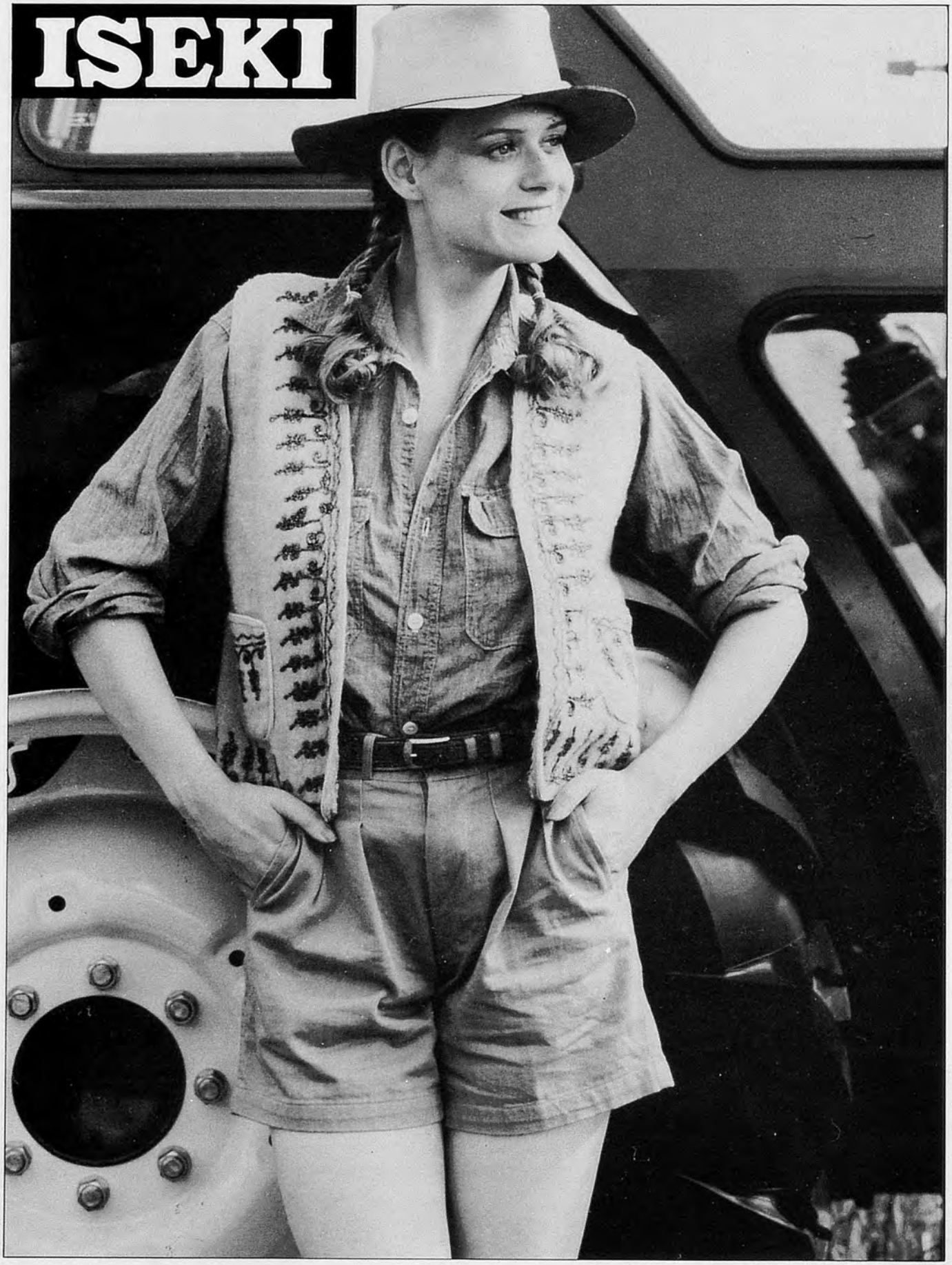
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AGRICULTURAL MECHANIZATION IN ASIA

VOL. XI, NO. 4, AUTUMN 1980

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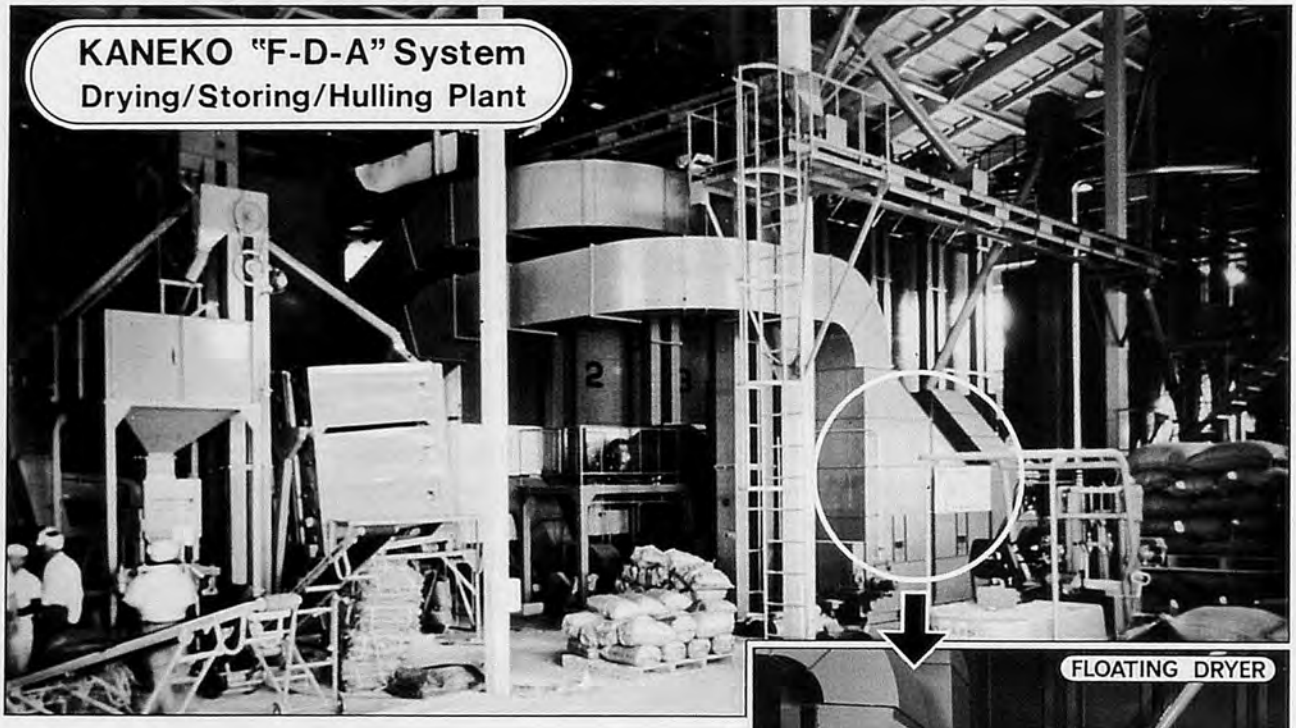
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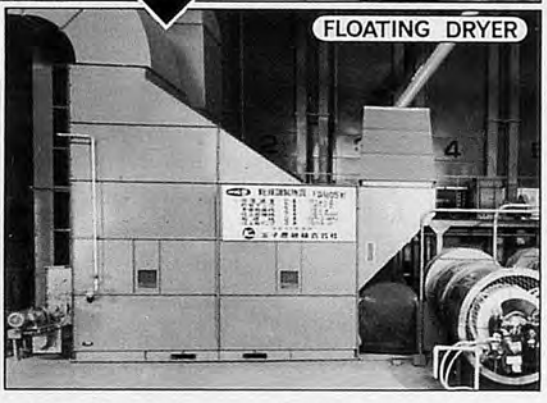


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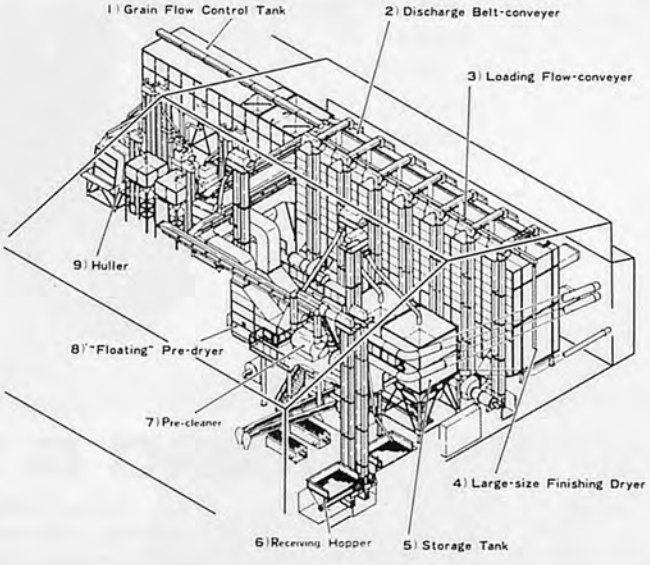
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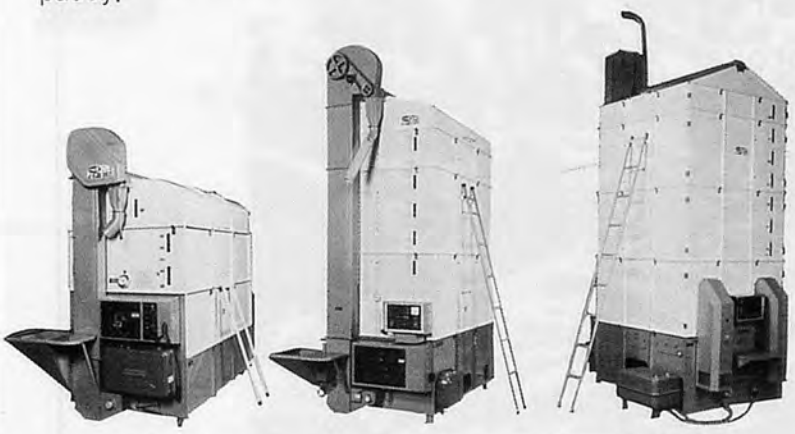
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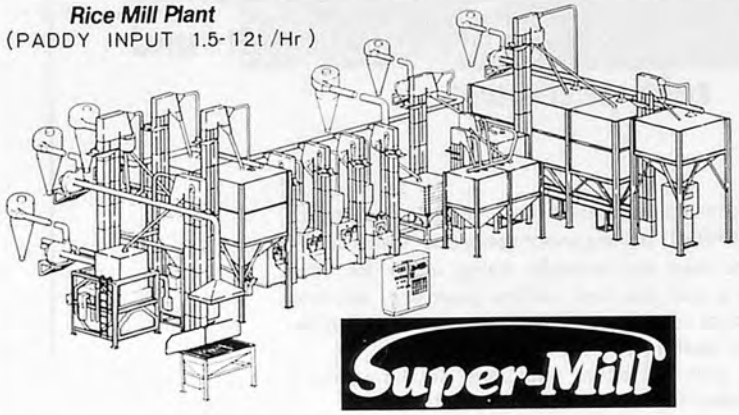
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This is the issue since the issue, Spring of 1971.

Editorial

The Energy Problem and More

This issue of the AMA carries five different articles on cushioning the detrimental effects of the energy problems that face both the developing and developed countries. Elsewhere, scores of scientists continue to find ways of harnessing such renewable resources as the solar energy, the wind and the waves; extracting alcohol from agricultural products such as sugarcane and cassava; and otherwise developing synthetic fuels to complement if not substitute the dwindling and costly supply of fossil fuel.

All this indicates a global awareness of the magnitude of the problem and a total effort to keep running the factories that manufacture the goods; the farms that produce the food; the machines that move the goods and the food; and to light, warm or cool the homes and offices so that life itself might be made more comfortable in the face of the problems that the energy shortage breeds.

As if to compound the problem, the vagaries of Nature occasionally contribute their toll. The recent eruption of St. Helens volcano in Washington State in the US has spawned agricultural problems that will defy solution for at least the next few years. Or, the past summer that was unusually cold and provided only about 50 percent of the total radiation normally required by the ripening grains and fruits in temperate and semi-temperate countries such as Japan and the Republic of Korea. The net effect of this unusual weather portends reduced yields of rice and other crops and, possibly, the emergence of new and more destructive plant pests and diseases. Add to this the devastating drought that recently brought havoc to life, agricultural crops and livestock in many African countries.

Inspite of these problems, the universal drive for farm mechanization technology and its transfer to needy areas must go unabated – perhaps with greater intensity than ever before. Such timely land preparation and planting of crops, or large-scale crop protection measures which are only possible through mechanization must always be given due consideration. This is the more hopeful and practical way of averting the bad effects of the energy problems and those that Nature cause now and then.

And as before, the AMA will continue to paly its role in disseminating research results or news of use to those who need it.

Yoshisuke Kishida
Chief Editor

October, 1980
Tokyo

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ENERGY RESOURCES

Bin Drying of Grain and Grass with Solar Heated Air



by
W. Wieneke
Professor and Head
Department of Agricultural Engineering
Göttingen University
West Germany

Introduction

Currently, considerable research and development projects are being undertaken in the use of solar energy for bin drying. Especially low temperature bin drying systems were equipped with solar air collectors to replace fuel energy. Low temperature drying means a temperature rise within 5 to 8°C. Most of the results in bin drying of cereals with solar heated air concern corn drying in the USA during September to October or later. Due to the relative high moisture content of maize and the late season with less intensive solar radiation, the solar heating systems of bin drying do not appear to be economically feasible in most cases in the american corn belt at the time (1). More favourable are the conditions for solar grain drying with initial moisture content of 20 – 22%. Generally, supplemental solar heat reduces the required air flow rate by 10 – 15% compared to ambient air drying.

The funds for the tests in 1977 and 1978 were supplied by Federal Ministry for Research and Technology.

Collector and Drying Tests

The tests carried out had the purpose of suggesting suitable solar air collectors for bin drying of grain and hay and to examine and optimize the complete system of air collector and drying plant.

Solar air collectors

Numerous collector designs with different efficiencies have been used in the application of solar air heating for drying.

For a low temperature rise of the drying air, simple collector designs are appropriate for bin drying of grain. Such designs have relatively high efficiencies at low temperature difference **(Fig. 1)**.

Collectors with double glass plates, selective coated or even vacuum insulated cover do not perform better in the low temperature range because of transmission loss of the rays. In the high temperature range they work, on the other hand, more effectively.

These designs are therefore advantageous, should solar collectors besides drying, be applied for heating purposes.

Figs. 2 and 3 show some characteristics of air collectors used for bin drying determined hitherto in numerous world-wide tests and our own results from Grimm and Hartmann (3, 4).

The air flow has decisive influence on the efficiency of all collector types. It appears that more complex collectors readily reach a better efficiency than the simpler designs at lower air flow rates.

The static loss of pressure of the collector increases with air velocity. For a re-equipment of an existing drying plant for hay, this loss of pressure should not exceed 10 – 15 mm column of water so that the available blower can still be used. For grain drying, it seems that a loss of pressure of 30 – 40 mm column of water is still tolerable.

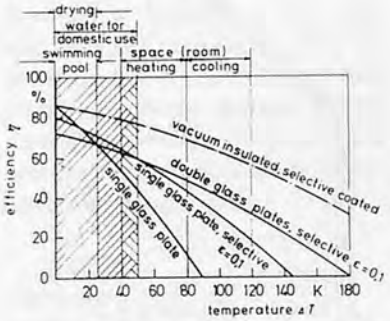


Fig. 1 Designs of solar collectors and their ranges of application (2, Kalischer)

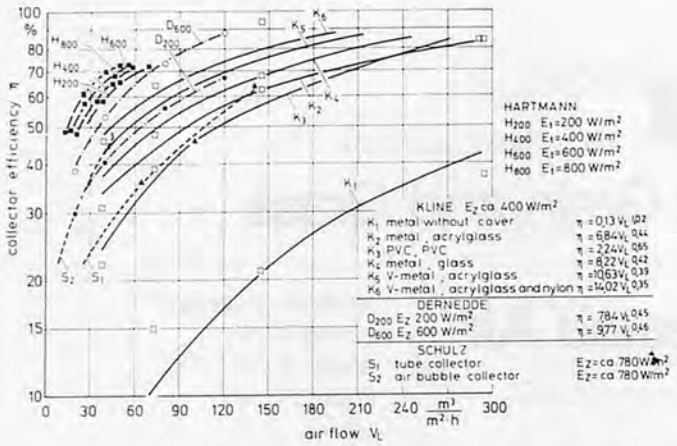


Fig. 2 Air collector efficiency versus air flow (5, Dernedde; 3, Hartmann; 6, Kline; 1, Schulz)

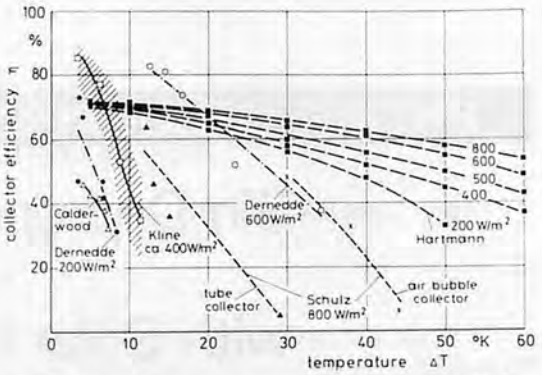


Fig. 3 Air collector efficiency versus temperature (8, Calderwood; 5, Dernedde; 3, Hartmann; 6, Kline; 1, Schulz)

Fig. 3 shows the influence of the temperature difference and the radiation intensity on the efficiency of the tested solar air collectors.

Simpler collectors indicate, especially because of poor insulation, a steep decline of the characteristic; complex designs still offer relatively high efficiencies in range from 40 to 50° C rise in temperature. High radiation intensity improves collector efficiency. It seems possible to integrate solar collectors and absorbers in the jacket of a building, especially in the roof.

A combination of the heat absorbing elements with the architectural jacket leads through the use of supporting construction as well as the inclusion of the available roof cover, to space-saving and cost-limiting solutions and can, moreover, contribute to the insulation of the building.

Figs. 4 to 7 show designs and efficiencies of solar-roof-air collectors. Roof absorbers with low conduction of heat, like currugated asbestos and corrugated bitumen, indicate a relatively low efficiency. The less common roof with zinc coated steel sheet permits the heat flow to penetrate more easily. A transparent cover of the absorber raises the efficiency.

Solar bin drying

Bin driers equipped with solar collectors were tested for grass and grain. The weather condition and radiation during 1977 and 1978 were unfavourable compared with the long standing average (**Fig. 8**); so the initial moisture content of grain ranges from 22 to 24%. By equipping the plant with 4 m² solar collectors in double glass design per m³ grain volume, we succeeded in drying the grain (**Fig. 9**). The energy of solar heated air in comparison to energy content of ambient air over a period is plotted in **Fig. 10**. **Fig. 11** illustrates the typical characteristic of energy supply and consumption.

It is clearly perceptible that in the afternoons the stored heat in the low staple region is recalled. In this case, it is the energy from irradiation which was stored in the morning. This energy heated the lower part of the corn staple to such an extent that the grain was over-dried.

