Klassen (1979) operated the rower pump in fields continuously for 5 hours daily for a period of four months and found wear in piston rod guide only.

Recommendations

The following recommendations may be made for the improvement of the performance of the pump:

1. Since the rower pump is operated by applying the pulling force which cannot be applied for a long time, but an operator is inclined to applying the pushing force, so a system should be developed in which the push force can be applied for operating it.
2. Improved design of the diaphragm and two-men operated gardening pumps should be made so that total weight is reduced for better portability. Trials should be made for making the pumps pedal operated.
3. The operating mechanism of the Y-pump should be easier and efficient.

Conclusions

In the light of the above discussion and considering the socio-economic condition, technical knowledge, repair-maintenance facilities, etc. the rower pump is considered as the best pump for the farmers requiring small scale irrigation facilities and operating at total heads ranging from 2 m to 6 m. On the otherhand, were the total head is below 2 m the "Done" is considered to be the best water lifting device.

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Socio-Economic Issues Pertaining to Agricultural Mechanization in Malaysia

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Introduction

Mechanization of agriculture has two main objectives, namely; 1) to increase the productivity per agricultural worker, and 2) to change the character of farm work, making it less arduous and more attractive. In the Western developed countries, farm mechanization has been considered as the critical factor in their industrialization process. It has released millions of agricultural workers to other industries, thus contributing to the nation's industrial expansion. Also, it has created a favorable situation, where it requires only a very small proportion of the population involved in food production for the entire population.

Agriculture in Malaysia is an extremely important business sector that has expanded during the last decade into a major contributor to the nation's economy. Steps are being taken by the Government and various private agencies to modernize this sector of the economy. One of the important components in modernizing the Malaysian agriculture is the introduction of agricultural mechanization.

Increased Food Demand

Dr. Norman Borlaug who received in 1970 the Nobel Peace Prize for his contributions to reducing world hunger by developing high-yielding varieties of wheat, stated that "the first essential component of social justice is adequate food for all mankind ..... If you desire peace, cultivate justice, but at the same time cultivate the fields to produce more bread; otherwise there will be no peace" (Borlaug, 1970).

The question of adequate food for the people is a critical question which is faced by every nation, especially those in the developing parts of the world. This problem is especially very critical in the Third World countries. A recent FAO report states that the Third World is heading toward a great food shortage that could lead to economic disaster within the next 20 years (Jara, 1979). This warning is more relevant in Asia, since another report from the Asian Development Bank (ADB) shows that Asia's annual food imports have grown from about 7 million t in 1960 to 26 million t in 1977. The ADB also projects that unless present food production trends are quickly reversed, Asia's food deficit will rise to 30 million t by 1985.

In the case of Malaysia, the growth rates of production of major staples for 1960 to 1975 has been better than its population growth rate, that is, 5.6 % and 2.9 % per annum, respectively. Even with that favorable food production growth rate, Malaysia is not yet self-sufficient in rice, its main staple crop. In 1977, the domestic production was able to meet about 82 % of the total requirement of rice (Ministry of Finance, 1978). The balance has to be imported from neighboring countries, mainly Thailand and the People's Republic of China. Thus, the demand for increased food production is still there. Mechanization can have an important and positive effect on the intensification of rice production in Malaysia, particularly as it permits timely cultural operations leading to increased yields and double cropping. In Malaysia's rice bowl area, Kedah and Perlis, double-cropping is becoming a common practice. The farmers are seeking out for more modern methods to enable them to stick to the rigid regimen imposed by intensive double cropping (Jasin, 1979).

Farm Labor Situation

Agriculture in Malaysia has always been a labor intensive enterprise. It has been able to acquire large amounts of labor required each year. However, with the

present trend towards industrialization, the farm labor situation is changing quite significantly. The The setting up of industrial plants around the country has created a keen competitor for the labor which traditionally goes into agriculture. Also, the intensification of agriculture, such as double-cropping, has increased the demand for labor in agriculture itself. These factors have created an acute labor shortage for agriculture in Malaysia. On oil-palm plantations, this acute labor shortage has caused them to lose millions of dollors each year. Planters estimate that at least 30 % of the harvest goes to waste because there are not enough hands to gather them (Danapal, 1980). According to the Planters' Association, they are losing workers to factories and firms in urban areas, because the workers would prefer the glamour of living and working in urban areas, despite the lower income which they might get compared to working in the plantations.

Much of this labor shortage can be alleviated by increasing the productivity of labor in the agricultural sector through mechanization. Mechanization can increase the productivity of labor significantly, as evidenced from the experience in the Western World. In the United Stated, it was estimated that the productivity of a man working in a mechanized harvest of fruits and vegetables is approximately 10 times that of a man working in a hand harvest (Barnes, 1966). This increase in labor productivity will drastically reduce the labor requirement in agriculture and thus alleviate farm labor shortage.

There is no question that mechanization would cause a temporary dislocation of a number of rural workers. However, this situation will be only temporary, since mechanization actually has not displaced people so much as it has shifted them from part-time and poor-paying seasonal employment on farms to full-time better-paying employment in agriculture-supporting industries.