Over-drying is to be considered uneconomical. In addition, the heating of the grain can take values that might eventually lead to grain spoilage. In the tests, temperature of the air supply in the corn staples up to 55°C were reached; this,

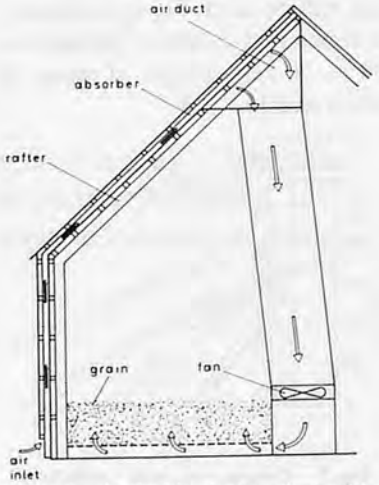
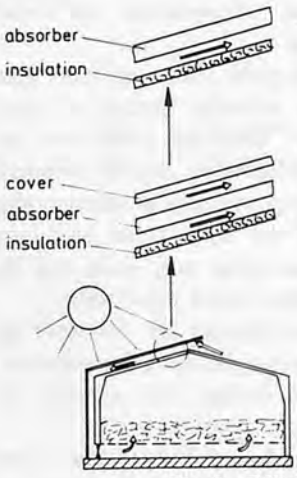


Fig. 4 Grain bin drying plant with solar roof (9, Jansson)



material		efficiency
corrugated bitumen,	black	= 20%
corrugated asbestos,	black	= 25%
corrugated asbestos,	dull lac (varnish)	= 33%
steel sheet,	zinccoated black	= 36%
GFK/ corrugated asbestos,	dull lac (varnish)	= 57%
Hostaphan/ corrugated asbestos,	dull lac (varnish)	= 62%

$V_L = 130\ m^3/m^2\ h$

$\Delta t = 5 - 10°\ C$

Fig. 5 Efficiencies of roof collectors (5, Dernedde)

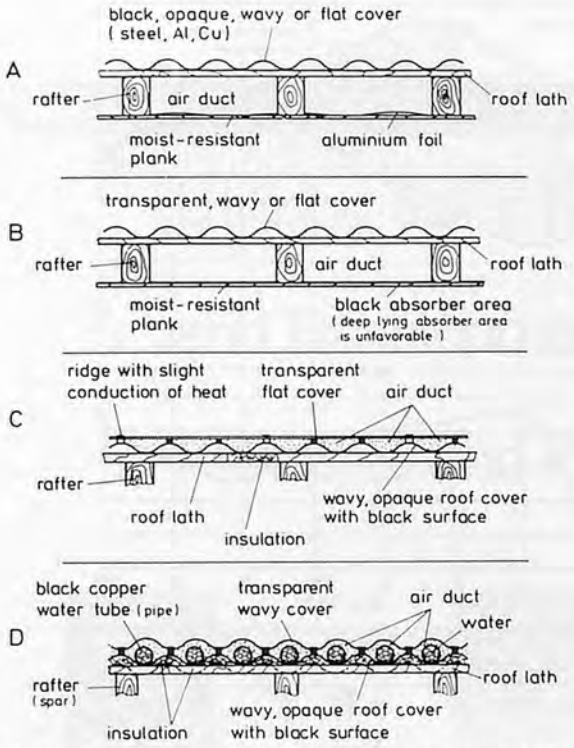


Fig. 6 Simple solar roof air collectors. Institute for Agric. Engineering Göttingen

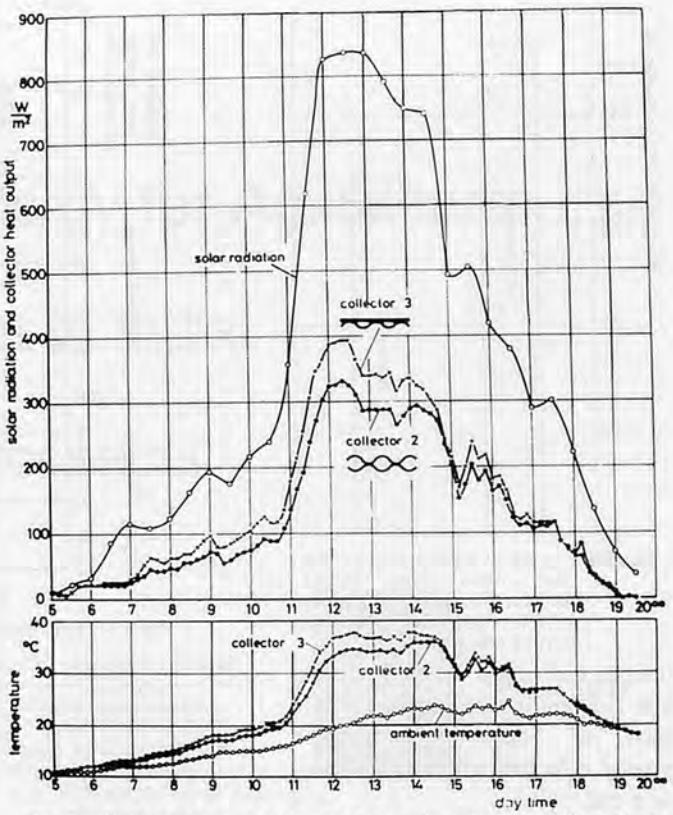


Fig. 7 Performance and temperature characteristics of roof air collectors (4, Grimm)

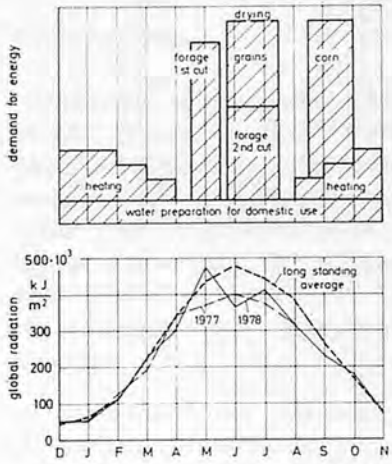


Fig. 8 Yearly radiation and demand of energy (3, Hartmann)

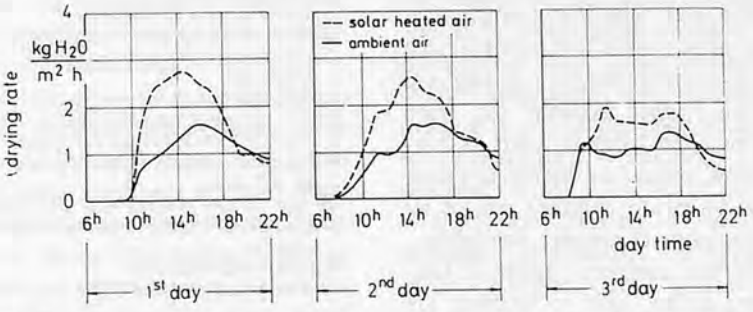


Fig. 9 Drying rate of wheat in a solar heated bin compared with ambient air drying (3, Hartmann)

however, didn't cause loss of germination.

The problems of over-drying and corn spilage give rise to the considerations that such dangers can be avoided. One could think of adjusting the air flow to the supply of sun energy, whereby limitation of this possibility is given by rising loss of pressure.

As a next step, a separate thermal storage device could be included in the considerations to serve as a short term buffer for the day-night-rhythm.

Economic Considerations

A collector energy output of 200 W/m² has resulted from the long standing average drying conditions prevailing in Göttingen region from June to October.

For a fuel price of 0.60 DM/liter, then 1 m² collector, including canal system, can cost about 40 DM/m² **(Table 1)**, which does appear feasible. In 1978 Kline and Odekirk (10) came to these comparable values; they consider it possible, at rising energy prices, for an economical application of a collector made of wood with ground insulation and acryl glass cover to cost nearly 50 DM/m².

In order to extend the utilization period of solar air collectors, it would be desirable if they were also used for preparation of warm water, and in connection with heat pump for home heating. These measures would improve the economy or would obviate higher collector prices.

Summary

Bin drying of grain and hay operates favourably within the low

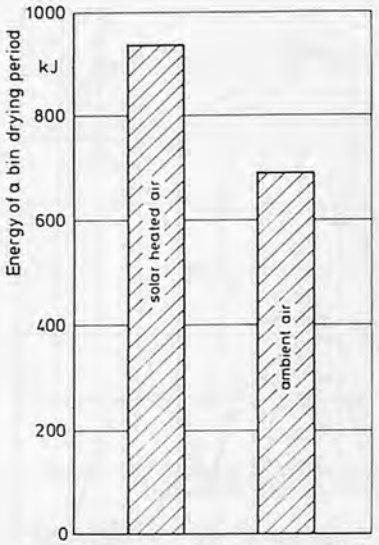


Fig. 10 Energy of a bin drying period over three days. Initial moisture content of wheat: 23.5%. Final moisture content of wheat: 16%

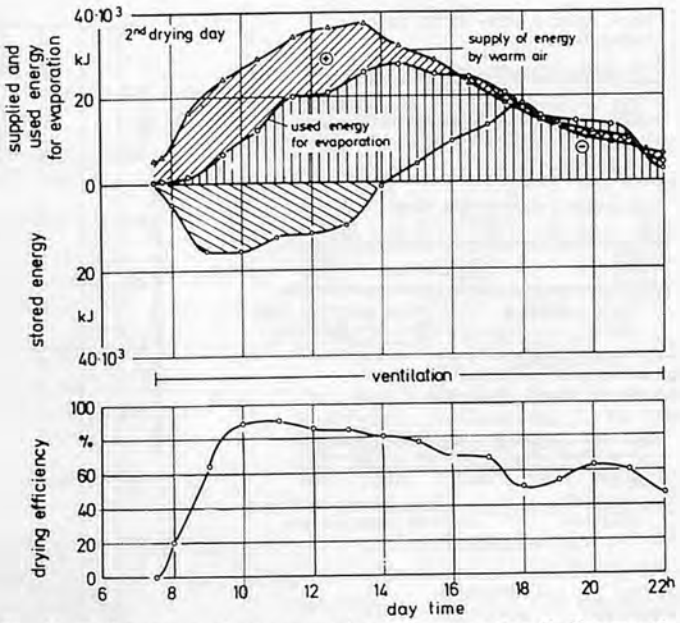


Fig. 11 Daily process of energy supply and consumption (3, Hartmann)

temperature range up to 8° C. For low temperature bin drying, simple solar air collectors have been proved effective with an efficiency of η coll. ~ 0.5.

The specific air flow of collector averages about 100 m^3 per m^2 collector area. The static pressure at this range should not exeed 10 mm water column for hay drying and 40 mm water column for grain drying. The filled bin acts as heat storage; means are therefore necessary to ensure constant rise of air temperature to prevent overdrying.

In the northern region of Germany during June to October the average solar radiation is 400 W/m^2. That means, the collector generates 200 Watt per m^2 collector area (η coll. = 0.5). In comparison with fuel heated air at a price of 0.60 DM per liter fuel, the price equivalent of 1 m^2 collector area is DM 40 to DM 80 corresponding to 200 – 400 hours of operation per season. Simple roof collectors are to be designed at this level.

Table 1. Economy of Solar Bin Drying

Average solar radiation June to October	W/m^2		400	
Collector efficiency			0.5	
Collector energy output	W/m^2		200	
Collector energy output	$kJ/m^2 h$		720	
Collector air flow	$m^3/m^2 \cdot h$		100	
Collector air flow	$kg/m^2 \cdot h$		120	
Specific solar energy supply per kg air	kJ/kg air		6	
Specific heat of air	$kJ/kg \cdot K$		1,005	
Temperature rise	K		5.97	
Specific air rate of bin drier	$m^3/m^2 \cdot h$		360	
Area of collector area of bin drier	m^2 coll./m^2 drier		3.6	
Water evaporation of grain per kg drying air	g_w/kg air		1.9	
Drying rate	g_w/m^2 drier h		820.8	
Hours of operation per season	h/a	200	300	400
Collector energy output per season	kWh/a·m^2 coll	40	60	80
Evaporated mass of water per season per m^2 coll.	kg/a·m^2coll.	45.6	68.4	91.2
In case of fuel heating with 0,13 DM/kg H_2O limited specific annual collector costs	DM/a·m^2 coll.	5.92	8.89	11.85
Limited collector cost (15% yearly depreciation)	DM/m^2 coll.	39.52	59.28	79.04

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ENERGY RESOURCES

Utilizing Solar Energy for Agriculture and Development in India: Problems and Prospects



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Introduction

India, like many other countries of the Tropics, is blessed with plentiful sunshine all the year round. In May, the hottest month of the year, India receives, on the average, 548 cal./cm^2/day of total solar radiation on horizontal plane, the highest being received at Bhavnagar (655 cal./cm^2/day), closely followed by Joadhpur (651 cal./cm^2/day). The annual average of the total solar radiation, for the country as a whole, is about 449 cal./cm^2/day. India, thus, possesses a large potential for utilisation of solar energy for various purposes.

More than 80 per cent of India's population resides in half-a-million dispersed villages. It is obvious, therefore, that agriculture and rural development should receive first priority in all programmes related to solar energy utilization.

The Problem

The general standard of living of the rural population is relatively poor as compared with their counterparts in cities. The production of food, fodder and fuel to meet the growing needs of human and livestock population, and household chores, continue to pose a serious problem in rural areas of developing countries, particularly in India. Conventional energy resources, which are non-renewable, are fast depleting. The only plausible course left is a) to search for alternate sources of energy, b) to conserve the non-renewable resources; and c) to utilize the non-renewable resources most efficiently.

The immediate basic requirements of the rural areas in India are : a) drinking water, b) fuel for cooking, and c) electricity for lift irrigation purposes, grinding corn and lighting for domestic use. There are many villages in India, mostly located in Rajasthan, Gujarat, Haryana and parts of Andhra Pradesh, where potable water is not available. It has to be fetched from far off distances and in doing so two or three members of the family have often to engage themselves in the job daily. This results in tremendous wastage of manpower. This vast potential could otherwise be fruitfully utilised in productive jobs relating to agriculture and cottage industries.

Fuel for cooking is another pressing requirement. Cowdung cakes, firewood and agricultural wastes are the three principal sources of energy available in the villages for cooking food. If the food could be cooked well and on time (mostly before sunrise), the common village folks will be satisfied. In the distant future, perhaps, the villages would be requiring energy of getting hot water for bathing, washing clothes, and cleaning of utensils. Currently, indiscriminate felling of trees for meeting the firewood requirements goes on unabated. This leads to serious imbalances in the ecosystem. The consequences are disastrous in a fragile ecosystem like that of the Indian Arid Zone. Large scale burning of cowdung cakes and agricultural wastes —

both low energy sources – deprives the farmers of the valuable organic resource, which when judiciously recycled, could lead to sustained agricultural production.

Fossil fuels are being currently used for pumping underground water for irrigation purposes and lighting for domestic use in rural India. A fortunate few, covered by the national electric grid, are able to use electricity. The possibilities of taking electric grid to all remote and dispersed villages are bleak, understandably because of economic constraints. Alternate sources of energy will have to be found – sooner the better. Solar energy and biogas hold bright prospects for providing an alternate source of energy for agriculture and rural development in India.

Potable Water for Rural Masses

Solar energy could be utilised for providing potable water to rural masses through the use of solar stills. Distilled water thus obtained could also be used in batteries needed for operating tractors and other farm machinery, and put multiple uses in rural health centres. In villages where availability of potable water poses a serious problem, solar stills could form part of the rural water supply scheme. Utilisation of wind power for lifting saline underground water through a wind mill and rendering the same potable through distillation by a series of solar stills, has formed a part of the rural supply scheme in village Bhaleri, district Churu, in Rajasthan State. A large solar still (capacity 5,000 litres/day) has been installed by the Central Salts and Marine Chemical Research Institute, Bhavnagar, in village Avania, near Bhavnagar. It is reported to be working satisfactorily.

A systematic study to optimize the size of the solar still and the effects of various climatic parameters on the solar still output has been conducted at the Central Arid Zone Research Institute, (CAZRI) Jodhpur (2). Double sloped solar still with base insulation and 10° angle of glass cover was found most effective when the direction of the long axis was along the east-west direction. The distillate output varied from 3 litre/m^2 day in winter season to 5 litre/m^2 day in summer season. The cost of distillate is about 3 paise/litre (**Fig. 1**).

Biogas Utilisation for Cooking and Lighting

Much of the problem of firewood shortage and cooking food with valuable organic resources (cowdung, agricultural wastes, etc.) could be alleviated, in great measure, by utilising biogas (mostly methane) obtained from anaerobic fermentation of organic materials, viz., cowdung, crop residues, water hyacinth etc. It is estimated that about 987 million tonnes of cowdung is available yearly in India. It can produce 66,644.3 million cu.m. of biogas. Besides biogas, it would give 428.7 million tonnes of organic manure containing 6.4 million tonnes of nitrogen, 5.4 million tonnes of P_2O_5, and 3.9 million tonnes of K_2O. One cu.m. of biogas is equivalent to 2.44 kg coal or 3.98 kwh electricity or 0.65 litre kerosene. The thermal efficiency of biogas is 60 per cent compared with only 11 per cent for cowdung. Thus, the cooking time is reduced with biogas giving more time to house-wives for other productive work. The blue flame of the gas keeps the utensils and kitchen clean, thus improving the hygenic conditions.

In India about 40 thousand biogas plants are in operation at present. Basically, those biogas



Fig. 1 Double-sloped solar stills installed at Solar Energy yard at CAZRI, Jodhpur.

plants comprise a digester or fermentation tank with an inlet through which the material after mixing with water is fed and a gas holder where the produced gas is collected and used through an outlet provided at the top of the gas holder.

The major problems which are associated with the operation of these biogas plants are : 1) There is a marked shortfall in gas output during the winter season when the temperature of the slurry is low, 2) The gas holder gets corroded in due course of time; and 3) The cost of installation is quite high.

To solve these problems, work on the development of a low cost biogas plant has started at the CAZRI. The objective is to utilize solar energy for maintaining the temperature of slurry in winter months and also to evolve a design which is cheap but efficient.

An IARI type biogas plant (capacity 3 cu.m.) has been installed at village Daijar near Jodhpur (**Fig. 2**). The gas output from this biogas plant is sufficient to cook food, twice a day, for five to six members of a family and provide light to a lamp for two hours. A solar water heater



Fig. 2 An IARI type bio-gas plant (capacity 3 cu.m) installed in village Daiger, District Jodhpur, Rajasthan, India.

is placed near the biogas plant and the slurry is made in solar heated water. The performance of the biogas plant was found satisfactory but adds to the cost of the system, which is already quite high.

Another biogas plant of KVIC type (capacity 1 cu.m.) has been installed in the Energy Laboratory of CAZRI, for studying the effects of several operational parameters on the gas output. To increase the gas output during winter months, a green house was installed around the biogas plant for conserving the heat inside the digester. Though there was an increase in the gas output, it was not viable, because of weathering effect on plastic sheet and its disintegration through high wind speed.

The problem of heavy corrosion of metallic gas holder is also severe. It requires quite frequent paintings of the drum with a view to increasing its life. Other materials, like plastic coated sheet, ferrocement, asbestos etc., can also be used for making the gas holder.

The Planning Research and Action Institute (PRAI), Lucknow has made several biogas plants based on Chinese technology where the slurry is always under the ground and is never exposed to the sky. The distinct feature of this design is that the gas holder and the digestor are combined into one unit. When the biogas is formed, it ascends towards the top of the roof and pushes the effluent down. The displaced level of the effluent thus provides the necessary pressure for the gas. There are several advantages in this type of biogas plants, viz., i) the slurry is inside the ground and is not exposed to the sky; ii) the temperature is comparatively higher than in conventional biogas plants and as such there is no problem with regard to its operation in the winter months, iii) the wear and tear, and maintenance are reduced to the minimum as there are no moving parts in the design; and iv) problems associated with the metallic gas holder, viz., corrosion, is also eliminated. The cost of this biogas plant is reported to be almost half of the cost of the conventional biogas plants. However, gas leakage is the major problem associated with such types of plants. Work on designing, constructing and installing an efficient biogas plant is currently under progress.

Solar Cookers for Farmers

Several Institutes in India, like KVIC, Ahmedabed; PAU, Ludhiana; NPL, New Delhi; Defence Laboratory, Jodhpur have developed solar cookers of different types. However, none of these cookers appeal to the rural masses. An efficient but cheap cooker could be a boon to the housewife of small or marginal farmer.

An economic and more systematic study on the development of suitable solar cooker was undertaken at the CAZRI. Five different types of solar cookers were designed, fabricated and field tested. Of these, a solar oven has been found to be the best (3). The oven can be manually tilted and oriented towards the sun. A cradle-like cooking platform is made in the oven which helps keep the vessel containing food horizontal, irrespective of the position of the sun.

Few such solar ovens fabricated at the Institute have been installed in villages for demonstration-cum-test purposes and performance has been found satisfactory (**Fig. 3**). On very clear days, the maximum plate temperature in the oven reaches 350°C in summer and 250°C in winter. Almost all food preparations like cooking, roasting, baking and boiling can be done within 25 to 75 minutes under clear sky conditions.

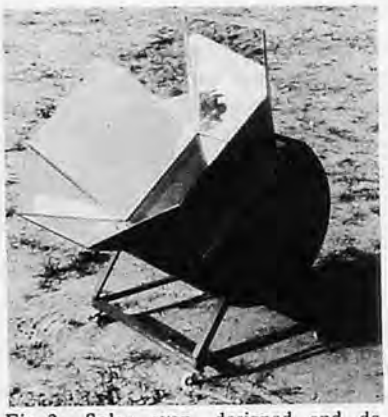


Fig. 3 Solar oven, designed and developed at CAZRI, Jodhpur

The main raw materials required for the oven are aluminium sheet, wooden plank, aluminium and M.S. angle iron, looking glass sheets, castor wheels, etc. all of which are locally available. The cost of production of this solar oven is Rs. 350, including the material and labour cost. The main advantage of this solar oven lies in its high efficiency because its performance is unaffected by wind. Further, there are no chances of dust falling into the cooking pot, a problem commonly encountered in the arid zone of India.

Because of the food habits of the Indian rural masses, it is doubtful that the solar cookers will become popular in the near future. However, efforts to design, fabricate and field test a cheap and yet efficient solar cookers should continue.

Solar Drying of Farm Products

Solar energy could be fruitfully utilised for processing fruits and vegetables. Of the three major processes, viz., canning, freezing and dehydration, it is dehydration which could conveniently be made solar-energy-based. Because of high cost of cans, sophisticated technology involved, and high cost of freezing equipments, it is the dehydration method of preservation which suits the Indian condi-

tions. The solar dryers developed at various places can be grouped as a) national sun dryer, b) direct radiation type dryers; c) forced convection type dryers, and d) mixed dryers.

For the natural sun dryer, the material is directly exposed to solar radiations. Ambient temperature, relative humidity, solar radiation intensity and wind speed are the factors which control the drying rate. The drying of grapes in racks comes under this category. The other two types of dryers in use are direct radiation type and forced convection type. The direct radiation type dryers are based on a hot-box principle: a box insulated at the base and painted with black board paint from inside and covered with transparent glass cover. Ventilation holes are provided at the base as well as at the top of the sides of the box to facilitate natural convection of air. The material, to be dried is kept inside the box. Solar radiations are absorbed by the material and inside of the chamber. Air, entering through the holes at the base, takes the moisture out. Solar cabinet dryer comes under this category.

In the forced convection type solar dryers, two separate units, one for heating the air and another for drying the material, are provided. Air is blown through the solar air heaters where it gets heated and the hot air is allowed to pass through the drying bin where the material is dried. This type of dryer is used when large quantity of agricultural produce is to be dehydrated. Sometimes the two modes of drying, viz., natural convection and forced convection are incorporated into one unit, which is known as mixed dryer. The product is heated directly by solar radiation in a chamber as well as by the hot air coming from the solar collector. Solar timber kilns are usually made of this type.

Both the direct radiation type and the forced convection type dryers for fruits and vegetables have been developed at the CAZRI. In the cabinet dryer developed at this Institute, 15-20 kg of fruits and vegetables (chillies, datepalm, *ber* etc.) could be dehydrated within 2 to 6 days (5). The cost of this dryer is about Rs. 300. The design is simple and a village carpenter can make it. In this dryer sometimes the temperature goes beyond 80°C even after loading it with the material. For reducing the inside air temperature, the door at the rear side of dryer is to be opened manually. Recently, an improved cabinet dryer with a chimney has been developed for regulating temperature (**Fig. 4**). In this dryer the chimney facilitates the natural convection of air and also regulates the temperature. It was observed that the temperature does not go beyond 60°C inside this dryer and the dried product is of better quality.

A special dryer for chillies, onions, *ber*, datepalms, grapes etc. has also been developed. (**Fig.5**). It consists of an electric blower connected to six solar air heaters connected in series and then joined to a vertical drying chamber having nine drying shelves equally spaced. The dryer was designed to dry 100 kgs of chillies from 75 per cent moisture content (w.b.) to 8 per cent moisture content (w.b.) in one day (4, 6).