Efficiency of Agricultural Production

One way of overcoming the food shortage is to increase the efficiency of agricultural production. This will increase the farm productivity and also, subsequently, increase the income of farmers. To increase the efficiency of agricultural production requires inputs from various sources. There has to be an improvement in the stock or seed for agricultural production. Also, there is a need for the improvement of the crop or livestock maintenance such as pests and diseases protection, fertilizer use, and field upkeep and operations. Improvements also have to be made in the efficiency of crop collection which includes reduction of loss during harvest, proper handling and transportation of product, and proper processing and storage.

Mechanization can have significant positive role on the improvements of the processes mentioned above for increasing the efficiency of agricultural production. It can contribute to timeliness of these operations, since they can be done at a faster rate. This is especially true for some of the field operations which must be performed within rather short period, such as grain harvesting which has to be done quickly to prevent them from germinating in the field. Through mechanization there is the possibility of operating for 24 h a day, if necessary, during the critical periods.

Mechanization also encourages better management of farm enterprises and it makes this possible by providing more free time for planning and study. This will surely tend to increase the efficiency of agricultural production as a whole. Mechanization will also increase the efficiency of agricultural workers due to the fact that it improves the working conditions. It facilitates the performance of jobs that would otherwise be difficult or impossible to do. Also, it can eliminate the back-breaking job such as manual-harvesting of paddy, thus alleviating the physical burden which are imposed on farm labor. Thus, mechanization will not only increase the efficiency of agricultural production, but will also provide a service to society by eliminating some of the physical burdens on the parts of farmers.

Appropriate Technology

Technological change in agriculture in the developing countries was originally a matter of importing new seeds, animals, and equipments from industrialized countries. While this continues to be true to some extent, the question of appropriateness of the imported technology has been a focal concern of many organizations both in the developed and developing countries (Schumacher, 1973; Ruttan et. al., 1973; Eckaus, 1977) The concept of appropriate technology was viewed as being the technology mix contributing most to economic, social and environmental objectives, in relation to resource endowments and conditions of application in each country. Appropriate technology was stressed as being a dynamic and flexible concept, which must be responsive to varying conditions and changing situations in different countries. It was considered that no single pattern of technology or technologies could be considered as being appropriate, and that a broad spectrum of technologies should be examined and applied (UNIDO, 1979).

In Malaysia, appropriate technology in agricultural mechanization consists of two categories, namely;

appropriate locally-developed technology, and appropriate technology transfer. For example, in paddy production, much of the mechnanization aspect has been based on technology transfer by the introduction of foreign-developed machinery, such as the power tillers and the 4-wheeled tractors. Some of these machines, such as the latest model pedestrian power tiller, are specially built to suit the Malaysian conditions. Even the most modern technology in rice harvesting using the large self-propelled combine has been successfully introduced in Malaysia. In 1979, it was reported that about 30 units of the large self-propelled rice combine harvesters worth around M$5 million were sold to farmers and various government agencies in the country (Ali, 1980). At present, these machines are economically operated in Malaysia through a custom-operation system.

Some aspects of the agricultural mechanization program in Malaysia do require appropriate locally-developed technology. One such example is the use of mechanization in harvesting groundnut which is being developed at local institutions such as the University of Agriculture Malaysia.

In the area of perennial crops, namely, rubber and oil palm, the modernization must be based on locally-developed technologies. This is because plantation mechanization is unique to Malaysia. Thus, there is very little possibility of adopting implements developed in other parts of the world. At present, there is a strong indication that the mechanization of plantation crops is inevitable in the country. In fact, there have been agitations from the plantation sector that more machines be devised for use in rubber and oil palm estates in order to ease the impending labor shortage (Anon, 1979). Efforts are being made by various institutions in Malaysia to develop implements for the mechanization of plantation crops. (Webb, 1976; Ishak, 1980; Tam, 1980).

Institutional Factor

The modernization of agriculture through mechanization requires various institutions which will support the program. One of the most prominent institutions which was set up in Malaysia for this purpose is the National Farmers Association (NAFAS). It is the national 'umbrella' of all farmers organizations, representing nine state-level farmers' associations and 180 district-level farmers' organizations and cooperatives. Since its inception in 1972, it was engaged mainly in the supply of farm requisites. It has now expanded its activities to include the marketing of agricultural machinery through its subsidiary Nafasjentera, which was created in 1976. Nafasjentera is also given the task of promoting mechanization in agriculture. Besides being the marketing agent for agricultural machinery, it also maintains service centers and parts depots at strategic locations as well as at farmers cooperatives centers. It also has several mobile service vans which travel to the farmers' door-steps in remote areas, bringing its services closer to where the action is.

Besides the NAFAS, networks of private agricultural machinery suppliers also operate in Malaysia. They also deal with various agricultural implements ranging from the large self-propelled combine harvesters to fertilizer spreaders. These private suppliers also act as agents in introducing new machinery products into the Malaysian market.