Solar Pumps for Irrigation

The development of a small solar pump for irrigation purposes of (a) 2-5 kw capacity can result in an agricultural revolution. In (a) solar pump, the collector receives energy and transmits it to the heat engine. The solar energy is converted into mechanical power and, in turn, the hydraulic pump coupled with the heat engine pumps the



Fig. 4 An improved solar cabinet dryer (capacity 15-20 kg) designed and developed at CAZRI, Jodhpur

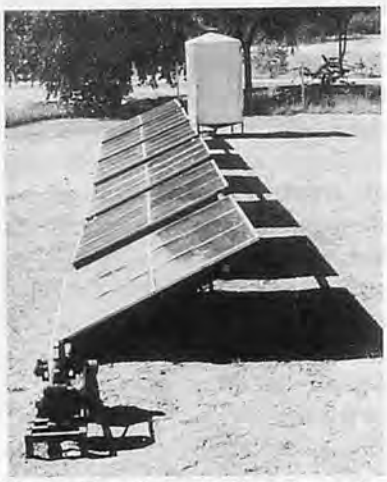


Fig. 5 Forced convection type solar agricultural dryer (capacity 100 kg)

water. The SOFRETES (A French Organization) has developed 0.15-1 kw solar pumps and installed them in Africa and Latin America. In these solar pumps, the solar heated water transfers heat to the low boiling liquid like methyl chloride, which on evaporation, produces high pressure. A reciprocating engine is actuated with the vapours of high pressure. The engine operates a hydraulic pump which lifts the water and the water thus lifted, cools the vapours. The condensed liquid is pumped back for the next cycle through a reinjection pump which is coupled with the engine. At the Aurivelle Centre for Environmental Studies, Pondicherry, the same pump is installed with locally designed flat plate collectors.

Other types of solar engines have also been developed. Farber and Prescott (1) developed a



Fig. 6 An array of tube-in-plate type flat plate collectors for heating 600 litres of water upto 80–90°C for use in a solar pump

closed cycle hot air engine plant. A solar powered irrigation plant (25 HP) near Willard, New Mexico began operation in June 1977 which can pump 2.6m^3 water per minute from a 34 m deep well (8). However, it has been estimated that at present the cost of irrigation per acre by using solar energy is 7.0 to 10.7 times higher than the diesel driven pumps (9).

Work on development of a low cost solar pump is in progress at several places in India, viz., BIT, Pilani; NPL, New Delhi; Jyoti Limited, Baroda; PAU, Ludhiana; IIT, Kanpur; CSMCRI, Bhavnagar, etc. Studies on the design and development of low cost solar pump is underway at Central Arid Zone Research Institute, Jodhpur (Fig. 6).

Rural Electrification Through Solar Energy

Solar energy can be converted into electricity directly by using semi-conductor devices known as solar cells. These devices can convert 3 percent to 24 percent of the incident solar energy into electricity with efficiency depending on intensity of solar radiation, solar cells design, material, temperature, etc. Of the various types of photovolttaic devices developed so far, only silicon cells are now commercially produced. Solar cells with efficiency up to 10 percent have been developed by IIT, Delhi and SSPL, New Delhi. India's Department of Science and Technology, has established the Central Electronics Limited for carrying out the R and D work on solar cells.

Generation of electricity can also be achieved through a central receiver type solar test facility. A large number of reflectors are placed on a large area of ground with tracking towards the sun. The reflected rays are concentrated at the top of a tower. This energy is utilised in making steam and then through turbine, electricity is generated.

Solar Energy Research for Agriculture

A coordinated research programme on operational research in solar energy utilization in agriculture has been recently (1979) initiated in India, with five cooperating centres, viz., the CAZRI; Punjab Agricultural University, Ludhiana; Tamil Nadu Agricultural University, Coimbatore; University of Udaipur, Udaipur; and the Central Rice Research Institute, Cuttack, in collaboration with the USA. The coordinating unit is located at the CAZRI. The main objective of the project is to utilize solar energy effectively for a few selected and important agricultural applications which would have an impact on both crop production and post-harvest operations. The main thrust of the programme consists in designing, developing and field testing of solar grain dryers, besides solar energy utilization biogas plants.

The test of various solar energy appliances developed by different agencies/organisations in India and abroad lies in their wide adoption by the rural masses. Poor financial resource-base of rural masses stands in the way of individual adoption of some of the appliances. However, solar stills, biogas plant, crop dryers, and solar pumps, hold the key to rural development, when adopted on a community basis.

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ENERGY RESOURCES

Availability of Solar Energy in Thailand



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Abstract

The time series of daily totals of width 100 cal/cm² d. Comparisons of the simulations by the process by dividing the daily totals of solar radiation into six classes of width 100 cal/cm² d. Comparisons of the simulations by the purely random model and the Markov chain model with the observed series of six radiation classes for different seasons of the year were made. Dividing the daily totals of solar radiation into classes of width 100 cal/cm² d and the hourly radiation into classes of width 10 cal/cm² d, fluctuations in the hourly solar radiation among these classes were examined for different seasons of the year.

Introduction

The most commonly reported data on solar radiation are in the form of monthly means of daily totals of global solar radiation. Sometimes data on diffuse solar radiation are also available. Information of this type for Thailand has been published in a paper, which surveys the geographical, seasonal and diurnal variations of mean global solar radiation and gives rough estimates of the mean diffuse solar radiation (1).

The best description of the fluctuations in solar radiation at a particular station would contain probability distributions enabling one to simulate the fluctuations accurately. Results of special interest, such as the frequency of runs of consecutive days with low radiation, could then be calculated from the probability distributions. A step in this regard has been taken by Bennet with the publication of the percentage distributions of the daily totals of global solar radiation at a number of stations in North America during June and December (2).

The simplest simulation model of time series of daily solar radiation amounts uses probability distributions estimated from the data such as those published by Bennet. The method is explained in a later section. It assumes that the radiation amount on a particular day is independent of the amount on the previous day. In reality this assumption is not correct because of the persistence of the meteorological conditions (3). The incorporation of persistence into the model requires that the time series of the daily radiation amounts be treated at least as a second order random process, and further refinements require higher order probability distributions relating radiation amounts on three or more consecutive days.

In the present paper fluctuations in an unbroken 5-yr sequence of daily totals of solar radiation in Bangkok and Chiang Mai are analysed as a discrete second order random process. Seasonal effects are shown for eight 1½ month periods into which the year has been divided for studying the seasonal variations of solar radiation. These periods, which are based on the analysis by Heywood (4), have a practical advantage over calendar months in being defined by standard solar declination values (**Table 1**). Sample results are given for the purpose of illustration. The complete results and the computer programs developed for this study are available elsewhere (5).

The term "solar radiation" as used in this paper means the sum of direct and diffuse solar

Table 1. Seasonal Periods

Date	Mean Solar Declination	
Jan 14-Feb 26	−15°50'	
Feb 27-Apr 12	0°	Spring
Apr 13-May 28	15°50'	
May 29-Jul 15	22°47'	Summer
Jul 16-Aug 31	−15°50'	
Sep 1-Oct 15	0°	Autumn
Oct 16-Nov 29	15°50'	
Nov 30-Jan 13	−22°47'	Winter

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radiation on a horizontal surface. In all the data used for this study, and in all the calculations, solar radiation was expressed in calories per square cm.

Time Series of Daily Totals of Solar Radiation

The daily totals of solar radiation were divided into six classes: A (over 600 cal/cm² d), B (500 to 600 cal/cm² d), C (400 to 500 cal/cm² d). D (300 to 400 cal/cm² d), E (200 to 300 cal/cm² d) and F (below 200 cal/cm² d). An example of the time series of radiation classes that occurred in Bangkok is shown in **Fig. 1.**
in **Fig. 1**.

A complete statistical description of the time series would contain the first order relative frequencies $f_1(A)$, $f_1(B)$, ..., $f_1(F)$ of the radiation classes A,B, ..., F respectively, the second order relative frequencies f_2 (A,A), $f_2(A,B)$,....., $f_2(B,A)$,....., $f_2(F,F)$ of the 36 pairs of radiation classes AA, AB,....., BA,....., FF respectively, on two consecutive days, the third order relative frequencies such as $f_3(A,B,C)$ on three consecutive days, and so on. The second order relative frequency distribution completely defines the first order relative frequencies in its two marginal distribution. For example $f_1(A) = f_2(A,A) + f_2(A,B) + ... + f_2(A,F) = f_2(A,A) + f_2(B,A) + ... + f_2(F,A)$. Likewise the first and second order relative frequencies are completely defined by the third order distribution, and so on. A statistical test has shown that the actual series differs significantly from this model because of the tendency of meteorological conditions to persist for several days at a time. However, it is found that the series can be adequately represented as a Markov chain with different initial probability distributions and transition probability matrices for each 1½ month periods of the year. In the present study the second order relative frequencies were determined for each 1½ month period by counting the observed occurences of each of the 36 possible pairs of radiation classes. The results are given in **Table 2.**

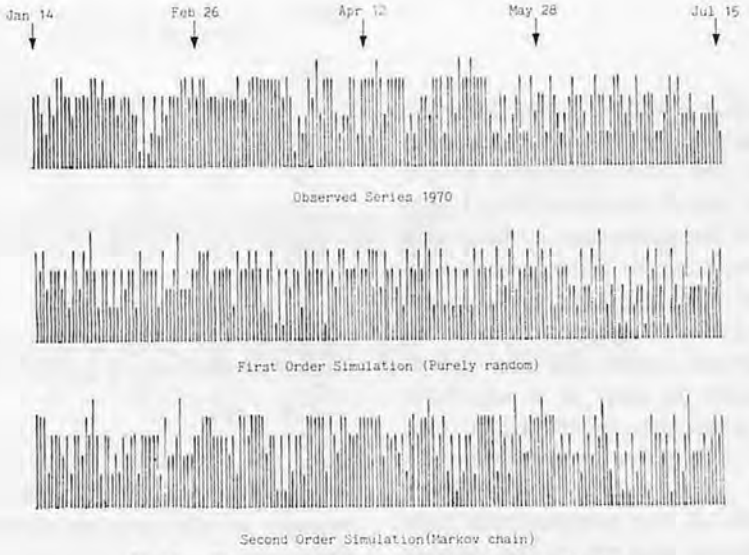


Fig. 1 Time series of solar radiation levels in Bangkok.

Table 2. Relative Frequencies of Pairs of Radiation Classes on Consecutive Day in Bangkok

Pairs of Radiation Classes	Jan 14 to Feb 26	Feb 27 to Apr 12	Apr 13 to May 26	May 29 to Jul 15	Jul 16 to Aug 31	Sep 1 to Oct 15	Oct 16 to Nov 29	Nov 30 to Jan 13
AA	.0020	–	.0023	.0020	–	.0030	.0020	–
AB	.0024	–	.0215	.0027	–	.0026	.0019	–
AC	.0036	–	.0081	.0033	–	.0021	.0043	–
AD	.0022	–	.0052	.0027	–	.0025	.0028	–
AE	.0015	–	.0016	.0008	–	.0017	.0005	–
AF	.0005	–	.0005	.0003	–	.0008	.0002	–
BA	.0024	–	.0215	.0027	–	.0026	.0019	–
BB	.0269	.2120	.1987	.0404	.0130	.0256	.0230	.0050
BC	.0391	.0969	.0753	.0494	.0261	.0215	.0520	.0154
BD	.0241	.0291	.0484	.0406	.0509	.0249	.0338	.0076
BE	.0165	.0173	.0146	.0116	.0062	.0168	.0063	.0026
BF	.0055	.0087	.0044	.0043	.0018	.0077	.0020	.0014
CA	.0043	–	.0087	.0024	–	.0023	.0039	–
CB	.0476	.1000	.0725	.0365	.0257	.0231	.0469	.0121
CC	.2279	.1929	.0871	.1278	.0478	.0686	.1649	.3099
CD	.1406	.0579	.0559	.1053	.0934	.0796	.1072	.1519
CE	.0334	.0338	.0431	.0530	.0362	.0559	.0554	.0443
CF	.0111	.0169	.0129	.0199	.0120	.0256	.0173	.0241
DA	.0027	–	.0050	.0020	–	.0027	.0025	–
DB	.0294	.0305	.0466	.0301	.0503	.0269	.0305	.0059
DC	.1406	.0579	.0559	.1053	.0934	.0796	.1072	.1519
DD	.0868	.0174	.0359	.0867	.1825	.0923	.0697	.0748
DE	.0206	.0102	.0277	.0437	.0707	.0648	.0360	.0217
DF	.0069	.0051	.0083	.0164	.0212	.0297	.0113	.0119
EA	.0006	–	.0020	.0019	–	.0014	.0011	–
EB	.0062	.0147	.0180	.0286	.0069	.0143	.0127	.0058
EC	.0404	.0359	.0407	.0431	.0359	.0571	.0531	.0421
ED	.0249	.0108	.0262	.0355	.0702	.0663	.0333	.0207
EE	.0152	.0098	.0154	.0328	.0728	.0644	.0517	.0226
EF	.0051	.0049	.0046	.0123	.0218	.0295	.0161	.0123
FA	.0002	–	.0006	.0007	–	.0007	.0003	–
FB	.0021	.0073	.0054	.0107	.0021	.0066	.0040	.0032
FC	.0135	.0179	.0122	.0162	.0108	.0262	.0160	.0229
FD	.0083	.0079	.0133	.0211	.0304	.0104	.0054	.0113
FE	.0051	.0049	.0046	.0066	.0135	.0050	.0066	.0067
FF	.0017	.0024	.0014	.0046	.0066	.0135	.0050	.0067

The incorporation of persistence into the simulation model requires that the time series of the daily radiation amounts be treated as a second order random process. Simulations of the first order as purely random process are made using the percentage distributions of the daily radiation amounts in Bangkok. Simulations of the second order are made using the calculated

Markov transition probabilities and assigning the radiation class from the first order simulation to the first day of the period. **Fig. 1** compares the simulations by the purely random model (first order simulation) and Markov chain model (second order simulation) with the observed series for the period January to July. It is very hard to judge the simulations by eye, but the better representation by the second order theory shows spells of fine weather with high radiation amounts in the periods Feb. 26 to Apr. 12 and late Nov. to early-Dec., and spells of bad weather in the periods Sept. to mid-Oct., and Jan. 14 to Feb. 26.

Hourly Fluctuation of Solar Radiation

Measurements of hourly totals of solar radiation in Bangkok and Chiang Mai are available (5). **Table 3** gives the percentage frequency distributions of the hourly totals among radiation classes of width 10 cal/cm² h for the summer solstice period in Bangkok.

In order to use the available data it is necessary to make a conversion to apparent solar time from zone mean time, which is influenced by the equation of time and the difference in longitude between the observing station and the standard meridian 105°E. The method that has been adopted in the conversion process with the help of computer has been discussed elsewhere (6).

Studies of fluctuations are made by dividing the daily total radiation amounts into classes of width 100 cal/cm² d. Also, for each hour of the day (AST) the hourly totals of solar radiation were divided into classes of width 10 cal/cm² h, including a class for zero radiation. Then for each 1½ month period and for each class of daily totals percentage frequency distributions are determined directly from the converted five years sequence of data. **Fig. 2** shows an example of the radiation fluctuations.

Table 3. Percentage Frequency Distributions of Hourly Solar Radiation in Bangkok During the Period May 29–Jul. 15

ZMT (h)	Radiation Classes (cal/cm²h) 00-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90
5-6	100								
6-7	98	2							
7-8	19	57	23	1					
8-9	2	21	29	29	18				
9-10	1	6	11	26	26	27	4		
10-11	1	1	9	17	21	26	21	4	
11-12	1	2	5	16	12	29	16	17	2
12-13	2	4	9	12	16	24	15	16	2
13-14	2	4	10	16	18	24	14	9	2
14-15	2	11	12	19	27	14	14	1	
15-16	8	14	24	22	24	7	1		
16-17	19	28	36	16	1				
17-18	73	26	1						
18-19	100								

From the analysis it is found that spring is the best season of the year which gives higher hourly radiation amounts with a peak of nearly 85 cal/cm² h and with the same peak value, fairly uniform radiation amounts are possible within the time interval from 10 h to 14 h (AST). In the dry season, the daily radiation amounts are more uniform with a less peak value in comparison with the radiation amounts in the spring transition period. During the rainy season and autumn season, more clouds occur in the afternoon hours and causes the radiation amounts to be less than that in the morning hours. It is also found that spring and winter are the best seasons of the year to have continuous output from the solar appliances of larger sizes and medium sizes, respectively.

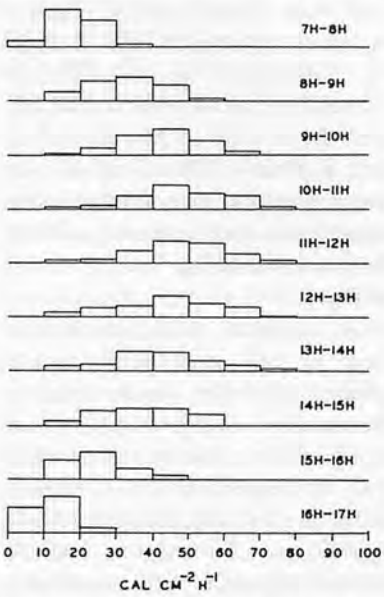


Fig. 2 Relative frequency histograms of hourly total solar radiation in Bangkok for days with daily total solar radiation from 300 to 400 cal/cm²/d in the period Sept. 1 to Oct. 15.

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ENERGY RESOURCES

Some Practical Applications of Alternative Energy Sources in Guyana



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Introduction

Guyana, the land of many waters, lies on the north-eastern coast of the South American continent. It is a fairly small country which became independent in the mid - 1960's from the old British colonial rule, when it was known as British Guiana. The approximate location of Guyana on the world map is between 2 and 8 degrees latitude north of the equator and between 57 and 61 degrees longitude west of the Prime Meridian. The north-eastern border of Guyana is the Atlantic Ocean, while it is surrounded by Venezuela and Brazil on the west and south, and by Surinam (old Dutch Guiana) on the east.

The young Co-operative Republic of Guyana has an overwhelmingly agricultural base at present, with bauxite being the only major non-agricultural export commodity. Sugar, rice and timber constitute the major products of the land which are exported along with secondary or processed products like rum and, very recently, vineger. The relatively small population of some 800,000 live mostly along the north-eastern coastal plain, of which some 220,000 live in the beautiful capital city of Georgetown at the mouth of the Demerara river.

Industrial activity in Guyana is at a low level, compared to agricultural production. A number of plans prepared by the socialist-oriented Government to increase industrial output are in various stages of completion and augurs well for the near future. One of the most common traditional energy sources, oil, is not produced in Guyana to date, although exploration activities are on hand and expectations in this respect are high. In today's market place, imported 'oil' energy is very rapidly becoming a luxury which very few developing countries like Guyana can afford. In fact, an ever increasing agricultural production is becoming necessary more to keep abreast of the rising fuel bills rather than develop the economy of the country any further than its present difficult state. A potential energy solution for Guyana exists, however, in the proposed Upper Mazaruni hydroelectric project; it is estimated that when completed it will even have energy to spare for export to neighbouring countries. While the Government of Guyana is actively pursuing this project, it is hampered by the lack of finance to undertake the entire project on its own. A number of international financial institutions are said to be actively studying the possibility of cooperating with the Government on this project.

At a smaller level of operation, a number of other projects are also being actively pursued in Guyana to provide alternative sources of energy which are considered in the present report.

Energy Needs

In order to understand the overall energy requirements of the country, it is of interest to examine the various areas of activity where energy is used and needed.

Industry

In the field of large industry, a textile mill, a glass factory and a household cooking range factory are under different stages of construction. Existing distilleries pro-

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duce various types of alcoholic products; refrigerators are manufactured in Guyana and are also exported to neighbouring countries; items of clothing manufactured in the country are popular in the Caribbean region; p.v.c. pipes are now manufactured in the country. A number of light industries produce most items of the furniture from popular Guyanese timber which have found ready markets overseas. A majority of these industries require energy in a form (electrical, mechanical or heat) which could be easily supplied by a hydro-electric plant.

Transportation

Approximately 750 km of major asphalt roads exist in the country, mainly along the coastal belt where the population is concentrated. A number of road building projects are on hand in order to open up the interior or the hinterlands. Perhaps the most important of these is the road leading south to connect Guyana with neighbouring Brazil. The interior areas are now generally served with fair weather roads and tracks where only four-wheel drive vehicles can venture during the rainy season. A considerable amount of transportation among different parts of the country is also carried out via its numerous rivers and canals. The equipment used varies from large ships requiring matching quantities of fuel oil to muscle-power operated dugout canoes.

Energy required for transportation, whether by land or water, is gasoline or diesel fuel, all of which is imported. In the absence of a well-developed public transportation system, cars operating either as private or as hired cars, usually carrying a full load of passengers, proliferate and congest the generally narrow roads. Efforts are being made to put more busses on the road, whose load carrying efficiency for a given amount of fuel is generally higher than that of cars.

Household Cooking/Lighting

The standard method of cooking, even in the remote interior areas, is at present by bottled gas which is imported. This dependence on imported energy, in a country where firewood (and also charcoal) has been extensively used in the past and is still available in plentiful supply, has come about under the aegis of 'development'. Cooking gas offers the advantages of cleanliness and efficiency which helps sell the product and the system to the masses during the last few months. However, there has been at times chronic shortages of cooking gas and has resulted in a trend to repopularize the use of more efficiently designed stoves for firewood and charcoal pots. Some enterprising individuals have already brought into the market various designs of locally manufactured stoves, which is in abundant supply, particularly in the rural areas where the cost of bottled gas is higher than in Georgetown due to additional transportation expenses.

Household lighting is almost universally provided by electricity, even in the remote areas. However, almost all of the electrical generators in the country are dependent on imported fuel oil. Due to some difficulties recently experienced in the country in receiving regular supply of fuel oil and due to mechanical breakdown of the generators, availability of electricity is not possible at all times. Kerosene lamps as a standby lighting source has again became popular. However, the oil used in the lamps is also imported and is subject to the same problems as fuel oil for generators.

Agricultural Processing

The major activities in primary agricultural processing, e.g., drying crops or fish, at the farm level, by sun-drying, while at the state or privately-owned processing plants more sophisticated and sometimes more hygienic methods are used. These include steam heaters, oil fired burners or electrical resistance heaters, most of which ultimately depend on the use of imported oil. A number of large and small agro-based industries are now operating in Guyana, producing items like jams, jellies, preserves, condiments, sauces etc., all of which need heat and electrical energy inputs in varying quantities.

Alternate Energy Sources Considered Practical

The preceding introduction indicates that the major energy requirements of the country are heat, electrical and mechanical energy, perhaps in that order of importance. A number of alternate energy sources exist in Guyana which are considered practical for development at present, in the context of the existing energy situation where locally produced oil or natural gas is not available. As and when either of these two sources are available within the country, however, the difficult energy equation as it exists now may undergo a very quick and drastic change for the better. The various alternate and practical energy sources are for producing heat, electricity and mechanical energy.

Heat Energy

Solar — Guyana is fortunate in being located close to the equator where the intensity of the sun is at its highest most of the year,

and with a population pattern where most of its inhabitants live along the flat coastal belt. Another redeeming feature is the comparatively low intensity of population, except in the capital city of Georgetown, which permits the construction of a large number of small solar collecting devices close to the spot where heat energy is needed.

A solar collecting device absorbs the energy available from the sun during the daylight hours and converts it into heat energy. While the amount of heat energy available from the sun is maximum on a clear day, even on a cloudy or overcast day approximately half of the sun's energy reaches the ground and can be utilized by a solar collector for conversion to heat energy. Although recent development of solar cells have made it possible to convert sunlight directly into electrical energy, the amount of electricity that can be produced per unit area of solar-electric cells is very small and the cost of producing the cells is still considered to be highly uneconomical, even at the present time. In addition, the sophisticated technology required for the manufacture of solar - electrical cells is beyond the realm of a developing country like Guyana and will remain so for the next decade or longer. For all practical purposes, therefore, conversion of sunlight into heat energy is the reasonable path for immediate development and utilization. The present state-of-the-art limits the use of the energy extracted from the sun for heating only, while at a later date it may be economical to use this energy also for cooling (air-conditioning) buildings during summer.

Charcoal – Guyana, located on the tropical rain belt with a largely unexplored land mass is richly endowed with various types of trees, including those useful for producing charcoal. A flourishing charcoal industry, run at a small-scale or village level, existed in the country before the advent of the modern bottled gas for household cooking purposes. Charcoal has a definite edge over timber in its natural state for use as firewood, particularly for household cooking, as it is cleaner and faster in producing heat, along with the added advantage that it is already processed for immediate use as compared to firewood.

Direct burning of wood/ agricultural waste – Firewood or agricultural waste like bagasse or rice bran, the latter items being available in large quantities only at certain times of the year, can also be used to generate heat energy in the required quantity within a confined space. Compared to charcoal they have the disadvantage of producing smoke during their release of heat, resulting in the need for a properly designed chimney to expel the smoke into the atmosphere. These sources for producing heat are considered to be more suitable today in factories or processing plants where their utilization can be more easily organized and controlled, rather than in an individual household where the cleanliness and appearance of the property is of immediate concern to the dweller.

Bio-gas – The technology of producing bio-gas from farm animal excreta, certain types of vegetative matter and from a major part of household refuse is now fairly well developed. The system has been in use in many developing countries of the world for a number of years, the technology itself is relatively simple and can be applied easily to the Guyanese way of life in its existing state of industrialization, particularly in the rural areas where the basic materials are more easily available. The fermentation or the digestion process used to produce the gas adapts itself to small-scale production, and the gas produced can be used in existing household gas cookers and ovens with only minor modifications. The system has much to recommend itself to Guyana and can go a long way to alleviating the chronic energy shortage. An added advantage of introducing the system in rural areas would be that the residue left after digestion is a very valuable organic compound which can be fed back to the soil for improved and sustained plant growth.

Electrical Energy

Perhaps the most abundant and potentially rich source for producing electricity in the country today is the famous hydroelectric project proposed at the upper reaches of the Mazaruni River, which is one of the major tributaries of the well known Essequibo River system. While much has been said and written about this scheme, as mentioned earlier, its realization is hampered by lack of funds.

There are a number of other, though lesser known, sites in the country where hydroelectricity from a natural and practically round-the-year waterfall can be produced to alleviate the energy shortage. A natural waterfall as a source of hydroelectric production has a very big advantage over hydroelectric schemes used by a number of countries where a river is dammed to form an artificial lake and then the stored water is released in regulated quantities to turn the turbines connected to the electrical generators. In the case of a natural waterfall the need for a costly dam construction and its maintenance is eliminated.

An abundant and cheap supply of electricity, as envisaged from the proposed Mazaruni scheme, would also be able to solve to a large degree the energy requirements of the country in the area of trans-

portation in the near future. Recent developmental work in industrialized countries has resulted in the production of an electrically-operated road vehicle, where the conventional engine consuming gasoline or diesel fuel is replaced by a set of batteries which provide energy to turn the wheels by means of an electric motor. The batteries are charged or replenished with electrical energy at strategically located points along the roads like the present day gasoline stations. Commercially available cars operating on electrical energy only are already available with a range of 100 - 150 kilometers on a single charge, although their prices are somewhat higher than engine-operated vehicles. Further development work and mass production techniques, however, are likely to result in a reduction of price and an increase in the range of operation in the near future.

Mechanical Energy

Wind – The use of a natural strong breeze or wind to turn the blades of a wind-mill have been used for many years in parts of Europe, and the technology needed for such utilization of wind power is relatively simple. Along most of the coastal belt of Guyana, where a major part of the people live, an abundant supply of wind is available to make the system not only feasible but also economical. While the traditional windmills of Holland, a pioneer country in this field, has been mainly used for lifting and moving water, modern wind generators are capable of producing from small to large quantities of electrical energy, depending upon the requirement.

The design and construction of a modern wind generator may not be easily accomplished locally in the present context of Guyana's industrial development. Like other mechanical equipment they can also be easily imported and would have the added advantage that once commissioned, they will continue to produce electricity day and night without any inputs like imported fuel oil. At the same time, application of the principle to simple tasks at hand can be easily initiated at present in the field of agricultural processing.

Animal (horse) – Guyana has an advantage over many other developing countries of the world, particularly those located in Africa, that the use of the draft animal for providing mechanical power is an established part of the social system. Although draft animals are not normally used in Guyana for agricultural field work like plowing, unlike most Asian countries, horses are used regularly for transportation of materials of construction, particularly long pieces of timber, over considerable distances. Good quality timber, which is easily available, is a basic material of construction for most Guyanese houses, including posts on which the house is built like a stilt under waterlogged conditions common in the coastal areas.

The long horse-drawn carts of Guyana are usually built from discarded axles and wheels of automobiles by local mechanics, working under a minimum of facilities. There is considerable room for improvement in this area of the national activity, as a more carefully designed and built horse-cart would be much more efficient than they are at present. As food and fodder for horses are quite easily available, particularly in the coastal areas, more extended use of this form of transport for many other materials of construction could reduce the consumption of imported fuel oil to a considerable extent. The country's requirement for imported trucks and other transport vehicles could also be reduced in this way.

Human (bicycle) – The direct conversion of human energy (muscle-power) efficiently to mechanical power is a subject which could easily recommend itself under a careful analysis not only in Guyana today but also in many other developing and developed countries. One of the main disadvantages of muscle-power is that the quantity available per person is small; the other important disadvantage is the resulting fatigue in the human body after a fairly short period of time under traditional methods of operation, like felling of trees or sawing of lumber, where the human hand is used as the power source.

However, the latter and more important disadvantage can be easily eliminated if efficient methods are employed for converting muscle-power into mechanical energy. The power generated by human legs are of a higher magnitude and can be sustained over a longer period of time than that by human hands. Hence, the most efficient way of converting the human effort into mechanical energy is by using the common pedal bicycle.

The bicycle, as a mechanical appliance, is used and understood almost universally at present. It is also manufactured and is available at a fairly cheap price in most developing countries of the world, where it has become a recognized means of personal and sometimes family transport.

As a means of transport, the bicycle operator has to overcome not only rolling resistance of the surface on which he travels, but also has to encounter other problems like traffic, wind resistance, unfavourable weather conditions etc., along with concentrating on steering and balance. The resistance offered by the bicycle itself, however, can be easily minimized to a very low level by proper maintenance, which is quite simple.

For transportation, an average operator can continuously use a bicycle for several hours at a moderate speed.

Without impairing the use of the bicycle as a means of transport, if it is put on a suitable stand so that the rear or the driving wheel is just off the ground, the mechanism becomes a very effective and efficient device for converting muscle-power directly into rotary motion, a form in which mechanical energy is most commonly used for operating machinery and appliances. The efficiency of conversion as a power source is also much higher than that in transport if all the other negative factors mentioned earlier are easily eliminated. The power available from the bicycle operated under stationary conditions would vary between 1/3 to 1/2 horse-power within this limit. However, a whole range of machinery and equipment can be very effectively driven by an average operator for a number of hours continuously where electricity would be otherwise needed.

At present in Guyana, where electrical power supply is frequently unobtainable, the bicycle mechanism would be a very suitable standby system; in many other situation, when electricity is simply not available in the area or electric motors are cost-prohibitive to a peasant farmer or to a rural mechanic, the bicycle mechanism would be a practical alternative. As the operator rides the bicycle mounted on a stand for developing rotary motion, his hands are free and can be utilized to perform other tasks at the same time, e.g. feeding grain into a hopper, thus increasing the efficiency of operation.

A number of practical applications of the system in the country at present are considered later in this report. While bicycles are not locally manufactured at present, immediate government action in this respect would pay large dividends to the country, as it will also ease the transportation problem to a great extent, both in urban and rural areas.

Utilizing Alternative Energy Sources

A number of proposals by individuals, organizations and various government departments have been initiated in Guyana within the last year or so for the purpose of utilizing and developing alternative energy sources. The scope and volume of the proposals vary, as their actual or potential value; these have at least clearly indicated, however, that the Government and people of Guyana are aware and very actively concerned with the dimensions of the problem and want to do something towards their solution.

From the above mentioned proposals reaching the administrative level, a few have emerged as viable, worthwhile schemes for follow-up investigation, both in terms of finance and overall scope. Those which have been given the approval are necessarily small to medium scale, practically oriented programmes. The wisdom of this line of approach is unassailable: a successful completion of even a relatively small project which can be easily watched and managed would provide the needed confidence and generate grass-roots level expertise to tackle larger, more complex and expensive schemes as the next logical step, particularly in a situation like Guyana where local expertise is rather restricted. Mistakes, if any, made at the small scale can also be locally contained and rectified without jeopardising the country's economy.

The various projects at hand and their state of development are discussed below in the same sequence and grouping as in the previous section.

Heat Energy

Solar projects at the Guyana School of Agriculture – As a result of the proposal initiated by the author during his current assignment of expert assistance through the UNESCO to the Guyana Government in the field of agricultural engineering, two projects are under execution at the Guyana School of Agriculture (GSA), located at the Mon Repos complex of the Ministry of Agriculture near the Atlantic coast, some 16 km east of Georgetown.

The first solar project at the GSA is designed to provide crop drying facilities by means of an active hot air system. Three independent flat plate solar collectors, each 14.8 sq.m. in area, are being mounted near to each other on the south facing galvanized-iron corrugated sheet roof of the newly constructed cannery building as a retrofit. Each unit is designed to draw ambient air at around 21°C for heating to around 65°C inside the collector in a single pass; the heated air is extracted from the collector by a centrifugal type fan driven by an integrally mounted fractional horse-power electric motor and conveyed by a length of p.v.c. pipe to the drying facilities located at ground level close to the cannery building. The lower surface of the solar collector and the conveying pipes in their entirety are boxed in and filled with dry sugarcane bagasse, a locally available agricultural waste which has a good heat insulating property.

The construction cost of the collector has been reduced considerably by utilizing the existing roof structure of the building as part of the collector system. It includes the existing sheet meal roof which is painted with flat black paint on the upper surface to act as the heat absorbing unit, and the existing roof frame-work which is put to additional use to

hang the box for the insulating material located under the corrugated sheet in order to minimize heat losses through the lower surface of the sheet metal roof. The depth of the box is approximately 16 cm. As the additional weight on the roof of the specially designed flat plate collector is small, no reinforcement of the existing roof structure has been necessary.

The collector frame, made out of locally available building grade timber, is bolted to the roof structure through the corrugated sheet. The two-layer light transmission system of the collector is built from 1 mm thick 'Sunlite' premium grade fiberglass sheeting, which is now manufactured in the USA for solar collector construction work. The sheet is available in any desired length and is sold in a roll, for case of handling, in widths of either 1.22 or 1.52 m. The lightweight, durable material is also treated during manufacture to withstand the effects of ultraviolet radiation. The 'Sunlite' has been selected for this project primarily because of its performance, coupled with ease of handling, and because ordinary plate glass, commonly used as an alternative transmitting material for solar collectors, is not available in Guyana. The imported fiberglass has the added advantage of being unbreakable, unlike glass, while it compares well in price with sheet glass. A specially compounded elastromeric glue is now commercially available for bonding the fiberglass to materials of construction like wood and metals.

The overall design of the solar collector system is based on that recently developed by the author for heating his home in the outskirts of Philadelphia, USA, located at around 42° latitude north of the equator. The hot air produced in the present system would be fed from underneath a wire-mesh drying tray of approximately 3 sq.m. in area, the ratio of the collector to the drying area being approximately 5 : 1. A rock-bin type heat storage facility would be built at a later date as the second stage of the project's development.

The second solar project, to be located at the recently constructed milking parlour of the G.S.A.'s livestock farm at Mon Repos, would also be a retrofit unit generally similar in design to the hot air systems mentioned above. However, this unit would provide hot water for use at the livestock farm and would incorporate a storage unit sufficient to supply hot water for a period of two days in case of inclement weather. The 3 sq.m. collector unit would be made out of a flat metal sheet, unlike the hot air systems where the existing corrugated sheets of the roof are used. The flat sheet would be mounted directly over the corrugated roofing and would have a length of 1 cm diameter copper tubing laid on its upper surface, like a radiator coil, so that water flowing through the copper tubing would have a long passage while traversing the sheet from the top to bottom. The outer surface of the tube and the upper surface of the flat sheet would be painted black like the hot air systems. The water would recirculate through the tube by means of an electric motor-driven pump to heat it from around 21°C ambient to around 90°C. As the local water supply carries a considerable amount of fine sediment in suspension, a water filtering device would be provided on the intake side of the system.

The construction of the first of the three hot air systems is on hand at present and is expected to be commissioned by mid-1979, the remaining two units and the hot water system are due for completion by the end of 1979.

Plate 1 and **2** illustrate two views of the solar crop drier systems developed in Guyana.

Charcoal project – The charcoal project, jointly administered by the National Science Research Council (NSRC) of Guyana and the University of Guyana (UG), is primarily aimed at developing a more efficient method of producing charcoal through a pyrolytic process, whereby valuable essential oils, resine and other chemicals would be recovered during the conversion of timber into charcoal. The highly complex chemical reactions involved for the various types of Guyanese timber which can be used for charcoal

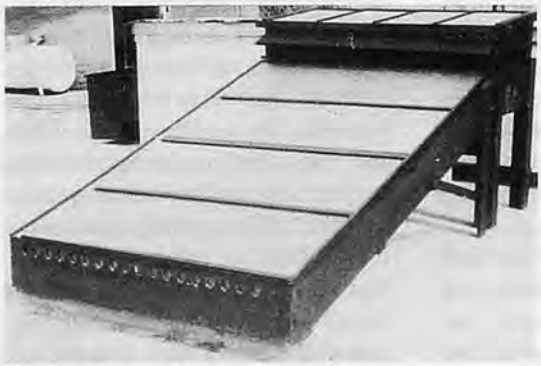


Plate 1 Passive Solar Crop Drier

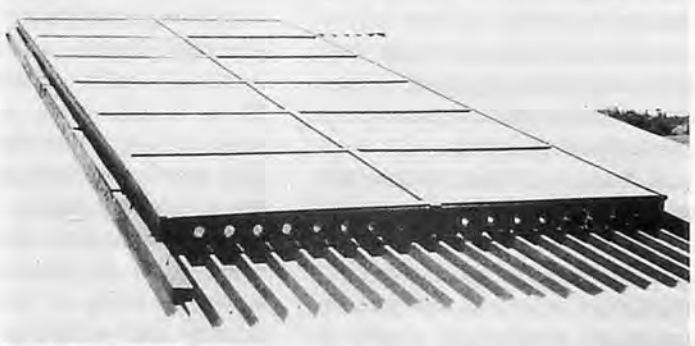


Plate 2 Solar Collector mounted on the top of an existing roof

production are being examined, and a pilot plant is under development at present.

The most common varieties of Guyanese hardwood which can be utilized for making charcoal are "Mora," "Moraballi," "Yaruru," "Kakaralli," "Wallaba," "Kautaballi" and "Greenheart," along with coconut shell, which is in plentiful supply along the coastal region of Guyana. The hardwoods grow easily in the interior areas and are much prized for their resistance to weather and salt-water without any treatment being necessary. "Wallaba" is generally used for electric and telephone posts in its natural state and has a lifespan of 20 - 30 years, while Greenheart is the most popular variety for the building construction industry. It is particularly well known for it's resistance to corrosion from salt-water.

Bio-gas project – This project has been initiated under the joint collaboration of NSRC, UG and GSA. Earlier work done in this field by NSRC and the Government Technical Institute (GTI) in Georgetown had resulted in a small experimental plant made out of oil drums for batch operation. This plant has now been modified for continuous operation and relocated at the livestock farm of GSA, where suitable raw material like farm animal excreta, plant refuse, sugarcane bagasse, rice straw and husk along with waste from the processing of fruits and vegetables in the GSA cannery and from the student cafeteria are easily available. Two students of UG are at present executing the project as part of their practical engineering training under the supervision of the author. The bio-gas project aims to provide household cooking needs of the Mon Repos community. The second stage of this project would be to design and develop a bigger plant, to be located near the present experimental unit, and will also provide fertilizer for crop farming and algae for fish farming.

Electrical Energy

Hydroelectric project at Mazaruni River – As mentioned earlier, this project envisages the production of electricity from a natural water-fall at the upper reaches of the Mazaruni river. A detailed consideration of the project, however, is outside the scope of this report because of its national and political implications.

Emergency home lighting equipment – A small but interesting side result of the author's present assignment in Guyana has been the popularization of an emergency home lighting equipment which can be used for an extended period of three to four hours at a time, basically using discarded electrical components of an automobile, tractor or truck. In a situation like Guyana where frequent disruption in electrical supply takes place, often during evening hours, the emergency lighting system has proved to be very effective and useful.

The system consists of an automobile battery and a headlamp unit, both of which can be salvaged items to reduce capital cost. While a battery becomes unsuitable for use in an automobile if one of the cells loses its vitality, the crippled but charged battery can still provide electricity to light a bulb as the level of current drawn is much lower than that needed for starting the engine. Similarly, while a dual beam (high and low) type headlamp becomes unsuitable for road use if one of the two beams is inoperative, the second beam still provides sufficient light, in conjunction with the reflector, for normal activities inside an otherwise dark house. In operation, the headlamp unit is mounted inside a simple wooden or other suitable frame and a translucent plastic container (of the type used for storing food items in a refrigerator) placed in front of the headlamp glass to act as an attractive lamp shade and an effective light diffuser for the concentrated beam of the headlamp. The resulting diffused light closely resembles the soft and pleasing light produced by a florescent light bulb. A battery charger, drawing household current at 110 or 220 volts when the electricity supply is available, is used to keep the battery in a charged state by recharging at regular intervals of at least about once a week. A wall mounted electrical switch in the system makes it almost identical to the normal household lighting system.

The system put together by the author in his home at Mon Repos has been highly commended by friends and colleagues, some of whom have already duplicated the system in their homes. The system can also be used in a tropical situation like Guyana to operate in the home a 12V ventilator fan, which is another common automobile fitting today.

Mechanical Energy

Human (bicycle) – The driving mechanism of a bicycle originally used by the author in East Africa for powering a fan winnower-grader without prejudicing the bicycle's normal use for transportation had been first reported in 1970; follow-up work on that line led to the development of a versatile power-take-off (p.t.o.) unit which can be easily attached to or detached from the bicycle or relocated with ease. The p.t.o. unit, like that available on a farm tractor, could be utilized to drive any machine or equipment needing rotary power in the range of around 1/2 horsepower maximum and a speed range between 400 - 2,500 r.p.m. at the p.t.o.

shaft with the bicycle being driven at a speed equivalent to 3.5 - 20 km/h, the effective bicycle speed which an average operator can easily maintain. This stage of the development has been reported in 1976.

In the present programme of utilizing the bicycle operated p.t.o. system, in which the NSRC, UG and the GSA are cooperating, the first p.t.o. unit to operate a chicken plucker has been fabricated. This machine is now ready for testing at the GSA livestock farm, where an almost identical unit driven by a fractional horsepower electric motor is in operation. The second unit under construction is planned to operate a crop winnower-grader. While this machine would be generally similar in design to the original unit developed by the author in East Africa, it would incorporate a number of additional features to improve the convenience and efficiency of operation.

Plate 3 and 4 illustrate the bicycle operated chicken plucker developed in Guyana.

Further developments planned under this project include the provision of mechanical power to a gasoline pump at service stations when electricity is not available, a low lift irrigation pump for use by peasant farmers and to small workshop equipment like drills and grinders. As the project programme develops, a number of additional applications where the system could be useful are likely to be identified.



Plate 3 General view of bicycle operated chicken plucker



Plate 4 Chicken plucker in operation

Conclusions

In a developing country like Guyana which does not have to date a known reserve or supply of oil of its own, practically every phase of its national activity needing the expenditure of energy is at present dependent on imported oil. This situation has developed mainly because until very recently oil has been plentifully and cheaply available, and the machinery and equipment being used in Guyana have been developed in those parts of the world where oil has been the major source of energy. In order to shift the political and the economic risks involved in such large scale foreign dependence, it is vitally necessary to develop alternate sources of energy which are available within the country.

The various alternative sources which are considered practical for development in the context of Guyana at present have been discussed in this report, along with a discussion of those projects which are actually under development for the purpose. It is also seen from this report that a number of other potential areas of development exist where work could be initiated immediately to advantage. Two of the most important constraints in this respect are perhaps the lack of finance and local expertise; further, considerable local ingenuity and a commitment to developing the potential of the country in the field of alternate energy utilization is also very urgently needed. ■■

ENERGY RESOURCES

Efficient Use of Agricultural Wastes for Energy Production



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Introduction

Agricultural wastes like rice husk, groundnut shells, paddy straw, cotton sticks, etc., represent some of the most renewable agricultural-based fuel materials in the world. India produces about 14 million m.t. of rice husk, 150 million m.t. of paddy straw and 2 million m.t. of groundnut shells. The other agricultural wastes, such as cotton sticks, corn cobs, bagasse, etc., represent a huge amount of offal. It is estimated, that this may represent an energy source equivalent to about 24 million m.t. of coal every year, worth 465 crores of rupees.