There are also various Government agencies which are contributing to the modernization of agriculture in Malaysia. The principal agency for agricultural research is the Malaysian Agricultural Research and Development Institute (MARDI). The Fedral Agricultural Marketing Authority (FAMA) regulates marketing and provides market information through marketing cooperatives. An agricultural bank, Bank Pertanian Malaysia, serves as a lending agency for the farming community. The Farmers' Organizations Authority (FOA) was set up in 1973 to start farmers' organizations through the merger of existing agro-based cooperatives and farmers' associations. The National Padi and Rice Board (LPN) was created to deal with the drying and milling requirements of farmers through the setting up of large integrated grain dryer complexes in the country. Other related agencies include the Rubber Research Institute of Malaysia (RRIM), the Palm Oil Research Institute of Malaysia (PORIM), and the Federal Land Development Authority (FELDA).

National Economic Policy

Malaysia is classified as one of the middle-income countries which is defined as countries with a per capita income exceeding US$250 (World Bank, 1978). Amongst a group of 58 middle-income countries cited in the report, Malaysia ranks 34, with a per capita income in 1976 of US$860. Present indications show that Malaysia's productive capacity will continue to expand steadily, thus increasing the per capita income of the country.

The dominant sector of the economy in Malaysia is agriculture which contributed 45.5 % of the foreign exchange earnings, 29.8 % of the Gross Domestic Product (GDP) and employed about 1.9 million workers or 49.3 % of the total work force in 1975 (PMD, 1976). In the Government economic development program, the agricultural sector is expected to progress through increased productivity on agricultural land, thus increasing the income levels of the

farmers. The agricultural programs include improvements to existing agricultural areas, the conversion of traditional to modern agriculture, and the enforcement and improvement of tenancy regulations.

The Government will also continue to give high priority to increasing rice production to achieve self-sufficiency. The target will be attained through increased double-cropping supported by the provision of credit, subsidies, extension and other measures to increase yields. With double-cropping program, timeliness of operations in the production process will become more critical thus requiring the accelerated implementation of agricultural mechanization. To support the agricultural mechanization program, farm mechanization training centers and farm mechanization service centers are to be established in the country. Subsidies and credit facilities will also be provided for farm mechanization and the use of transport services and agricultural inputs. Subsidies for farm mechanization and transport will be provided by the FOA through farmers' organizations. Subsidies for agricultural inputs will continue to be given to the growers of permanent crops, food crops and other crops requiring replanting, such as rubber, coconut and pineaple.

The total allocations for agricultural development under the Third Malaysia Plan (1976–1980) amounted to M$4.7 billion, which is 25.5 % of the total allocation. The amount for the Fourth Malaysia Plan (1981–1985) will increase, considering the importance of the agricultural sector in the country.

Conclusion

Agriculture in Malaysia is an extremely important business sector that has expanded during the last decade into a major contributor of the nation's economy. The Government in its economic development program, is embarking on the process of improving the agricultural productivity. One of the steps taken by the Government, with the help of the private agencies in the country, is the introduction of modern equipments and the provision of subsidies aimed at modernizing the agricultural sector. The socio-economic factors existing in the country tend to support the direction taken by the Government and are expected to continue in the future in favor of agricultural mechanization. However, to ensure the success of the program, more efforts will have to be made by the institutions concerned with agricultural mechanization to develop and adapt appropriate technologies which are consistent with the situations in the country. This should be taken as a challenge to these institutions for the betterment of the agricultural sector.

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Performance of the Japanese Impeller-Type Rice Husker

by
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Introduction

Although the centrifugal rice husker invented in 1916 has considerably gained popularity in Japan, some rubber roll type huskers have mainly been used up to this time. However, as an impeller type husker has been newly developed in recent years, some tests have been carried out in order to evaluate the husking performance of the machine.

Fig. 1 shows the husker used in this test. It consists of two husking impellers and a cleaning fan. They are driven by one shaft. The specification of this machine is shown in **Table 1**. **Fig. 2** shows another impeller type husker improved after the present research. This type has only one impeller and a cleaning fan and a grain-screen set which ensures the separation of rough rice and brown rice.

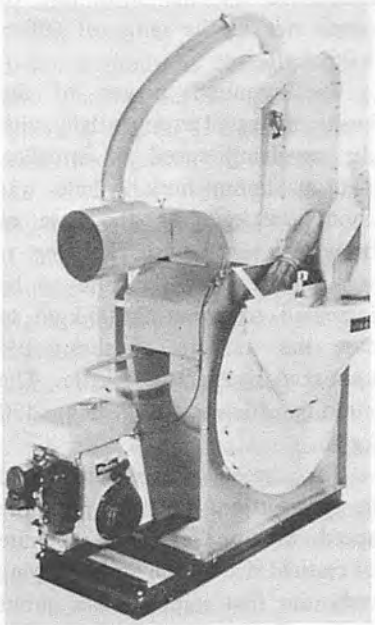

Fig. 1 The husker used in this test

Table 1 Specification of impeller type husker

Length	1120 mm
Width	700 mm
Height	1750 mm
Weight	100 kg
First impeller's diam.	500 mm
Second impeller's diam.	400 mm
Revolving speed	1350 ~ 1650 rpm