Rice husk and other agricultural wastes are efficient fuel for drying purposes of all types. The modern rice processing industry requires heat energy for mechanical drying of raw or parboiled paddy and for generating steam which can be used for parboiling process and for power generation to operate rice mills.

Unprecedented world energy crisis triggered by the continued rise in oil price has changed the aspect of global economic balance and has driven the non-oil producing countries to seek alternative sources of energy. In consequence, the status of rice husk has undergone a change from a disposal nuisance to that of an important raw material. To illustrate its value in today's economy 3 kg of rice husk equal to 1 kg of fuel oil.

In order to exploit the potential benefits of this value, the authors undertook the present study on utilizing energy from agricultural wastes.

Chemical Composition of Rice Husk and Groundnut Shell

The chemical composition of rice husk and groundnut shell is necessary for the computation of air requirements and the volume of products of combustion which, in turn, determines the size of blowers. The sensible heat carried away by the flue gases at different temperatures may be obtained from the nomographs based on the chemical composition. Similarly,

Table 1. Composition of Rice Husk and Groundnut Shell

Component	Molecular Weight	Rice Husk		Groundnut Shell	
		wt. in kg	mole	wt. in kg	mole
Carbon	12	39.26	3.271	45.92	3.826
Hydrogen	2	4.99	2.495	5.37	2.685
Oxygen	32	32.70	1.022	36.31	1.134
Nitrogen	28	1.99	0.071	1.09	0.0389
Sulphur	32	0.10	0.003	0.11	0.0034
Moisture	18	3.56	0.198	7.30	0.4055
Ash	–	17.40	–	3.90	–

Acknowledgement: The authors are very much thankful to Messrs. P.K. Jana, J.K. Chatterjee, P.C. Singha and S.C. Sarkar for their help in fabrication, erection and testing of these experimental units.

the Ostwald charts for assessing the state of combustion, i.e., the excess or deficiency of air during combustion, are based on the chemical composition.

Ultimate analysis gives the chemical constituents which take part in combustion, i.e., total carbon, hydrogen, nitrogen, sulphur and oxygen. The total carbon includes both the fixed carbon and the carbon in volatile matter. All this carbon appears in the products of combustion as carbon dioxide when the fuel is completely burnt. The chemical compositions of rice husk and groundnut shell are given in **Table 1**.

Tables 2 and **3** illustrate the theoretical computation of requirement and products of complete combustion of rice husk and groundnut shell. The calculations are based on chemical reaction of different constituents with oxygen during the combustion process. The minus sign in **Table 2** indicates the oxygen present in the fuel which reduces the total air requirement for combustion. Thus, combustion of 1 kg of husk requires 4.807 kg of air (3.733 m^3) and yields 5.632 kg (4.302 m^3) of products of combustion. **Tables 4** and **5** illustrate the material balance for complete combustion of 100 kg of husk and groundnut shell, respectively.

Table 6 gives the chemical composition of various kinds of fuel.

Table 2. Determination of Theoretical Air Requirement and Products of Complete Combusiton, 100 kg Rice Husk.

Component	Mole	Requirement Mole		Produced Mole			
		O_2	N_2	CO_2	H_2O	SO_2	N_2
C	3.271	3.271	12.3095	3.271	–	–	–
H_2	2.495	1.248	4.6949	–	2.495	–	–
O_2	1.022	−1.022	−3.8447	–	–	–	–
N_2	0.071	–	–	–	–	–	0.071 +13.167
S	0.0031	0.003	0.0113	–	–	0.0031	–
H_2O	0.193	–	–	–	0.198	–	–
Total		3.500	13.167	3.271	2.693	0.0031	13.238

Air required
= 3.5 × 32 + 13.167 × 28 = 480.7 kg of air/100 kg of husk = 373.3 m^3/100 kg of husk
Total quantity of combustion products
= 3.271 + 2.693 + 0.0031 + 13.238 = 19.2051 mole/100 kg of husk
Hence, total volume
= 19.2051 × 22.4 ÷ 100 = 4.3018 m^3/kg of husk
By multiplying their molecular weight, the total weight of these gases
= 143.924 + 48.470 + 370.664 + 0.1984 = 563.2564/100 kg of husk
Thus the specific weight of flue gases
= 563.2564/430.18 = 1.3093 kg/m^3 = 1.31 kg/m^3

Table 3. Theoretical Air Requirement and Products of Complete Combustion, 100 kg Groundnut Shell

Component	Mole	Requirement Mole		Produced Mole			
		O_2	N_2	CO_2	H_2O	SO_2	N_2
C	3.826	3.826	14.3857	3.826	–	–	–
H_2	2.685	1.342	5.0459	–	2.685	–	–
O_2	1.134	−1.134	−4.2633	–	–	–	–
N_2	0.0389	–	–	–	–	–	0.0389 +15.1305
S	0.0034	0.0034	0.0127	–		0.0034	–
H_2O	0.4055	–	–	–	0.4055	–	–
Total		4.0374	15.1805	3.826	3.0905	0.0034	15.2194

Air required
= 4.0374 × 32 + 15.1805 × 28 = 554.25 kg of air/100 kg of groundnut shell = 5.542 kg/kg of shell = 4.303 m^3/kg of shell
Total quantity of combustion products
= 3.826 + 3.0905 + 0.0034 + 15.2194 = 22.1393 mol/100 kg of grundnut shell
Hence, the total volume
= 22.1383 × 22.4/100 = 4.9613 m^3/kg
By multiplying the molecular weight, the total weight of these gases
= 168.388 + 525.409 + 0.2176 + 55.620 = 749.59 kg/100 kg of groundnut shell
Thus, the specific weight of flue gases
= 749.59/496.13 = 1.5108 kg/m^3

Ostwald Charts

The modified Ostwald charts were prepared for rice husk and groundnut shells for use on furnace test. **Figs. 1** and **2** illustrate the Ostwald charts for rice husk and groundnut shell. This chart allows a very close estimate of the excess air from a flue gas analysis for carbon dioxide and oxygen.

Table 4. Materail Balance for Complete Combustion, 100 kg Rice Husk

Input		Output	
Husk containing	Air:		
C = 39,260	O_2 = 112.000	CO_2 = 143.926	
H_2 = 4.990	N_2 = 368.676	N_2 = 370.664	
O_2 = 32.700		H_2O = 48.470	
N_2 = 1.990		SO_2 = 0.198	
S = 0.100		Ash = 17.400	
H_2O = 3.560			
Ash = 17.400			
Total = 580.676 (Husk + Air)		580.648	

Table 5. Material Balance for Complete Combustion, 100 kg Groundnut Shell

Input		Output	
Shell Containing			
C = 45.92	O_2 = 129.21	CO_2 = 168.344	
H_2 = 5.37	N_2 = 425.32	N_2 = 425.409	
O_2 = 36.31		SO_2 = 0.2176	
N_2 = 1.09		H_2O = 55.620	
S = 0.11		Ash = 3.90	
H_2O = 7.30			
Ash = 3.90			
Total = 654.53 (Shell + Air)		653.49	

Table 6. Chemical Composition of Various Kinds of Fuel

Fuel	C	Percent by Weight				Ash	Moisture Content
		H_2	N_2	O_2	S		
Fire wood	35.0	4.3	0.4	29.6	0.0	0.7	30.0
Peat	30.9	3.2	1.3	17.8	0.4	6.6	40.0
Straw	36.0	5.0	0.5	38.0	0.0	4.7	15.8
Oat	41.0	5.2	0.7	36.7	0.2	6.3	10.0
Corn	38.0	4.8	0.5	34.9	0.4	1.6	20.0
Rice husk	39.2	5.0	2.0	32.7	0.1	17.4	3.6
Groundnut shell	45.9	5.4	1.1	36.3	0.1	3.9	7.3
Coal	70.5	5.1	1.2	3.4	1.3	18.4*	–
Liquid fuel	84.8	12.7	–	1.4	1.1	–	–
Producer gas	CH	CO	CO_2	N_2	C_2H_4	O_2	–
	15.2	20.0	8.0	54.0	1.3	0.5	–

* Moisture + Asha

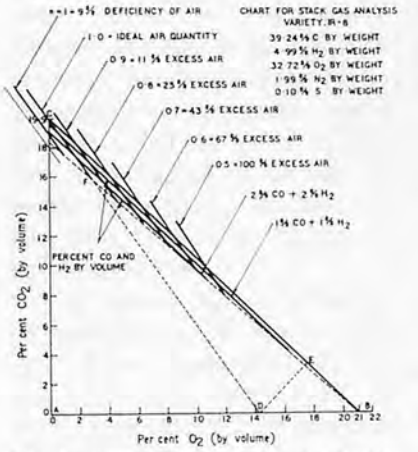


Fig. 1 Ostwald's chart for rice husks-IR-8

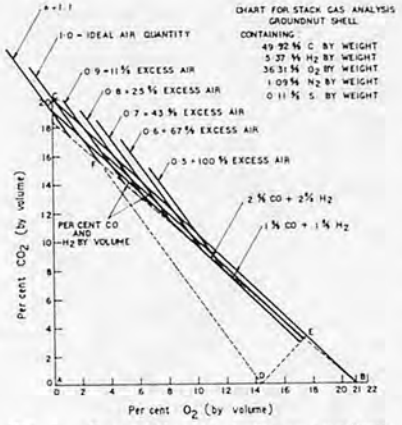


Fig. 2 Ostwald's chart for groundnut shells

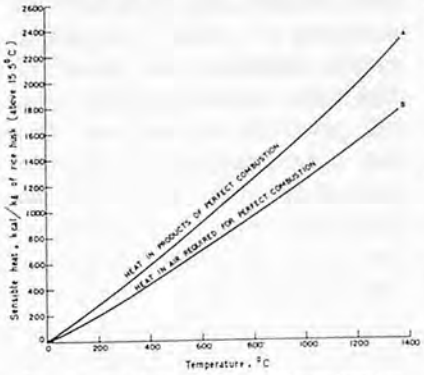


Fig. 3 Heat in products of combustion of IR-8 rice husks

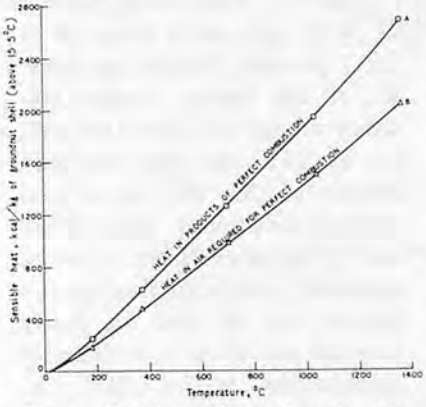


Fig. 4 Heat in products of combustion of groundnut shells

Nomograph for Heat Balance Computation

The nomographs (Figs. 3 and 4) for determining the heat carried away by flue gases from the burning rice husk and groundnut shell and the heat loss due to CO and H_2 in flue gases were prepared. Curve A in Fig. 3, furnishes the sensible heat content (above 15.5°C or 60°F) in the products of perfect combustion without excess air of unit quantity of fuel. It does not include the latent heat of the water vapour. For this reason, the heating value that should be used in the calculation of the curve is the lower heating value. If the higher heating value is used instead, then the latent heat of the water vapour (which is the difference between higher and the lower heating values, should be added to the heat content as read from the curve A.

Curve B represents the heat in that quantity of air which is required to burn a unit quantity of fuel, plotted as a function of the temperature of air.

Burning Characteristics of Rice Husk

The next step in developing a suitable machinery (furnace) for husk energy utilization involves the combustion studies on husk to study its behaviour when combustion takes place. Preliminary combustion studies were carried out with combustion pot technique, prior to large scale burning, so as to obtain practical information which would be useful in designing a husk-fired furnace. The maximum rate of combustion of 69.79 kg per sq. m of grate area per hour for IR-8 rice husk occurred at an air flow rate of 532.42 kg/m^2 hr. The optimum thermal grate load for husk-fired furnace is recommended as 184,000 kcal/m^2 hr.

The effect of physical factors such as air flow rate, fuel bed height and particle size of husk on the rate of combustion and fuel bed temperature were studied for husk of IR-8 and Patnai 23 rice varieties. The average combustion rates increased with the increase in air flow rate till a maximum value is reached. A further increase in the air supply resulted in lifting the fine particles of husk from the bed, thereby lowering the combustion rate. Patnai 23 rice husk exhibited higher rates of combustion than IR-8 rice husk. The combustion rate was found to increase with the increase in fuel bed height. The experimental results are compared with the computed results from Thring's theory and a considerable

deviation was observed since the theory is concerned with carbon air reaction only.

Development of Grate Type Husk-Fired Furnace

Taking into consideration the functional requirement of furnaces for grain drying, data obtained from the above mentioned studies and the known principles of furnace design, a husk-fired furnace was designed and developed to match a 1.25 m.t. capacity dryer. The box type furnace (Fig. 5) is equipped with an inclined grate adjustable at 40, 45 and 50° angle of inclination, and consists of cast iron bars arranged in a staircase fashion. At the bottom of the inclined grate there is a horizontal revolving grate which disposes off the accumulated ash periodically. In order to prevent any fly ash or unburnt husk from going into the outlet with the hot gases, a curtain wall was installed throughout the width of the furnace at the end of the horizontal grate. The husk is fed into the furnace at the top of the inclined grate with the help of a fluted roller placed at the bottom of the hopper itself. The husk is spread in thin layer on the steps of the grate and it slides down by gravity while combustion takes place. The air necessary for combustion is sucked in through the opening for feeding the husk and partly through the grate openings. In order to reduce the flue gas temperature to the drying temperature level for paddy drying, additional air is introduced through the secondary inlet to the blower. The blower delivers the flue gas air mixture to the dryer with a by-pass arrangement to the chimney. The furnace was coupled with RPEC recirculatory paddy dryer. The highest furnace efficiency (64.5%) occurred at the feed rate

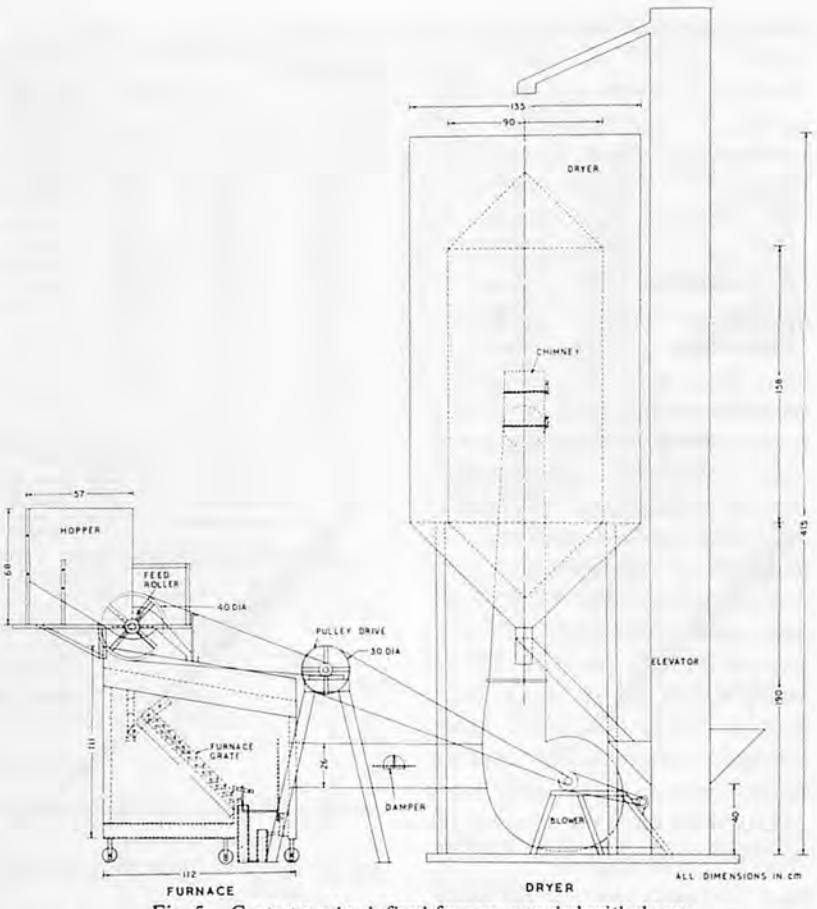


Fig. 5 Grate type husk-fired furnace coupled with dryer

of 14.25 kg/hr with excess air of 285.7 per cent. The flue gas analysis, at the highest furnace efficiency showed CO_2 as 4.0 per cent, O_2 as 15.8 per cent and with absence of CO. The rest is inert nitrogen constituting about 80 per cent of flue gases. Hence, it can be concluded that the flue gas air mixture can be used for drying purposes and it has no undesirable consequences on the milled rice. The furnace has been adopted by various rice millers and pulse millers to provide heat energy to the dryers for drying moist grains, including parboiled paddy in more than 30 mills in India.

Development and Testing of Husk-Fired Parboiling System

An experimental unit comprising of a parboiling tank and a husk-fired furnace with chimney has been designd and fabricated for parboiling of paddy. The present system eliminates the boiler of high initial cost and needs no electric power for its operation. The hot water soaking and steaming of paddy is carried out in the same parboiling tank. The proposed system is an improvement over the traditional system of parboiling used in some parts of South India and Sri Lanka. The performance tests on the unit include the furnace efficiency and the milling quality of the parboiled paddy.

A husk-fired furnace for parboiling 100 kg of raw paddy was designed from the known principle of furnace design. The furnace was equipped with an inclined grate (0.5 Sq.m.) at 45° angle of inclination, and consisted of cast iron bars (60 x 5 x 1 cm) arranged in a staircase fashion. Admission of air to the furnace and subsequent movement of gases

throughout the system are brought in by the natural draft of 2.86 mm. w.g., created by the 5.5 m high chimney. A rectangular parboiling tank was fabricated of 3 mm. thick mild steel sheet. It is divided into upper and lower compartments. These compartments are separated by 1.6 mm. thick mild steel perforated sheet. The capacity of the upper compartment is 100 kg of paddy whereas the lower compartment is filled with water for producing steam at atmospheric pressure. The tank is provided with necessary free board along with a discharge gate for paddy and a drainage outlet for water. A glass tube was attached to the tank to see the water level in the tank. The husk-fired parboiling system is illustrated in **Fig. 6**.

The highest thermal efficiency of parboiling system was obtained as 21.4 per cent at the husk feed rate of 15 kg/hr. and 143.23 per cent excess air. The temperature of water (300 litres) during one hour of the experiment reached to 87°C at the husk feed rate of 35 kg/hr.

There is a considerable saving in the investment for this system of parboiling since it eliminates the need for boiler. Steaming was uniform and no discolouration due to prolonged steaming (as in the case with traditional process) occurred. A battery of these parboiling units may be installed in a commercial rice mill to match the parboiling capacity with mill capacity. Of course, a single unit can be an excellent aid for parboiling at the village to serve a community of farmers.

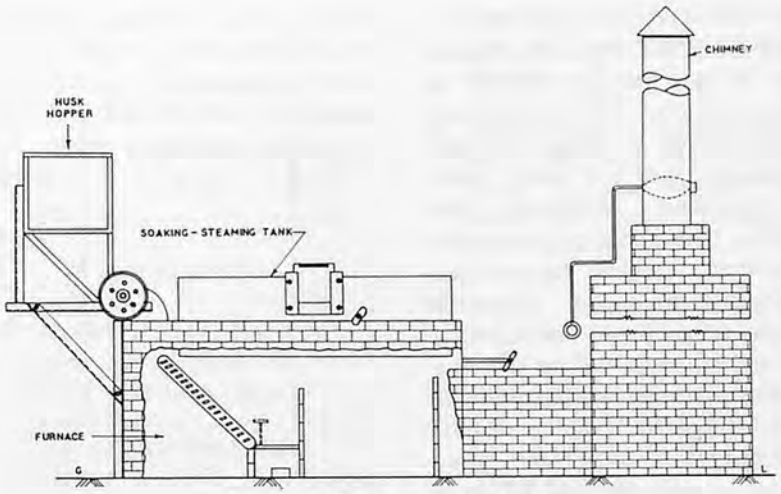


Fig. 6 Boilerless parboiling system

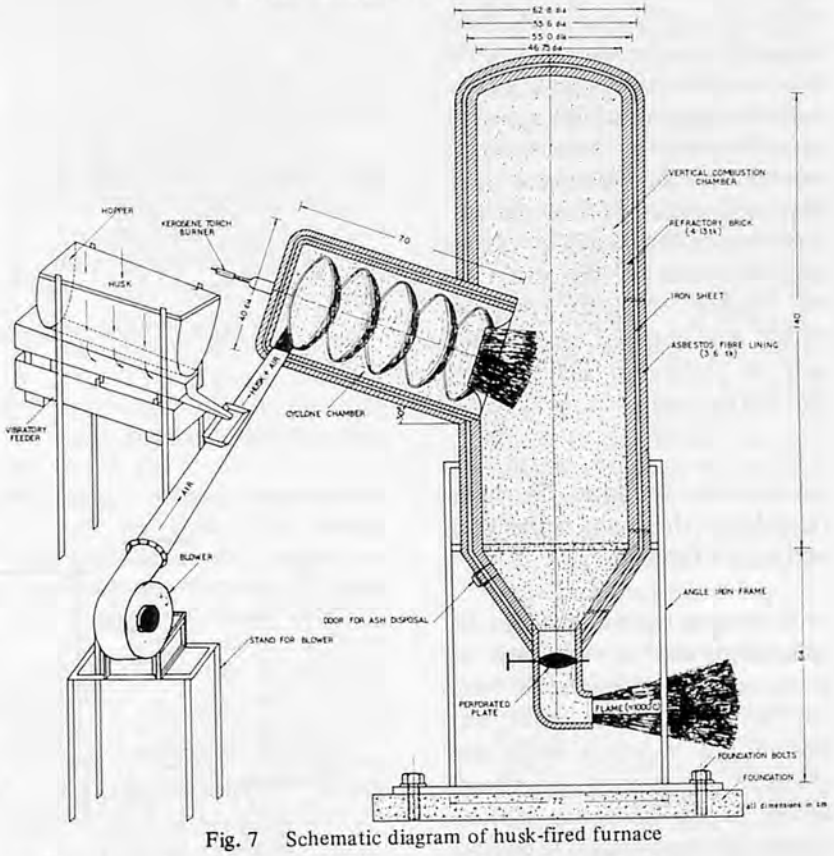


Fig. 7 Schematic diagram of husk-fired furnace

Development of Cyclone Furnaces

In order to burn the husk and other agricultural wastes efficiently experiments were carried out firing rice husk, groundnut shells and paddy straw in a cyclone furnace. These are described as follows:

Vertical Cyclone Furnace – The furnace (**Fig. 7**) was fabricated out used oil barrel (55 x 140 cm) having a conical bottom (40°) and a cyclone chamber at its side at an angle of 30°. The total volume of the furnace was 0.34 m^3 (12 cft). An exit pipe at the bottom provided an outlet for the flue gas as well as for the ash.

The husk was introduced tangentially at the outer end of the cyclone. For the insulation of furnace wall, the mixture of fire-clay and refractory bricks was pasted inside the furnace. A blower of 220 cfm (6.25 m^3/min) capacity was selected for the experiments. The highest furnace efficiency (80%) occurred at the feed rate of 20 kg/hr and

air flow rate of 2.83 m^3/min (100 cfm). The maximum temperature of flue gas was obtained at about 1000°C. The furnace was also operated on firing rice husk, groundnut shell and paddy straw.

Groundnut Shell-Fired Furnace – The horizontal groundnut shell-fired cyclone furnace was fabricated from two oil barrels in which one barrel was placed at an inclination of 15° to the horizontal and other was placed vertically (Fig. 8). The horizontal chamber was made of M.S. sheet, 58 cm in diameter and 87 cm in length. The conical end made of 0.3175 cm (1/8") thick M.S. sheet was welded to the open end of the horizontal chamber with a 14 cm. outlet for the exit of flue gases and ash. The vertical chamber was attached to the horizontal combùstion chamber to trap the ash. The furnace was tested at various feed rates and air flow rates and the highest furnace efficiency (63%) was obtained at the feed rate of 21.5 kg/hr. and 2.3 m^3/min air flow rate.

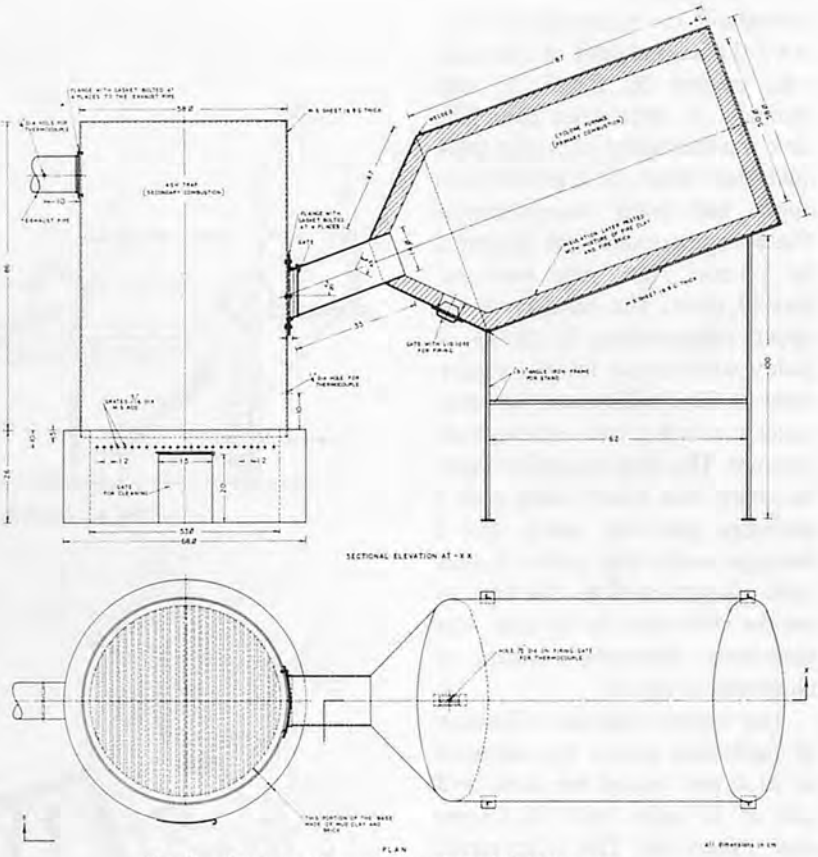


Fig. 8 Cyclone type groundnut shell-fired furnace

Horizontal Cyclone Furnace Coupled with Steam Generator and Grain Dryer

Keeping in view the design requirements and on the basis of preliminary experiments on various models, a pilot plant was worked out in which steam was produced by burning agricultural wastes in the horizontal cyclone furnace. The heat content in exhaust gases from the steam generator were utilized for drying in a dryer by eliminating the stack losses. The engineering drawing of the system is illustrated in Fig. 9.

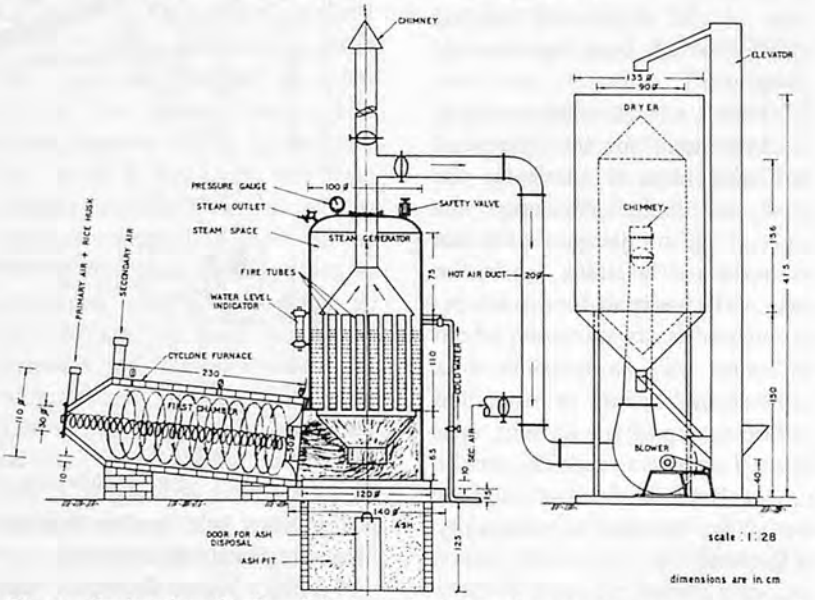


Fig. 9 Engineering details of horizontal cyclone furnace, steam generator and paddy dryer

The cyclone furnace was equipped with a circular chamber (1.10 x 2.30 m) consisting a re-entrant throat at one end and the other end was attached with a cone known as 'cyclone tip'. It has a hinged door with a collar to sit in the cone opening to make it air tight with three chamber bolts. At the centre of the hinged door is a smaller opening with open-shut arrangement for both firing the furnace and a quick glance at the inside burning process for the cyclone. The husk was introduced into a 10 cm dia. pipe connecting the cyclone tip and primary blower which delivered

6 m^3/min at 100 mm w.g. pressure. The secondary blower had a rated capacity of 10 m^3/min at 185 mm w.g. pressure. The inside wall of the circular chamber was lined with refractory bricks and fireclay.

The husk was introduced into the cyclone chamber with the help of a fluted roller placed in the hopper and with the help of a stream of air. The re-entrant throat was attached to the other end of the cyclone chamber. The furnace was fired by paddy straw and then blowers were switched one after another. The feeding of husk was also started at the same time. The highest furnace efficiency of 78.5 per cent occurred at the feed rate of 125 kg/hr with an excess air of 53.4 per cent. The flue gas analysis showed the presence of CO_2 as 12.65 per cent, O_2 as 7.4 per cent and CO as 0.10 per cent.

Having determined the suitability of cyclone furnace, a steam generator was designed and fabricated and attached to the cyclone furnace to test its performance. The boiler was designed to generate 200 kg steam per hour at 5 kg/cm^2 to fulfill the steam requirements for the parboiling of one m.t. of paddy. The exhaust of the boiler was coupled with a grain dryer (1.25 m.t. holding capacity). The highest combined furnace – boiler efficiency of 37.5 per cent occurred at the husk feed rate of 125 kg/hr and air flow rate of 12.74 m^3/min. The best over-all efficiency (76.45%) of the complete system (including drying system) was obtained at the husk feed rate of 125 kg/hr and air flow rate of 12.74 m^3/min. The furnace was also operated on firing groundnut shell and paddy straw successfully and efficiently.

The fabrication cost of cyclone furnace and steam generator was Rs. 3,000 and Rs. 5,500, respectively. The total operating cost of the cyclone furnace and steam generator was Rs. 6.27 per hour for steam generation and grain drying.

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Performance Evaluation of Modern and Traditional Ploughs in Bangladesh







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Abstract

This paper describes a newly designed bullock drawn mouldboard plough to enable farmers in the country to cultivate their land more efficiently. A comparison of performance of the new "Chashi" plough and the traditional "Deshi" plough was made in June, 1979 in fallow and tilled land of different texture and consistency. The "Chashi" plough performed better in all the tests except that in hard clay soil.

Introduction

In Bangladesh most of the tillage operations are performed with the help of animal-drawn ploughs. Lands are fragmented and 47 percent of the total households have land area in the range of only 0.4 to 0.8 hectares, (Statistical pocket book of Bangladesh, 1978). The economic and social conditions are not favourable for the use of big tractor. Small tractor and power tiller can be used reasonably by the co-operative agricultural farms, rich farmers, Agricultural Research Stations and Government agricultural farms.

As the prices of exotic machines and fossil fuels have increased exorbitantly in recent time, the people are becoming very reluctant to use those machines, hence the bullock power and plough drawn is still widely used. The same views were expressed by the experts on agricultural engineering in the first Agricultural Research Workshop held in June, 1979 under the auspices of the Bangladesh Agricultural Research Council.

Hussain and Sarker (1978) studied the performances of a good number of country ploughs collected from different parts of Bangladesh. The maximum depth of cut and width of cut were 9 cm and 15 cm, respectively. The authors recommended the change of overall shape of the plough and incorporation of a mouldboard and landside so that efficiency could be increased. The mouldboard plough is one of the oldest of all agricultural implements and is generally considered to be the most important tillage implement (Kepner et al, 1972). Although minimum tillage is now gaining popularity in a few countries, the tillage has some advantages such as controlling weeds, thorough mixing of trash, harvesting roots of some crops, mixing of fertilizers and pesticides, etc.

The current use of traditional ploughs cannot invert and break the soil and effective field capacity is low. Also, the length of life of the ploughs is short. Hence, an improved plough capable of inverting and breaking the soil and pulled by a pair of bullocks has been designed and tested in the Agricultural Engineering Workshop of Bangladesh Agricultural Research Institute. Quite a good number of this plough were supplied to the farmers for testing the performance and they found it very suitable for their use.

Theoretical Consideration

The purpose of a tillage tool is to manipulate (change, move or form) a soil as required to achieve a desired soil condition. Three abstract design factors: initial soil condition, tool shape and manner of tools movement control or define the soil manipulation, (Kepner et al, 1972). The designer has complete control only on the tool shape and the user may very the depth or speed of operation. Depending on soil types, plough shape should be designed. The shape of the "Chashi" plough has been developed by the cut-and-try method. Change in soil

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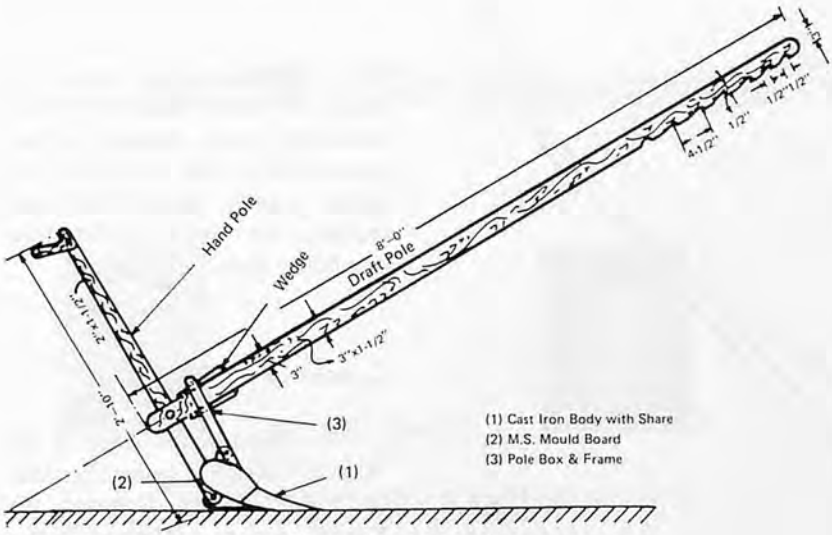


Fig. 1 Chashi plough

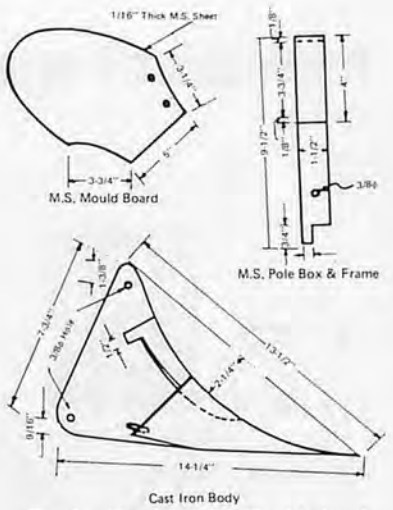


Fig. 2 Metal parts of Chashi plough

conditions and tool forces are the two basic aspects of tillage tools performance. The design should be aimed to use minimum energy input to have desirable soil manipulation.

The "Chashi" Plough

The plough has four main parts, namely mouldboard; share; hand pole; and draft pole. The mouldboard is made of mild steel and share of cast iron. The hand and draft poles are made of wood; generally "gorjon" wood is used for this purpose with some grooves on the draft pole to adjust the depth of ploughing. But the depth adjustment can be done only to a limited extent by adjusting the main body of the plough to the hand pole. The plough and its parts are shown in **Figs 1** and 2 and its picture is shown in **Fig. 3**. The plough weighs 6.8 kg, US$5 and its approximate life expectancy is 4 to 5 years. The construction of the plough is simple. After a brief orientation, the village artisan can manufacture it from materials available locally. The share point is the only part which is subject to maximum wear due to continuous friction with the soil.

The main characteristics of the plough are:

i) It breaks up the soil and turns under the remains of plants, straw, manure, compost, etc.

ii) It unearths roots, rhizomes, remains of stalks and speeds the rotting.

iii) It destroys parasites of which the eggs, grubs and spores are laid bare.

iv) In sandy lands it raises the fertile soil from underneath.

v) Deeper ploughing is possible which permits a better utilization of water reserves, and thus the plant is resistant to draught.

vi) In tilled land the Chashi plough saves nearly half the time.

vii) Ploughing is more homogeneous and regular but needs intensive harrowing.

viii) As work time is short, it allows for rest and grazing of animal.

ix) Its higher initial cost is compensated by its longer use.

x) Better utilization of fertilizer reduces the requirement of it and increases the amount of production.

xi) When the soil is very hard and dry, it becomes difficult for a pair of small-sized bullocks to pull the plough.

xii) The depth of cut is 10 - 15 cm and width of cut is 12 - 29 cm.

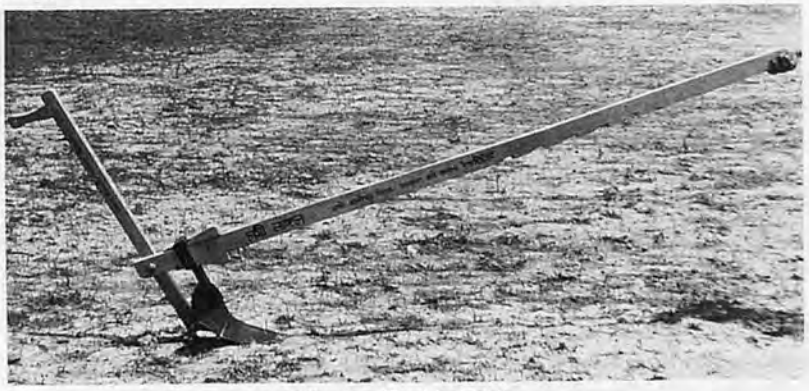


Fig. 3 Chashi plough

The "Deshi" Plough

There are so many designs of "Deshi" plough in Bangladesh. The designs vary from region to region depending on soil texture, consistency, size of bullocks, etc. All these ploughs are made by village carpenters. A typical design of Deshi plough is shown in **Fig. 4**. The plough test was done in the adjacent areas of Dacca City. Its weight was 5 kg, total cost of manufacture was US$3.75 and life expectancy was

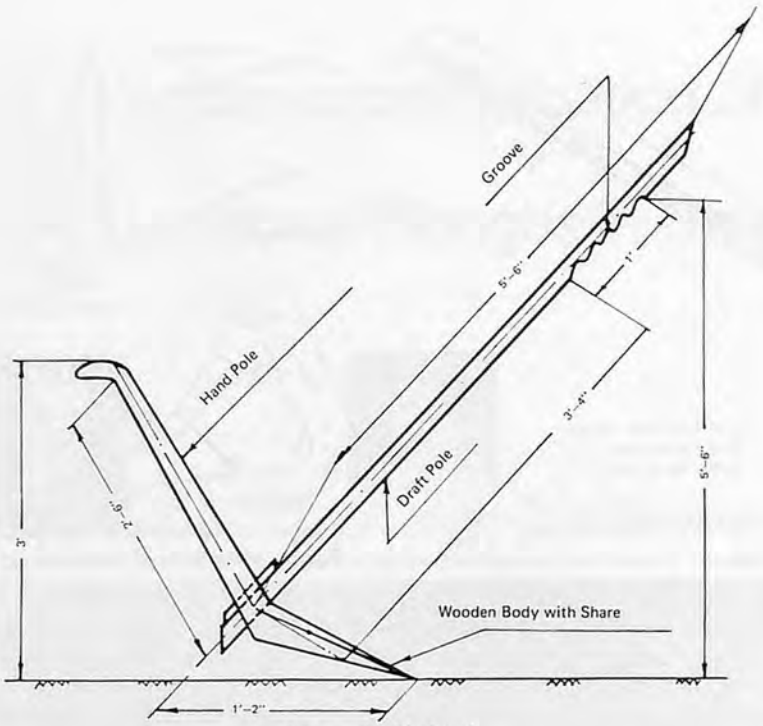


Fig. 4 Deshi plough

about 2 years.

The main characteristics of Deshi plough are:

i) It makes a 'V' shaped furrow in the soil and cannot break up nor turn the soil.

ii) As the plough is light in weight it is easier for a small pair of bullocks to pull it.

iii) The manufacturing technique of the plough is simple and the cost of the plough is less.

iv) It can work well in puddling operation.

v) The depth of cut is only 7 - 9 cm and width of cut 10-15 cm.

Methodology

The performance tests of the ploughs were undertaken in June, 1979. In different textured soils, fallow land and land after first tillage were taken to compare the performance of both ploughs on equal land area, homogeneous soils simultaneous and ploughing. Soil texture and moisture content were determined in the laboratory. Width of cut, depth of cut, pull and time taken were measured.

Results and Dicussions

Table 1 shows the results of the performance tests of both ploughs in the field in sandy loam soil with friable and hard consistency.

In tilled land with friable consistancy, the depth and, width of cut and effective field capacity were greater for the chashi plough. The "Deshi" plough performed better in fallow land with hard consistency and promises to improve after it has been used for several weeks when the edge sharpens for deeper penetration into fallow land.

Conclusion

The overall performance of the "Chashi" plough is better than that of "Deshi" plough. However, the "Deshi" plough performed better in hard clay soil. As the currently used traditional ploughs cannot break and invert the soil, the depth and width of cut are shallow and narrow. Therefore, the use of the "Chashi" plough is recommended for better performance in certain soil conditions as mentioned earlier.

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Table 1. Performance Characteristics of the "Chashi" and "Deshi" Ploughs

Type of Plough	Soil	Average Width of Cut (cm)	Average Depth of Cut (cm)	Total Volume Soil Displaced (m^3)	Moisture Content of Soil (%)	Average Total Pull (kg) (kg)	Area of Land Ploughed (m^2)	Time Required to Complete Ploughing (min)	Effective Field Capacity (ha/hour)	Average Speed (m/min)	Power Required (kw)
Chashi plough	Tilled	23.20	14.29	0.0166	10	25.00	111.52	12	0.056	45.30	0.38
	Fallow	12.52	10.76	0.0067	15	54.54	167.23	25	0.04	38.40	0.70
Deshi plough	Tilled	11.00	8.5	0.0047	10	29.54	111.52	20	0.033	42.70	0.42
	Fallow	8.00	6.5	0.0026	15	60.15	167.23	26	0.039	36.60	0.74

Disk Harrow—An Appropriate Tillage Implement







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Abstract

For preparing a suitable seedbed, proper implements must be used. Excessive cultivation, on the other hand, causes a wastage of fuel and machine time. It is, therefore, important that proper implements are selected and used to a desired extent in order to prepare a suitable soil environment for the growth of crops.

In this investigation, the comparative performance of different tillage implements like tine cultivator, disk harrow and sweep cultivator was studied for wheat and corn planting on sandy loam soil. It was observed that narrow tine cultivator produced the highest penetration resistance of soil. The shear strength of soil was found lowest for operation with disk harrow and sweep cultivator. Disk harrow superseded tillage operations with narrow and sweep cultivator, as regards soil tilth and emergence/yield of crop. Further, the economic analysis indicated that two passings of the disk harrow were superior to the three passings of the narrow tine cultivator.

Introduction

Tillage implements are used to weaken soil strength, reduce compaction and allow the free movement of air and water in order to promote plant growth. It is important, however, that proper tillage implements are selected for achieving a suitable seed bed environment for the emergence and growth of the plants. The use of improper and heavy implements results in compacting the soil which may upset the balance between air, soil and water components. Excessive soil manipulation is, therefore, detrimental to soil structure with serious consequences on the emergence and yield of crops. However, slight compaction is desirable in order to gain good contact between the seeds and soil during germination. Again, the implements selected should be economically feasible and must not involve high cost of operation. Accordingly, different combinations of tillage implements were selected in this study with a view to establishing their effects on soil characteristics, emergence and yield of crops, and cost of operations. It may be realized that the implements selected may prove ideal for seedbed preparation, but may be costly because of their initial investment and low field capacity. It is, therefore, important that the implements used for tillage operations should not only be technically and biologically suitable, but also economically feasible and acceptable to the farming community.