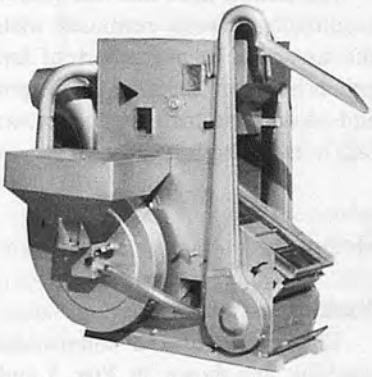

Fig. 2 The improved type husker

Experimental Methods

Structure of impeller

As shown in **Fig. 3**, an impeller has many blades and rotates in its casing. The side plates and blades are made of special plastics and the casing has a urethane lining of 10 mm thickness inside. The rough rice ejected from the impeller are given some impact action by the lining.

In order to understand the husking mechanism of an impeller, a commercial impeller and 5 modified ones were used for the test.

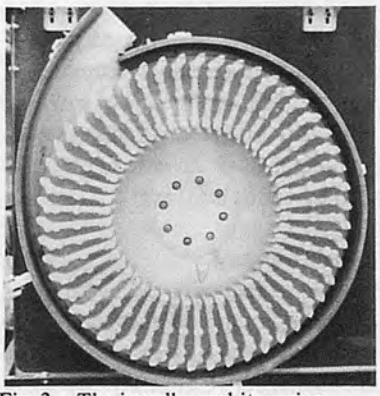

Fig. 3 The impeller and its casing

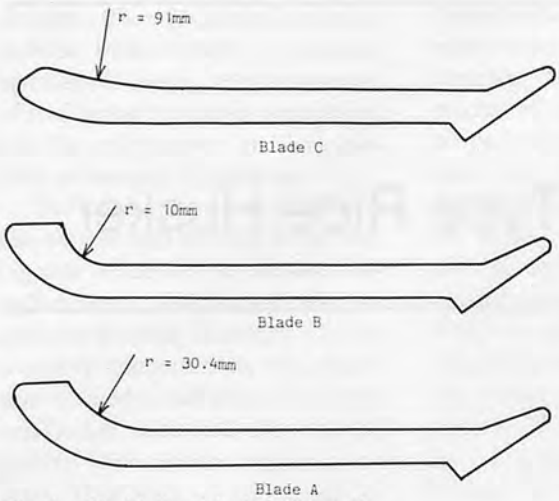

Fig. 4 The blade of the impeller used

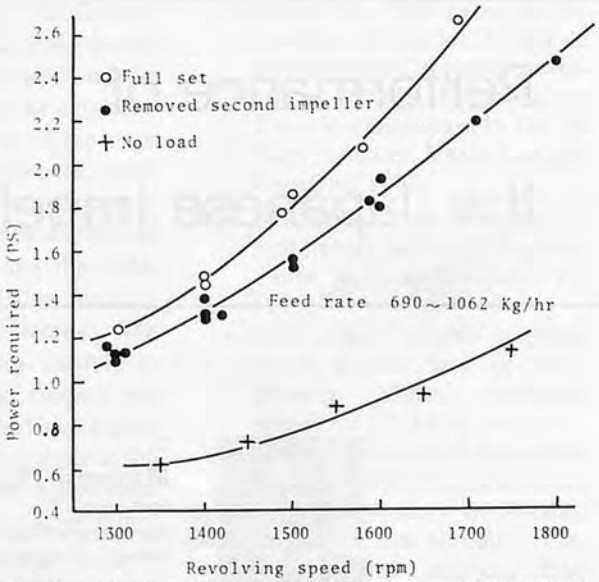

Fig. 6 Relation between required power and revolving speed

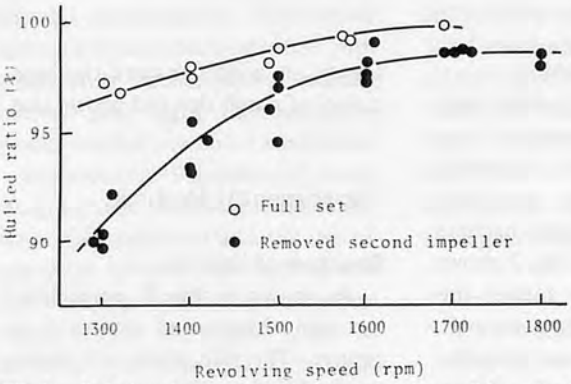

Fig. 5 Relation between hulled ratio and revolving speed of impeller

A : Commerical, the shape of blades is a in **Fig. 4**.

B : Modified, the shape of blade is b in **Fig. 4**.

C : Modified, the shape of blade is C in **Fig. 4**.

A_1 : Modified, it has blades half as many as A.

A_2 : Modified, the upper part of half blades of A is removed.

A_3 : Modified, the lower part of half blades of A is removed.

The number of blades of A is 50 and the width is 50 mm.

Rough rice used

The Japanese rice varieties, *Kiyonishiki* and *Hanahikari*, were produced in the experimental farm of Yamagata University in 1977 and 1978. The moisture content of 13.5 ~ 14.3 % were attained by the use of a hot-air dryer. The rough rice grains were cleaned by a small winnower before the test. The weight of 1 000 grains of rough and brown rice was 26.23 g and 22.17 g, respectively.

The hulled ratio and the power requirements were examined with the use of revolving speed of impeller between 1 350 ~ 1 750 rpm and feed rate of rough rice at 540 ~ 1 440 kg/h.

Results

Husking performance

The results of the commercial machine are shown in **Figs. 5 and 6**. The blank circle in the figures shows the full set, normal machine which has two impellers, and the black one shows the machine removing the second impeller.

At the revolving speed of impeller above 1 550 rpm, the hulled ratio of the normal and other machines were more than 99 % and more than 97 %, respectively. Therefore, the husking action by the second impeller was very small.

The hulled ratio was scarcely influenced by the feed rate of rough rice in the range of 690 ~ 1 062 kg/h.

The required power of the husker increased exponentially with the revolving speed of impeller. The maximum husking rate was about 960 kg/h on the base of brown rice weight. However, it was possible for the rate to be increased to about 2 000 kg/h in case the mixture of about 1 % unhusked rice mattered little. The husking efficiency was 350 ~ 430 kg/h.

The crashed kernels increased in proportion to the revolving speed of impeller, and the rate of crashed rice by the husker having only the first impeller was about 1 % smaller than the husker having two impellers.

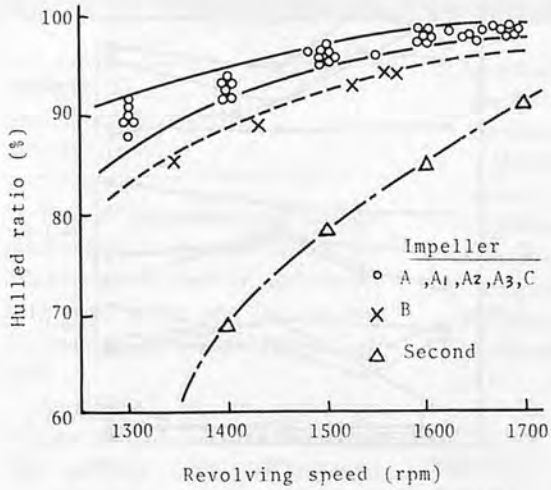

Fig. 7 Relation between hulled ratio and revolving speed (1976, *Kiyonishiki*)

Fig. 8 Test of the first impeller without its casing

Comparative test of impellers

The test was conducted in both cases: being driven with and without its casing. The feed rate of rough rice was 1 440 kg/h.

The result of the former is shown in **Fig. 7**. The hulled ratio of impeller A, A_1, A_2, A_3 and C were almost similar and B which had the largest curvature of the end of blade was the least. The hulled ratio of only the second impeller was very small possibly because of the smaller diameter.

The test of impellers being driven without its casing was put into practice in the open air as shown in **Fig. 8**. The grains ejected from the impeller fell naturally on the vinyl sheet without receiving any impact action on the way.

In order to examine the hull damage of rough rice as shown in **Fig. 9**, the following standard was decided.

No damage, no damage on the hull; Small damage, small split on the hull; Medium damage, small split on the hull and part of hull is missing; and Large damage, more than half of hull is missing.

The hull damage was examined by a stereoscope.

The results of this test are shown in **Figs 10** and **11**. From this test it was recognized that about 40 % of the grain fed were husked and about a half of the rest was subjected to various damage on the hull during the passing between the blades without any impact action by the lining of the casing.

Fig. 9 The standard of hull damage of rough rice

The husking action of B impeller was the largest and C impeller the smallest.

The hulled ratio of A_1 impeller was the lartest, which had half the number of blades as A impeller. Though the reason was not clear, this fact suggests one of the significant improvements of this husker.

From the test studying the course of grains between the blades of an impeller, it was found that the grains moved only on the front surface of a blade.

Summary

The husking performance of the newly developed rice husker which has the first and second impellers was investigated. The rough rice used for the test was cleaned by a small winnower.

At the revolving speed of impeller above 1 550 rpm, the hulled ratio was more than 99 %, and more than 97 % without the second impeller. Therefore, the husking action by the second impeller was very small.

The commercial impeller has 50 blades, but the modified impeller with 25 blades showed better results.

In Japan, brown rice containing 0.3 % rough rice is non-standardized, so with this standard the maximum husking rate and efficiency were 960 kg/h and 430 kg/ps·h.