Experimental Procedure

Research findings of the previous year indicated that mouldboard plow, disk plow and subsoiler were not suitable on sandy loam soil for wheat cultivation. Consequently, they were dropped from the list of implements for the present investigation. Instead, a new implement, sweep cultivator, developed in the University, was included in the experiments. Consequently, the following tillage treatments employing different sets of implements were used on sandy loam soil.

Treatment A : Disk harrow (2 times)
Treatment B : Sweep cultivator (2 times)
Treatment C : Disk harrow followed by 2 times cultivator (narrow tine)
Treatment D : Narrow tine cultivator (3 times)

Each of the above treatments were replicated thrice on plots of equal size. The penetration resistance of soil was then determined with the help of a cane penetrometer having an area of 6.45 cm^2. Five readings of the penetrometer were taken from each plot. The results are shown in **Table 1**. Further, the shear strength of soil was determined with the help of the Cohran Sheargraph by applying three levels of normal

stress. The process was repeated thrice on each plot. The regression analysis provided the values of cohesion and angle of internal friction, the parameters of shear strength of soil. The data is recorded in **Table 2.**

After tillage operations, wheat seeds (L.U.26) were planted on 28th November, 1978 by means of a carefully calibrated grain drill. The emergence of wheat seedlings were counted on 30th December, 1978, after 8 days of the first irrigation, by randomly selecting five rows, 125 cm long, from each plot. The observations are recorded in **Table 3.** The yield of wheat was determined by randomly collecting three samples of the crop at the time of harvest, from an area of 8361 sq.cm from the plots. The threshed grains were weighed and recorded in **Table 4.** The last column of the table shows the yield converted into kg per hectare.

After harvesting the wheat, the field plots were prepared again with the above mentioned tillage operations and maize seeds (Neelum) were planted on 13th August, 1979. The yield was observed on 3rd November, 1979 and recorded in **Table 5.**

Table 1. Penetration Resistance

	Tillage Treatment	Plot No.	Penetrometer Dial Readings	Mean dial Reading	Mean Penetration Force (kg)	Mean Penetration Resistance (kg/cm²)
A	Disk harrow (2 times)	1	30,50,50 48,58	47.2	23.6	3.66
		2	37,28,38,55,55	42.6	21.3	3.30
		3	58,48,44,44,48	48.4	24.2	3.75
B	Sweep cultivator (2 times)	1	48,43,60,50,51	50.4	25.2	3.90
		2	38,35,38,37,37	37.0	18.5	2.86
		3	38,39,40,41,41	41.0	20.5	3.17
C	Disk harrow followed by 2 times cultivator	1	43,54,53,55,58	52.6	26.3	4.10
		2	55,58,45,55,42	51.0	25.5	3.95
		3	40,43,44,50,55	46.4	23.2	3.51
D	Narrow tine cultivator (3 times)	1	73,60,65,80,85	67.2	33.6	5.2
		2	52,70,75,75,85	71.2	35.6	5.5
		3	80,85,62,80,85	78.4	39.2	6.1

(Penetrometer Area = 6.45 cm²)

Table 2. Shear Strength

Tillage Treatment	Normal Stress		Shear Stress	Mean Shear Stress	
	(psi)	(gm/cm²)	(psi)	(psi)	(gm/cm²)
A Disk harrow (2 times)	5	351	1.3,1.0,1.5,1.0,1.2	1.25	88
	10	703	2.0,3.0,2.5,3.0,2.6	2.60	182
	15	1054	4.5,4.0,2.8,3.8,3.3,3.5	3.65	256
B Sweep cutivator (2 times)	5	351	1.5,1.0,1.8,1.3,0.8,1.7	1.35	95
	10	703	3.0,3.0,2.1,2.1,2.5,3.0	2.61	183
	15	1054	4.2,4.1,2.5,4.8,4.2,3.3	3.81	271
C Disk harrow followed by 2 times cultivator	5	351	2.0,1.83,1.83,	1.89	133
	10	703	3.5,3.33,3.33	3.39	238
	15	1054	5.00,5.00,5.00	5.00	350
D Cultivator (3 times)	5	351	1.3,1.7,1.3	1.43	101
	10	703	2.0,2.4,2.2	2.20	154
	15	105	3.6,3.8,3.6	3.60	253

Table 3. Emergence of Wheat Seedlings

	Tillage Treatment	Plot No.	Emergence (No. of Seedlings)	Mean Emergence
A	Disk harrow	1	35,34,41,45	38
		2	34,28,43,33,30	37
		3	36,32,31,32,42	35
B	Sweep cultivator (2 times)	1	33,32,30,26,30	30
		2	33,30,39,28,35	33
		3	30,36,42,30,36	35
C	Disk harrow followed 2 times cultivator	1	33,28,24,30,31	29
		2	28,37,32,26,26	30
		3	39,36,23,38,28	33
D	Narrow tine cultivator (3 times)	1	27,23,20,33,40	29
		2	26,24,24,27,33	27
		3	27,26,32,30,30	29

Table 4. Yield of Wheat

Treatment	Plot No.	Yield (gm) from an Area 8361 cm²	Mean Yield (gm) from 8361 cm²	Mean Yield (kg) per Hectare
A Disk harrow (2 times)	1	414, 335, 370	372	4449
	2	406, 377, 330	371	4437
	3	356, 437, 326	373	4461
B Sweep cultivator (2 times)	1	222, 253, 380	285	3408
	2	330, 340, 386	352	4210
	3	350, 300, 325	325	3887
C Disk harrow followed by 2 times cultivator	1	266, 338, 260	288	3444
	2	321, 250, 217	263	3145
	3	247, 308, 177	244	2918
D Narrow tine cultivator (3 times)	1	248, 187, 202	212	2535
	2	248, 302, 291	280	3348
	3	270, 178, 300	249	2978

Table 5. Yield of Maize

Treatment	Plot No.	No. of Cobs from an Area of 92903 cm²	Mean No. of Cobs from 92903 cm²	Average Weight of Cobs with Cover (kg)
A Disk harrow (2 times)	1	48		
	2	50	47	0.294
	3	43		
B Sweept cultivator (2 times)	1	34		
	2	30	32	0.288
	3	32		
C Disk harrow followed by 2 times cultivator	1	35		
	2	32	33	0.295
	3	33		
D Cultivator (3 times)	1	30		
	2	26	26	0.288
	3	22		

Results and Discussion

Penetration Resistance

The statistical analysis of the penetration resistance data showed highly significant differences between the soil resistances for different tillage treatments. Further, Duncan's multiple range test indicated that the resistance was highest with the narrow tine cultivator (3 times), as compared to other tillage operations. This means that the traditional practice of using the cultivator again and again does not produce a good seed bed. The reason may be attributed to the fact that the narrow tine cultivator skips untilled soil between the tines and thus results in a cloddy surface which is hard to pulverize with three passes. The narrow tine cultivator is thus ineffective in reducing soil resistance. On the other hand, the sweep cultivator and disk harrow, because of their greater surface area, may produce greater friction resulting in a higher degree of pulverization at the soil-metal interface.

Shear Strength

The linear regression analysis of the shear strength data yielded the following equations:

Treatment	Shear Strength
A: Disk harrow (2 times)	$S = 7.4 + 0.24N$
B: Sweep cultivator (2 times)	$S = 7.08 + 0.25N$
C: Disk harrow followed by 2 times cultivator (narrow tine)	$S = 22.14+0.31N$
D: Narrow tine cultivator (3 times)	$S = 18.76+0.22N$

Where:

S= Shear strength of soil (gm/cm^2)

N= Normal stress (gm/cm^2)

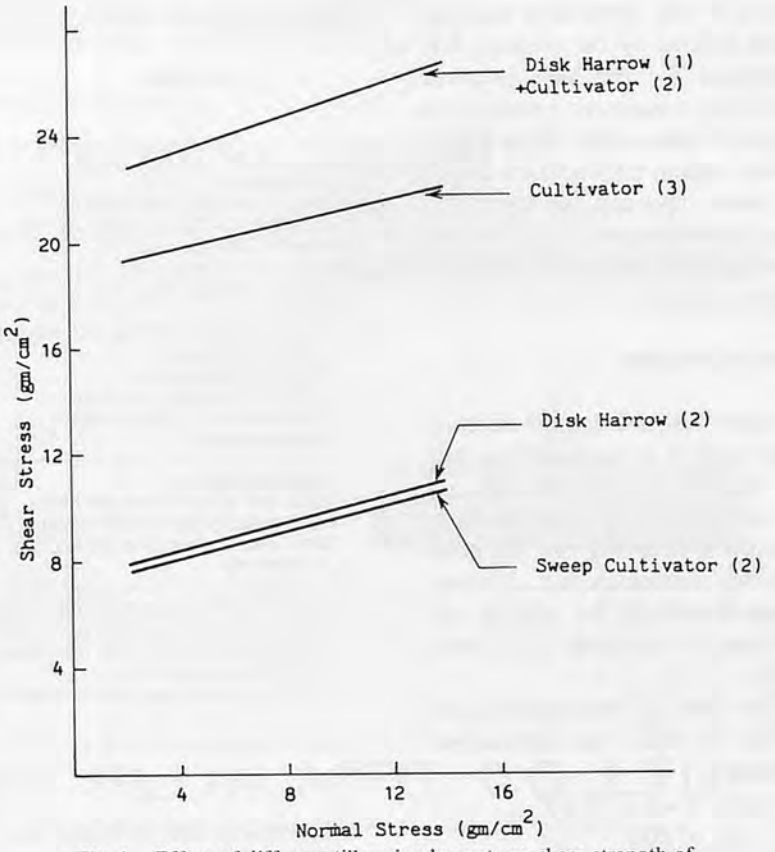


Fig. 1 Effect of different tillage implements on shear strength of soil

The intercept and slope of the equations correspond to cohesion and angle of internal friction of the soil, respectively.

The above equations are graphically shown in **Fig. 1**. It shows that the sweep cultivator (2 times) and disk harrow (2 times) decrease the shear strength of soil considerably. The reduction in strength may be referred to the explanation given above, in case of penetration resistance.

Emergence

The differences in emergence from different treatment plots were found statistically significant. The analysis further indicated that the use of disk harrow and sweep cultivator resulted in a better emergence of crop, as compared to other implements. This seems logical, since the penetration resistance as well as the shear strength of soil resulting from the application of disk harrow and sweep cultivator were established as least above. The less the soil resistance and shear strength, the better should be the emergence of seedlings.

Yield

The analysis of variance indicated significant differences among the yields for different tillage treatments. It was further established that the disk harrow (2 times) was superior to narrow tine cultivator (3 times) as well as the disk harrow followed by 2 times cultivator at 90% confidence level; whereas it was found superior to sweep cultivator at 95% level of significance. Two passings of the sweep cultivator were more effective than the three passings of the narrow tine cultivator.

The high degree of performance of the disk harrow may be attributed to the previous year's findings in

which it was determined that the force exerted by the seedlings was minimum for the plots prepared with disk harrow, as compared to those of many other tillage implements. Again, pulverization as well as partial inversion resulting from the operation of disk harrow could provide better tilth and may partly explain its increased yield.

Cost of Operation

Better soil tilth and the resulting high yield of crop could be offset by the high cost of operation of the implement. It was, therefore, considered necessary that the comparative economics of different tillage treatments be worked out in order to establish their feasibility.

The cost of operation for different machines was determined as Table 6:

Cost of tractor, 47 H.P.
= Rs. 65,000
Cost of disk harrow
= Rs. 12,000
Cost of sweep cultivator
= Rs. 3,200
Cost of cultivator
= Rs. 3,200
Life of tractor = (10 years
= 10,000 hours (1000 hours per year)
Life of implement = 10 years
= 10,000 hours (1000 hours per year)
Fuel consumption = 4.5 liters per hour)

It may be observed from the above that two passings of the disk harrow or sweep cultivator are economically superior to three passings of the cultivator.

Conclusions

Different tillage implements produced highly significant differences between the penetration resistance of soil.

Table 6. Cost of Operation

Cost Item	Cost per Hour (Rupees)			
	Tractor	Disk Harrow	Sweep Cultivator	Narrow tine Cultivator
Diesel oil (4.5 litres per hour)	12.00	–	–	–
Lubricants etc.	3.00	–	–	–
Repair = 10% per year of cost	6.50	1.20	0.32	0.32
Depreciation = 10% per year of cost	6.50	1.20	0.32	0.32
Interest = 14% per year	9.10	1.68	0.45	0.45
Insurance = 2% per year	1.30	0.24	0.06	0.06
Housing = 4% per year	2.60	0.48	0.12	0.12
Labour				
Tractor operator for Rs. 25/- per day (a day = 6 hours)	4.20	–	–	–
Helper for implement at Rs. 15/– a day = 6 hours		2.50	2.50	2.50
Overhead cost = 50% of labour (management)	2.10	1.25	1.25	1.25
Total cost per hour	40.80	8.55	5.01	5.01
Total cost of operation per hour	–	49.35	45.81	45.81
Field capacity (hectar per hour)	–	0.607	0.81	0.81
Total cost of operation per hectare (in rupees)	–	81.30	75.46	75.46

A) Cost of operation with disk harrow (2 times) per hectare = Rs. 162.60
B) Cost of operation with sweep cultivator (2 times) = Rs. 150.92
C) Cost of operation with disk harrow followed by 2 times cultivator = Rs. 232.22
D) Cost of operation with tine type cultivator (3 times) = Rs. 226.38

The narrow tine cultivator produced the highest soil resistance.

The shear strength of soil was lowest with the disk harrow and sweep cultivator.

Different tillage implements produced different effects on the emergence of seedlings.

Disk harrow and sweep cultivator produced a high degree of emergence.

Different implements produced different effects on the yield of crops.

In respect of yield, operations with disk harrow (2 times) and sweep cultivator were superior.

No clear differences in yield were noted between the operations with disk harrow and sweep cultivator.

The cost of operation was lowest with sweep cultivator and disk harrow.

Two passings of the sweep cultivator or disk harrow are effective and economically superior to the three passings of the narrow tine cultivator.

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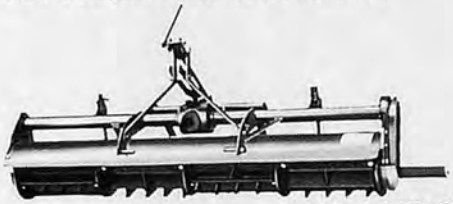
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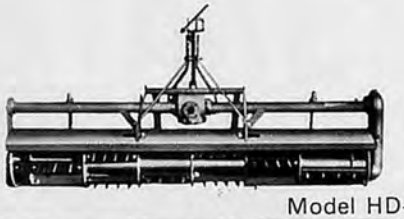
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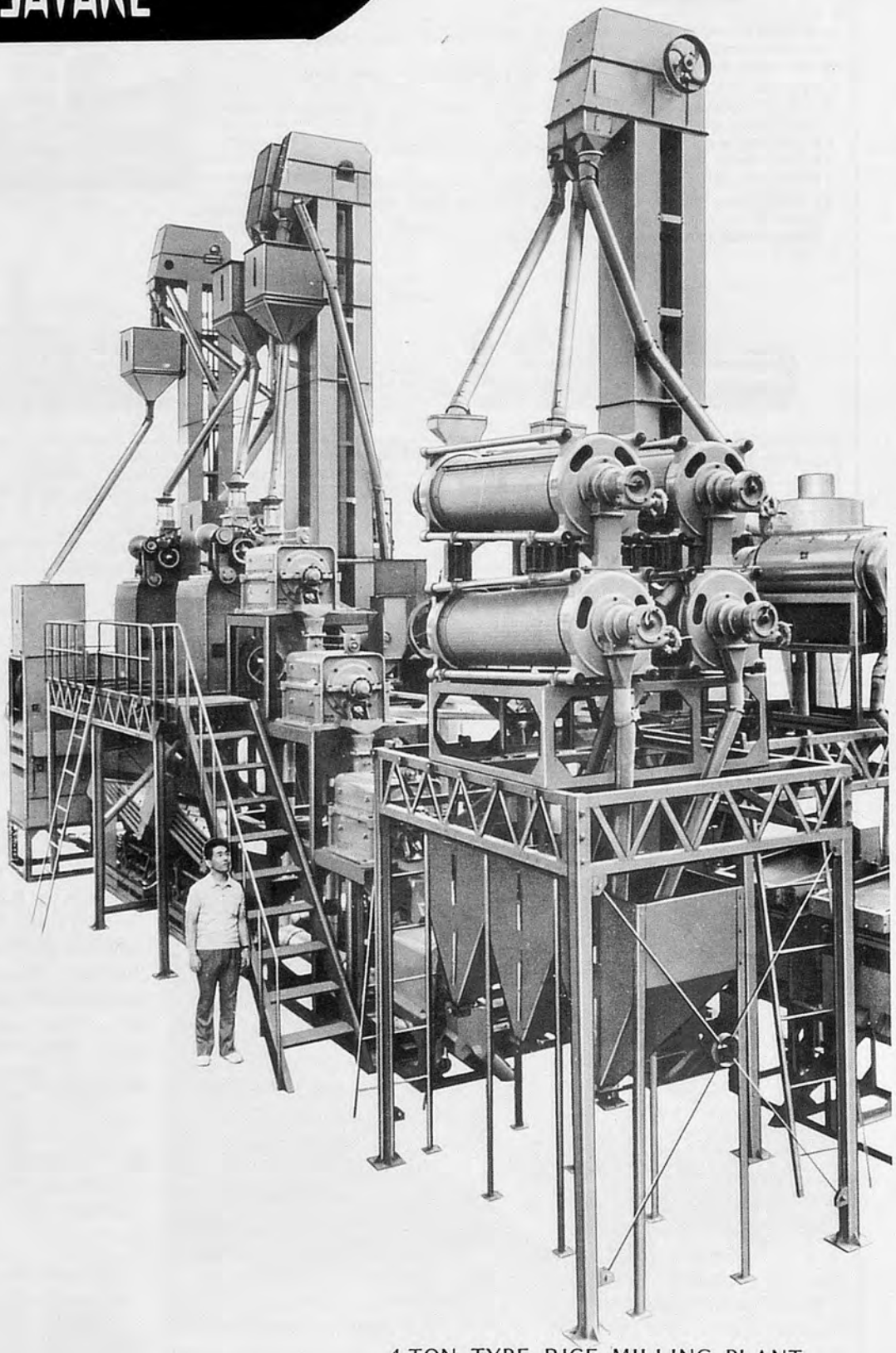
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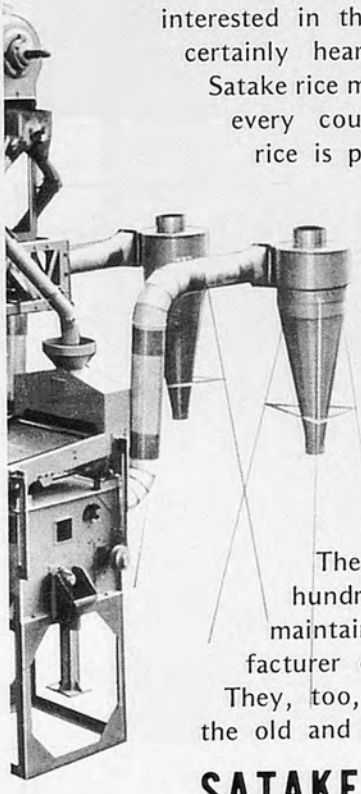
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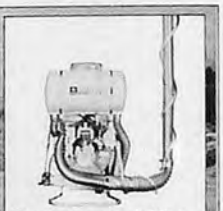
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Economic Farm Size for Rice Combine Harvester in Malaysia



by
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Abstract

Malaysian agriculture has expanded into a major contributor to the nation's economy. The introduction of modern agricultural machinery is necessary for its continued expansion. One machinery being introduced is the rice combine harvester. The economics of operating the combine can be a deciding factor for the viability of the machine in Malaysia. This factor is discussed in this paper with special emphasis given to the economic farm size. The methodology used can be applicable to other agricultural equipments as well.

Introduction

Agriculture in Malaysia is an extremely important business that has expanded during the last decade into a major contributor to the nation's economy. Steps are taken by the Government and various private agencies to introduce modern equipment and to provide subsidies aimed at modernising this sector of the economy. One of the modern equipments which is being introduced to Malaysian agriculture is rice combine harvester. It is becoming quite popular among the paddy farmers in Malaysia due to the fact that it is able to overcome the back-breaking chore of hand harvesting. Also, with the introduction of double-cropping (two-crops per year) in certain areas in Malaysia, the combine harvester is able to eliminate the possible labor shortage during the harvesting period. However, one of the critical factors which will determine the viability of the rice combine harvester in Malaysia is economy. The economic viability of a specific type of combine harvester is discussed in this paper, with special emphasis given to the economic farm size.

Rice Combine Harvester

The specific rice combine harvester considered in the study is the 'KANAN' Combine Harvester which is designed specifically for the tropical region. The harvester is a medium-size type with 1.5 meters cutterbar and about 2,500 kilogram in weight. It is powered by a 25 horsepower four-cycle diesel engine which drives both the working and travelling devices. The travelling unit is equipped with taper-patterned crawler. A test of its performance and adaptability was carried out by the Department of Agriculture, and was found to be suitable for Malaysian conditions (Siraj, 1977). Although specific reference is given to the above mentioned machine, the analyses in this study are applicable for other similar models* which are equally suitable for Malaysia.

Cost Analyses

Owning a combine harvester represents a sizeable investment. Thus, before a farmer or a farmers' organization decides to purchase a combine harvester, it is advantageous for them to know the economic factors affecting their decisions. The economic farm size, especially the minimum farm size, of owning a combine can be a deciding factor for the economic feasibility of combine harvesting. It can be a factor which determines how the farm should be organised for

* Other similar models available in Malaysia are Iseki HL 3500 and Satoh H 3001 D.

economic combine harvesting. This information can be useful to both the farmers and the government agency which are trying to introduce mechanization in the country.

Estimation of Costs

The cost of owning a combine harvester, as for other assets, can be divided into two components, namely; fixed and variable costs. Fixed costs are those which remain relatively constant regardless of the level of use. It implies that the fixed level is maintained whether output is nil or at 100% capacity. The fixed costs in this case are depreciation, interest on investment, taxes, housing and insurance. Variable costs are those which are generally proportional to output. For the case of the combine harvester, the variable costs are repair and maintenance, lubricant cost, fuel cost and operator's labor cost.