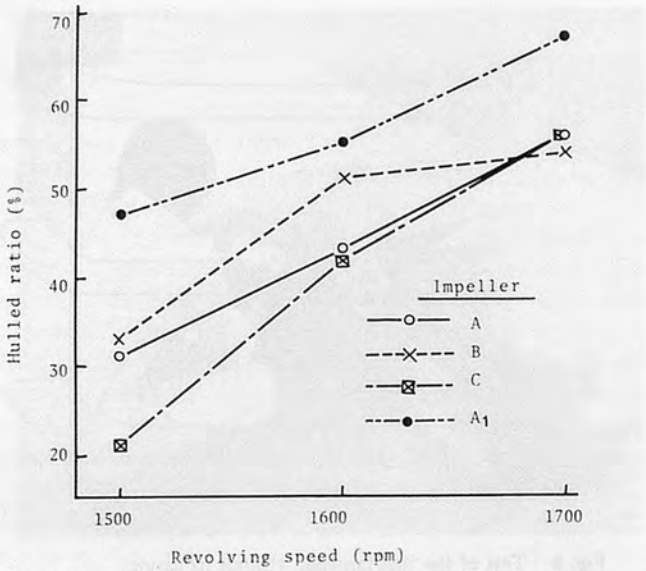

Fig. 10 Results of the first impeller without its casing (1978, *Hanahikari*)

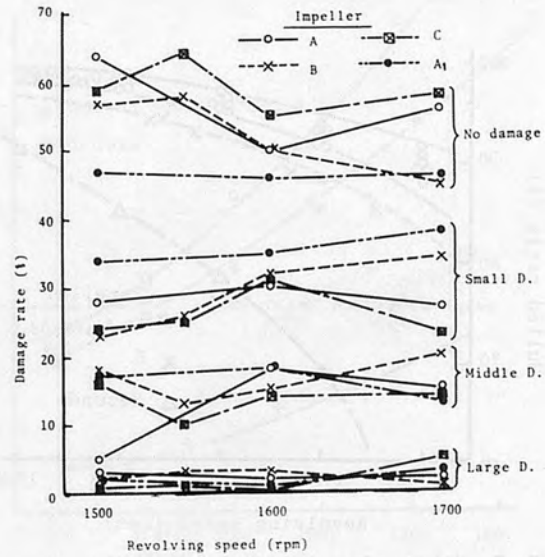

Fig. 11 Relation between hull damage rate and revolving speed

However, the husking rate of the machine with only the first impeller increased twice in case where the mixture of unhusked rice more than 1 % mattered little.

After the research, another impeller type husker was developed as shown in Fig. 2. This machine has only one impeller with 25 blades and a cleaning fan and a grain-screen set.

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Agritech '81
September 14 -17, 1981
Tel-Aviv, Israel

This is the major international mechanization and technology exhibition in the field of agriculture, held every other year for the past 16 years at the fairgrounds in Tel-Aviv.

Agritech'81 is an important worldwide showcase of more than 500 exhibits from 50 different countries, that no professional in agriculture can afford to miss.

Its displays cover all the major branches of the industry, giving the visitor a broad and comprehensive picture of existing and coming machinery, equipment, techniques, inputs, etc.:

- Machinery and Equipment
- Agrochemicals
- Irrigation Systems
- Livestock Handling
- Research & Development
- Energy Conservation
- Materials Handling & Transportation
- Plants and Seeds

Professional Symposiums:

- New methods in remote controlled irrigation
- Advances in row fertilization
- Orchard mechanization technology
- Cultivation of stony ground
- Uses of solar energy in farming

Within the framework of Agritech 81, the 2nd International Conference on Irrigation will take place in Tel Aviv. The conference will discuss the latest technological developments and up-to-date methods and techniques in the field of irrigation. The main topics include

Automation in Irrigation:

- Hydraulic, Electric and Computerized Automation Methods
- Levels of Automation
- Applications and Case Studies

Modern Concepts of Drip Irrigation:

- Soil-Water-Plant Relationship
- Spraying – Mini-Sprinkling
- Comparison to other Irrigation Methods
- Fertilization

Emmanuel U. Odigboh Received KISHIDA INTERNATIONAL AWARD

Emmanuel U. Odigboh, Professor and Head, Agriculture, University of Nigeria, Nsukka, Anambra State, Nigeria, has received the Kishida International Award from the American Society of Agricultural Engineers (ASAE).

The award is presented annually to "honor those who have made original contributions in research, development or design. . . or in the management of food processing equipment or techniques of significant economic value to the food industry and the consumer".

Odigboh was honored during the Society's Summer Meeting June 21-24 in Orlando, Florida.

ASAE is a non-profit technical, scientific and educational society committed to improving agriculture through the application of engineering principles. Headquartered in St. Joseph, Michigan, the Society's membership includes 9,000 full members and 2,300 student members in 50 states and 90 foreign countries.

Odigboh has spent much of his professional career involved in the design and development of machines to reduce drudgery from Nigeria's agriculture production. He has made significant contributions to the mechanization of tropical root crop planting and harvesting.

He is considered a primary contributor to the agrotechnology for Nigeria and the homologous countries of West Africa. He is an advisor to Nigeria's Federal Department of Agriculture and has toured European, Asian and South American countries to discuss agricultural mechanization and its impact on agriculture. He became one of the co-editors of AMA in1980.

He began his career as a math and physics instructor in Israel, and joined the University of Nigeria in 1966 as an assistant lecturer. In addition to his other accomplishments, Odigboh has authored or contributed more than 30 technical publications.

He also is active in numerous scientific and honorary societies.

Odigboh is a 1959 graduate of Bishop Shanahan College, Orlu; and a 1961 graduate of St. Patrick's College, Asaba. He is the son of Mr. & Mrs. Umennaerika Odigboh, Anambra State, Nigeria.

Odigboh obtained his bachelor's degree from the Israel Institute of Technology, Haifa, and his master's degree and doctoral degree from Pennsylvania State University, University Park.

He and wife Kate reside in Nsukka. They have six children.

The Chinese-IRRI reaper

by the IRRI reporter 1/81, March 1981

IRRI and the Chinese Academy of Agricultural Mechanization Sciences (CAAMS) initiated a collaborative project early in 1980. That project involved adapting a Chinese reaper-windrower – developed in 1973 – to the IRRI power tiller. A team of Chinese engineers brought a Chinese reaper to IRRI in July 1980.

The outstanding feature of the Chinese reaper is its lifting and gathering mechanism, which:

- holds the crop in a vertical position,
- prevents cut rice from falling even if the reaper stops while cutting,
- allows ground speed varying from 0.35 to 2.4m/ second, and
- permits harvesting of a moderately lodged crop.

The IRRI-adapted Chinese reaper is powered by the popular IRRI 6-hp diesel power tiller. Close mounting on the power tiller results in a compact, balanced, relatively light, 240-kg machine. It can operate effectively in mud 20cm deep. Reaper capacity is 0.5 ha/hour at a 3km/hour ground speed.

The reaper has performed well in field tests in Laguna, Iloilo, and Pangasinan provinces, Philippines. Grain losses range from 0.2 to 4% – much lower than average manual harvesting losses of 3-4%. Farmer reactions also have been good. Requests for information on the reaper have come from Burma, Thailand, Pakistan, and India.

IRRI engineers changed the Chinese reaper design to permit its easy manufacture in small, local shops. Belt and chain drives were added to eliminate costly, level gears. A smaller 1-m wide unit also was designed for use on a 3-hp tiller. The lighter machine worked efficiently in tests in the small paddies typical of most Central Luzon farms in the Phillipines, and many areas in Asia.

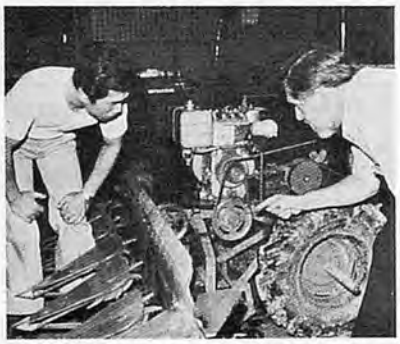
The anticipated market value for the reaper will vary depending on machine size. Two sizes are being tested – one with a 1.0-m header and the other with a 1.6-m header. The power requirements are about 2 hp/m of header. Basic cost information is in the following table.

Basic cost information for the 1.6-m Chinese-IRRI reaper

Engine cost (6-hp diesel)	US$750
Tiller cost (without engine)	US$700
Header cost	US$600
Diesel fuel	0.25/liter
Oil	0.94/liter
Diesel consumption rate	1.36 liters/h
Oil consumption rate	0.02 liter/h
Salvage value	10%
Wage rate	US$0.21/h
Interest rate	12%
Repair and maintenance rate	10% of initial cost
Tax and insurance rate	1%
Useful life	7 years
Field capacity	0.3 ha/h
Number of operators	1 person
Annual costs	
Reaper and Power Tiller as Integral Unit	
• Fixed cost ($/yr)	
Depreciation	US$236.50
Interest	123.00
Repair and maintenance	205.00
Tax and insurance	41.00
Total	US$605.50
• Variable cost ($/ha)	
Labor	US$0.69
Fuel	1.12
Oil	0.06
Total	US$1.87
Reaper Detachable from Power Tiller	
• Fixed cost ($/yr)	
Depreciation	US$ 77.14
Interest	36.00
Repair and maintenance	60.00
Tax and insurance	12.00
Total	US$185.14
• Variable cost ($/ha)	
Labor	US$0.69
Fuel	1.12
Oil	0.06
Total	US$1.87

Chief Engineer Ma Ji of the Chinese Academy of Mechanization Sciences (left) follows a reaper in on-farm tests near IRRI. Ma Ji headed a team of Chinese engineers that worked with IRRI engineers to adapt the Chinese reaper to the IRRI tiller.

In the photo at right C. W. Bockhop (left), agricultural engineer, and I. Manalili, assistant engineer, watch operation of the 1-m header powered by the IRRI 3-hp tiller.



M. L. Nafziger (right), associate engineer, and E. Dungo, agricultural engineering shop supervisor, IRRI, check the IRRI-designed belt drive for the reaper.

Publications from Central Institute of Agricultural Engineering (CIAE), Bhopal, India

1. Introducing CIAE, 1979: A pamphlet that gives CIAE's general scope. 14x22cm 16 page.

2. Annual Report for 1976-79: The first report for the beginning 3 years of CIAE. Main contents: Introduction, facilities, research activities, publications, organization, committees, trainings, meetings, awards, etc. 100 page.

3. Weeding Tools and Implements of India, Dec., 1980. Compiled by H. S. Biswas.

An attempt has been made to compile information on weeding tools and implements developed or used in India which may be useful to the research workers, small scale manufacturers and the users.

Efforts have been made to include at least one of all the important types of the weeding tools and implements used in India and the prototypes developed by the different research and other organizations. 87 page.

4. Harvesting Equipment Developed in India, Dec., 1980. Compiled by R.S. Devnani

This technical bulletin covers hand tools, bullock drawn implements and power machines for harvesting operations. Out of 30 harvesting tools and machines nine are hand tools, eight are animal drawn implements and thirteen machines are power operated. 26 of them are designed, developed, or modified under schemes supported by the ICAR. Harvesting equipment described in the bulletin are for various crops such as wheat, rice, potato, groundnut, sugarcane, safflower, fruits and grasses.

Hopefully, this bulletin will be useful to farmers, manufacturers of farm implements, research scientists and all others who are interested in agricultural development. 74 page.

5. Catalogue of Improved Agricultural Tools Implements and Equipment of India, June, 1979. Compiled by Nawab Ali, S.K. Patra and R.R. Lall

The Regional Network for Agricultural Machinery (RNAM) Program organized by the ESCAP of the UN advised that the participating country may have mutual collaboration and exchange of information with a view to manufacture and popularize improved agricultural implements. Under this program, it was decided that each country should produce a catalogue of improved implements. The CIAE has been designated as the participating national institute for this program and the scientists of the institute have taken lot of pains to prepare this catalogue which will be useful not only in India, but also other Asian countries which are participating in the RNAM project.

The authors of the publication really deserve lot of credit for undertaking this arduous task. This is the first time that such a catalogue is published in India which being incidentally an ICAR Golden Jubilee Release. 191 page

Size: 2-4 24.5x18cm, 5: 28x22cm

Study on Separation of Grain by Shape

(Japan)

by R. Yamashita, K. Goto, Hao Nguyen and H. Yoshitomi

This study deals with theoretical analysis of separating mechanism and utility approach of indent cylinder separator and thickness grader.

In rice processing facility such as milling plants, country elevators, etc., the removal of broken grain and thin unmatured grain is an important factor. The indent cylinder separator and the thickness grader have been utilized to remove broken grain and thin unmatured grain to control the quality of rice. However, the theoretical analysis of the separators has not been studied, and little is known on the separating mechanism.

This study analyses the mechanism of separation and determines the factors which have influence on the separation.

N. B. The reprint will be available upon request as long as the stock remains.

Size: 26cmx18cm, 37pp

Published by Faculty of Agriculture, Kyoto Univ., Kyoto 606, Japan.

Japanese Agricultural Machinery Catalogue '81

(Japan)

This bi-annual Catalogue is published in odd-numbered years. This 1981 edition introduces the latest models and designs of Japanese agricultural machines, equipment and facilities in 154 color and black/white photographs in 36 pages. Detailed specifications of each product are provided in 127 pages. It lists 300 leading machinery manufacturers in a directory that is conveniently indexed by trade and brand names of the product.

Other features in Japanese include recent breakthroughs and innovations incorporated in the design and functions of the new models.

The catalogue measures 18cm x 25.6 cm, contains 218 pages in limp cover and sells for ¥6,000 (sea mail) and ¥7,000 (air mail). Orders may be placed with the Shin-Norinsha Co. Ltd., 7, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo 101, Japan. ■■

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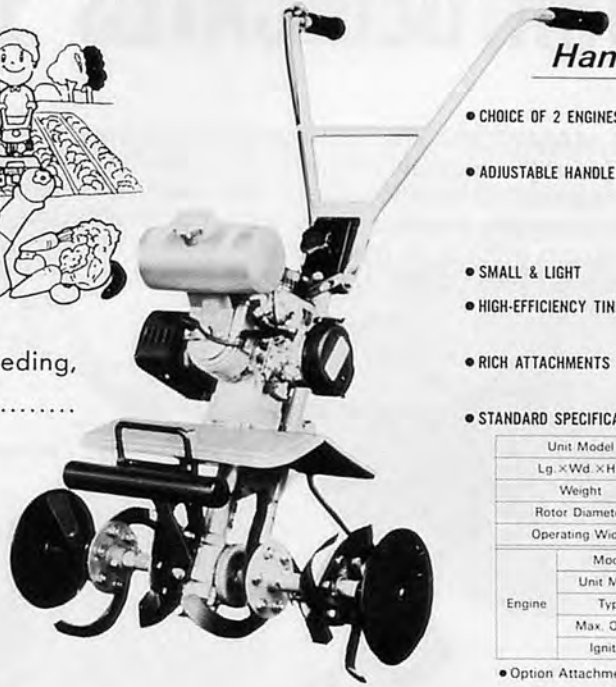

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