Depreciation

This cost reflects the reduction in value of the machine with time. The depreciation cost for each year is computed based on the on-farm values of the machine. The on-farm values at the end of each year are computed as suggested by ASAE (1975).

$$FV_n = 64(0.885)^n(LP)$$

where,

FV_n = on-farm value at the end of year n.
LP = list price.

Using the given equation, the on-farm values and depreciation for each year are listed in **Table 1**. The list price of the combine harvester in 1980 is US$25,714 (M$54,000) (NAFAS, 1980).

For the initial stage (year zero), the on-farm value of the machine is smaller than the actual list price. This difference is usually considered by the dealer as the cost of selling the machine (Peterson, 1975). As far as the buyer is concerned, this difference can be considered as sunk cost (Riggs, 1968; Thuesen, 1977). This sunk cost is the cost of acquiring the machine and is not recovereable, and thus it should have no bearing on any decision regarding the use of the machine.

Interest on Investment

The lack of capital is usually the factor which prevents the use of machinery in the farm. To overcome this problem, the Malaysian Government has set up an agricultural bank (Bank Pertanian Malaysia) to serve as a lending agency for the farming community (BPM, 1974). The bank charges farmers for agricultural equipment loan at 8% on the principal amount per annum. In this study, the rate of 8% is taken on the list price of the machine which is US$25,714.

Taxes, Insurance and Shelter

Tax is taken to be equal to 2% of the remaining value as suggested by ASAE (1975). Insurance and shelter were calculated at 1% of the remaining farm value at the beginning of the year.

Repair and Maintenance

The repair and maintenance cost was calculated by use of the formula suggested by ASAE (1975).

$$TAR = 0.096\ (X)^{1.4}$$

where,

X = 100 times the ratio of the accumulated life to the total hours of expected life.

TAR = ratio of total accumulated repair cost to the list price of the machine expressed as a percentage.

The expected life for the combine harvester is taken to be 2,000 hours as suggested by ASAE (1975). List price of the machine for use in the equation was the price of the new machine.

Fuel, Oil and Labor Costs

Fuel costs were estimated as suggested by ASAE (1975) for diesel engine.

Fuel cost/hour = 0.06 x (HP) x 0.73 x cost/gallon.

where,

HP = actual maximum horsepower, which is taken to be 30 for the rice combine harvester.

Oil cost was taken to be equal to 15% of the fuel cost.

The price of diesel fuel in Malaysia is subsidised by the Government at a rate of US$0.71 per gallon (M$1.50/gallon). From computation based on the above price and with a horsepower (HP) value of 30, the total fuel and oil cost is US$4.27 per hour.

The labor cost was computed based on recommendation for local condition which involves two operators (Siraj, 1977). The labor rate is US$1.20 per hour (M$2.50/hour). Assuming the efficiency rate is 75%, the total labor cost is US$3.20 per hour.

Total Cost of Combine Operation

The total cost of combine operation per hour is computed by adding both the fixed and variable costs. These total costs are computed for various number of hours of operation per year, by using the following formula:

Total cost per hour = fixed cost

for the year/hours of operation per year + variable cost per hour

The fixed cost for the year is made up of the depreciation, interest, taxes, insurance and shelter for that particular year. The variable cost per hour is the summation of repair and maintenance cost, fuel, oil and labor costs for each hour of operation.

The total cost per hour at various level of hours of operation per year are computed for each year from year 1 onwards. The values for year 1 to 6 at level of total operation per year ranging from 100 to 2,000 hours per year are presented in **Table 2**. Using these values, it is possible to determine the average total cost of keeping the combine for a total of 1 to 6 years, with the various level of hours of operation per year. These values are presented in **Table 3** and plotted in **Fig. 1**.

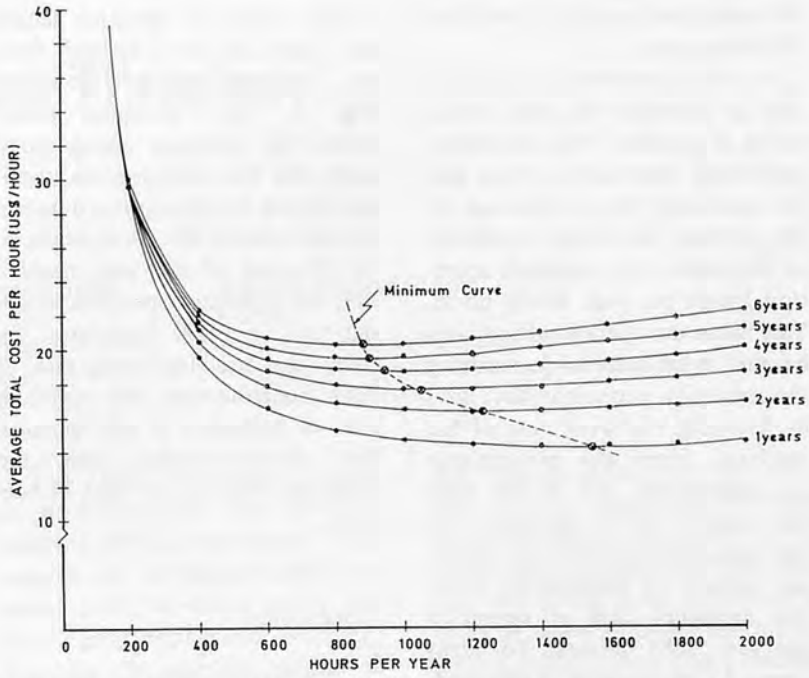


Fig. 1 Average total cost of combine operation per hour for various total life

Minimum Economic Farm Size

As can be seen from **Fig. 1**, the average total cost per hour of operating the combine decreases very steeply as the number of hours of operation per year increases from 100 to 600 hours. It then remains essentially horizontal between 600 to 1,200 hours/year. Beyond that it gradually increases as the number of hours of operation increases.

Table 1. On-farm and Depreciation Values for Rice Combine Harvester

End of Year, n	On-farm Value (US$)	Depreciation (US$)
0	16,457	1,893
1	14,564	1,674
2	12,890	1,483
3	11,407	1,312
4	10,095	1,161
5	8,934	1,027
6	7,907	

Table 2. Total Cost of Combine Operation per Hour for Each Year

Hours of Operation per Year	Total Cost per Hour (US$/hour)					
	Year					
	1	2	3	4	5	6
100	51.06	49.80	48.78	46.81	45.48	43.98
200	29.59	30.19	30.41	29.99	29.79	29.46
400	19.47	21.46	22.46	23.00	23.52	23.89
600	16.49	19.11	20.60	21.57	22.43	23.13
800	15.22	18.33	20.13	21.37	22.46	23.36
1,000	14.61	18.10	20.17	21.61	22.86	23.93
1,200	14.32	18.15	20.38	22.02	23.41	24.61
1,400	14.19	18.32	20.73	22.51	24.02	25.33
1,600	14.17	18.55	21.12	23.04	24.66	26.06
1,800	14.21	18.83	21.54	23.57	25.30	26.79
2,000	14.27	19.12	21.97	24.11	25.92	27.48

Table 3. Average Total Cost of Combine Operation per Hour for Life

Hours of Operation per Year	Average Total Cost per Hour (US$/hour)					
	Total Life (years)					
	1	2	3	4	5	6
100	51.06	50.43	49.88	49.11	48.38	47.65
200	29.59	29.89	30.06	30.04	29.99	29.90
400	19.47	20.44	21.11	21.58	21.97	22.29
600	16.49	17.80	18.73	19.44	20.04	20.56
800	15.22	16.78	17.90	18.77	19.51	20.15
1,000	14.61	16.36	17.63	18.63	19.48	20.22
1,200	14.32	16.24	17.62	18.72	19.66	20.49
1,400	14.19	16.29	17.75	18.94	19.96	20.86
1,600	14.17	16.36	17.95	19.22	20.31	21.27
1,800	14.21	16.52	18.19	19.54	20.69	21.71
2,000	14.27	16.70	18.46	19.87	21.08	22.15

This indicates that the marginal cost has a large absolute value for operation length of less than 600 hours/year.

In any operation, it is desirable to minimize the total cost as much as possible. From the above mentioned observation, it can thus be concluded that in the case of the combine harvesting considered in this study, the minimum operation length per year is 600 hours. This minimum operation length can be used as the basis for determining the minimum economic farm size, by knowing the work rate of the machine. From the performance and adaptability test of the combine (Siraj, 1977), the work rate was determined to be 7.41 hours per hectare (3 hours/acre). Thus, the minimum area of operation per year is 81 hectares. For areas where double-cropping is practised, the minimum farm size is 40.5 hectares.

The average size of land holding among the rice farmers in Tanjong Karang area, where double-cropping is practised, is 2 hectares (Selvadurai, 1976). This means that a cooperation or conglomeration of 20 neighboring farmers will be adequate to attain the minimum farm size for economic combine harvesting. In areas where farmers' associations are already established, there is not much problem in attaining the minimum economic farm size. The more critical factor to know for these areas is the optimum farm size.

Optimum Farm Size

The optimum operation length per year can be obtained from the 'minimum curve' shown in **Fig. 1**. This 'minimum curve' shows the minimum average total cost with the corresponding operation length for the various duration of the combine life. As an example, for the case of a 3 year machine life, the optimum operation length per year is 1,050 hours/year. By using the machine work rate of 7.41 hours/hectare, the optimum area of operation is 142 hectares. For double-cropping area, the optimum farm size is thus 71 hectares.

Conclusion

The determination of economic farm size for rice combine harvester in Malaysia is presented. The minimum economic farm size was determined by means of the total cost of combine operation. The optimum farm size for combine harvesting was also determined for various length of machine life. This information can be useful both to the farmers' associations as well as to the government agencies involved in introducing agricultural mechanization. The procedure used in the analysis can also be applied for determining the economic size of other agricultural equipments such as livestock production facilities, crop-processing equipments, and other farm implements.

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Development of Pantnagar-IRRI Multi-crop Thresher



by
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Introduction

A large number of machines are available in India for the threshing of crops like wheat, paddy, maize etc. Mechanical threshing of wheat crop is widely accepted whereas threshing of paddy and other crops is still done mostly manually. With the introduction of high yielding varieties, fertilizers, improved equipment and better farm practies more and more areas are being planted to multiple crops. The traditional wheat growing regions like Punjab, Haryana and Western Uttar Pradesh have started the cultivation of paddy whereas the paddy growing areas like West Bengal, Karnataka and Bihar have adopted the farming of wheat as the other major crop. Though there are a few makes of paddy threshers available in the country they could not become popular due to their low output, limited use in the season, relatively easy manual threshing of paddy and no pressure due to weather conditions. The wide acceptability of wheat threshers and multiple cropping system has generated a great potential for a multicrop thresher capable of threshing wheat and paddy crops with high outputs and also making fine quality straw ("bhusa") in wheat threshing.

The axial flow paddy thresher of the International Rice Research Institute (IRRI) was found to be capable of threshing freshly harvested paddy to stored paddy and it gave good performance on paddy threshing. It gave an output of 5.5 quintal/hr on paddy. The wheat threshing test on the original IRRI axial flow thresher with some minor modification gave an output of 1.5 quintals per hour of wheat grain but the straw was partially suitable for animal feed. The same thresher gave an output of 3.0 to 3.5 quintals per hour of wheat grain with long wheat straw unsuitable for animal feed.

"Bhusa" is an important animal feed in India. The requirement of "bhusa" making puts an essential constraint on designing a multicrop thresher which could thresh wheat as well as paddy and other crops efficiently. The differences in the threshing characteristics of different crops affect the design requirements of multicrop thresher. In the case of paddy it is desirable to thresh the crop at high moisture levels to minimize shatter loss, but in wheat threshing fine straw making is only possible at low moisture levels. Moreover, size reduction of paddy stem is not required for paddy threshing.

The axial flow thresher of IRRI design, being used for paddy, has peg type cylinder and open concave made of round bars. The peg type cylinders are being used in the latest wheat threshers in India and they are giving good performance as far as wheat threshing and bhusa making is concerned. This common feature of the two threshers was considered to be a feature which can successfully be used in a multicrop thresher. This concept was exploited in this study with the objective of developing a multicrop thresher which can thresh paddy, wheat and other grain crops successfully and make "bhusa" on wheat threshing. The basic parameters of the new thresher were decided, the components designed and fabricated and the thresher was tested for its performance on paddy and wheat crops.

Thresher Design and Description

The new thresher was designed for threshing of the paddy and wheat crops by incorporating the good features of the axial flow paddy thresher and peg type wheat threshers so that it could thresh paddy in different conditions and wheat with good quality straw. In order to meet these requirements it was decided to provide two separate upper concaves in the

Table 1. Specifications of Wheat Threshers

Type of Cylinder	Beater Bar 40 cm long	Peg-tooth Type* 7.5x1.27 ϕ cm	Chaff-cutter Type	Peg-tooth Type* with End Threaded 7.62 x 1.27ϕ cm	Peg-tooth Type* with End Threaded 7.62 x 1.58 ϕ cm	Straight Beater Bar 13x2x2 cm	Peg tooth Type* with End Threaded 7.62 x 1.59 ϕcm	Straight Beater Type
Cylinder diameter (mm)	890	430	840	304.8	304.8	660	317.5	770
Cylinder length (mm)	230	310	50 to 65	279.4	330.2	270	279.4	240
Cylinder speed (rpm)	460	850	275	800	820	700	850	450
Cylinder speed (mpm)	1286	1150	726	760.0	788.0	1450	847.5	1075
Clearance (mm)	20 to 30	27	40	25	25	20 to 45	25	–
Capacity (qtl/hr)	2.55	1.90	2.20	1.65	1.80	2.11	1.38	2.30
Energy (kwh/qtl)	3.67	2.74	1.25	4.89	4.28	2.00	3.60	1.57
Average power (kw)	10.1	4.9	2.7	3.5	3.6	4.0	2.5	3.6
Idle power (kw)	6.90	1.49	0.77	0.81	0.69	1.19	–	1.0
Grain loss (%)	3.35	6.70	–	4.30	1.51	1.65	1.82	–
Broken grain (%)	0.33	0.23	1.11	0.27	0.50	2.00	0.18	0.36
Trash in grain (%)	0.02 to 0.04	0.08	–	0.53	0.31	0.16	0.09	–
Maximum power (kw)	14.12	–	–	5.49	6.24	7.46	3.75	–
Type of blower & number	Suction 2	Suction 1	Non-suction one 40 ϕ x 20 cm	Suction 76.2 ϕ x	Suction 71.12 ϕ mm	Suction 71 ϕ cm	Suction 76.2 ϕ cm	Non-suction
Sieve size	(i) Upper 147x46 cm² 4.5 mmϕ holes, 1.7 holes/cm²	(i) 63 x 57 cm², 3.5 mm ϕ holes, 1.9 holes/cm²	Without sieve	(i) 40.6 x 58.4 cm² 5 mm ϕ holes, 1.5 holes/cm²	(i) 88.9 x 58.4 cm², 5 mm ϕ holes, 15 holes/cm²	(i) 72 x 62 cm², 4.5 mm ϕ holes, 1.7 holes/cm²	(i) 91.5 x 63.5 cm², 4.5 mm ϕ holes, 2 holes/cm²	Without sieve
	(ii) Ist half 56x56 cm & 2 mm ϕ holes, 4.5 holes/cm² IInd half 91 x 46 cm² & 4.5 mm ϕ holes, 1.7 holes/cm²	(ii) 63x57 cm², 12 mm ϕ 6.8 holes/cm²		(ii) 90.2 x 58.4 cm² wire mesh type		(ii) 116x62 cm², 2.5 mm ϕ holes, 4.5 holes/cm²	(ii) 127x63.5 cm², 2 mmϕ holes, 2 holes/cm²	
	(iii) 63.5x46 cm², 2 mmϕ holes, 4.5 holes /cm²							

* Also known as beater rod type

thresher for paddy and wheat crops. The upper concave for paddy was provided with louvers to help the axial movement of material inside the cylinder-concave assembly so that the paddy straw could be thrown out through the exit opening provided in the upper concave like the one provided in the case of axial flow thresher. The feeding to the thresher is to be done from one end of the upper concave and the paddy straw should pass after threshing and separation from the grain through the exit end. This system avoids unnecessary size reduction of paddy straw. In the case of wheat threshing, the upper concave makes a close chamber and feeding is to be done from the centre of threshing zone. The portion of the cylinder which holds the straw throwers remains outside the threshing zone during wheat threshing by providing a closure plate just before the straw throwers and blocking the escape of material from the other end. Different parameters like cylinder speed, cylinder diameter, and cylinder concave clearance were decided on the basis of data given in **Table 1** (P.A.U. Ludhiana). The length of the thresher cylinder was taken slightly more than the axial flow thresher which gave good performance on paddy threshing. Some design information of the thresher is given in **Table 2**.

Table 2. Effect of Peg Length on Capacity of Thresher on Paddy

Peg Length (cm)	Cylinder Speed (rpm)	Total Feed Rate (qtl/hr)	Moisture Content of Paddy (% db)
10.0	450	6.0	14.8
	500	6.2	
12.0	450	12.0	14.3
	500	12.54	
12.5	450	13.70	14.0
	500	14.84	
13.0	450	13.9	13.5
	500	14.89	
14.0	450	16.30	12.0
	500	16.83	
15.0	450	18.36	13.2
	500	18.92	

The different views of the threshers are shown in **Fig. 1** to 3. Details of the different assemblies are given below:

Frame – The frame was fabricated by 75 x 40 x 6 mm channel section. The size of frame was 1,200 x 1,500 x 1,150 mm. Necessary arrangements were made to attach the different assemblies on the frame. An axle was also provided to the frame for the support of pneumatic transport wheels. It was also provided with a drawbar for hitching and transport.



Fig. 1 Multicrop thresher with attachment of upper concave for wheat threshing - view from sieve side



Fig. 2 Multicrop thresher with attachment of upper concave for wheat threshing



Fig. 3 Thresher with attachment for paddy threshing

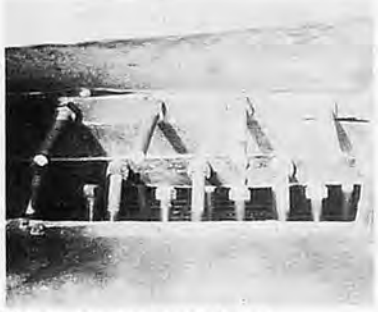


Fig. 4 Arrangement of pegs

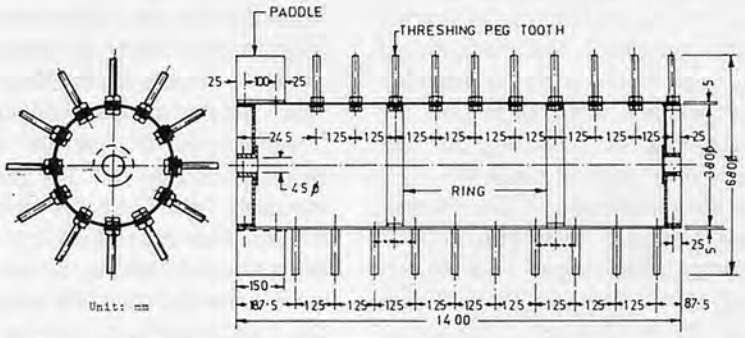


Fig. 5 Threshing cylinder (mm)

Cylinder – The cylinder consisted of 12 peg tooth bars of 139.5 cm length made of 40 x 5 mm flat to support the pegs. The peg tooth bars were fixed over a drum of 380 mm diameter consisting of m.s. rings and sheet. The total number of pegs on the cylinder were 120. The pegs were 18 mm in diameter and 150 mm length. The arrangement of pegs on the cylinder is shown in **Fig. 4**. The cylinder shaft has a 45 mm diameter. The cylinder was also provided with straw throwers at the exit end of the cylinder to throw the paddy straw outside from cylinder-concave assembly after necessary threshing and separation. The details of the cylinder components are shown in **Fig. 5**.

Lower concave – The lower concave of the thresher was made of m.s. bars of 6 x 6 mm which were placed at 12 mm centre to centre spacing. These bars were welded on the curved members made of 25 x 5 mm m.s. flat. It covered 170 degrees and was fabricated in semi-circular shape. The length of the concave was 1,410 mm. A half moon-shaped plate was also attached to the lower concave at 16.5 cm from the exit end. This plate partly checks the grain loss from the straw thrower exit in paddy threshing and makes a close chamber in conjunction with the upper concave in wheat threshing.

Upper concave – The thresher was provided with two upper concaves. The thresher with attachment for wheat threshing is shown in **Figs. 1** and **2**. The concave for wheat was semi-circular in shape. It was made of square bars of 6 x 6 mm which were welded at 12 mm centre to centre spacing on a frame made of m.s. flat of 25 x 5 mm. These bars were covered from outside by a 16 gauge sheet. The sides of concave were made of 16 gauge m.s. sheet. It was also provided with a half moon-shaped plate which made close space in association with its counterpart on the lower concave.

The upper concave for paddy was made trapezoidal in shape to simplify the fabrication. It consisted of a frame made of angle iron of 25 x 25 mm and flat of 25 x 5 mm. This frame was covered with the sheet of 18 gauge. The concave was provided with louvers of 6 cm width at a spacing of 30 mm. Arrangements were also made to shift the position of louvers and also to change their width. **Fig. 3** shows the thresher with attachment for paddy threshing.

Screw conveyor – This conveyor was placed at the end of the lower sieve to collect materials coming from the sieves. The pitch and outer diameter of the screw was 10 cm each. The screw conveyor was fixed to deliver grain to a centrifugal elevator.

Reciprocating-system – The thresher was provided with three reciprocating screens which were mounted on a frame made of angle iron of 25 x 25 x 3 mm and flat of 25 x 5 mm. The uppermost sieve has 169 x 90 cm^2 with 5 mm diameter holes. The bottom sieve was 90 x 90 cm^2 with 1 mm

diameter holes. The aim of this sieve was to remove the dust and small weed seeds from the clean grain and also to deliver grain to the screw conveyor. The assembly was reciprocated at 240 rpm with 3.5 cm stroke length. The side plates of the assembly were made of 18 gauge m.s. sheet. The whole assembly hangs on four arms for its movement. The upper and middle sieves were horizontal and the bottom sieve had an inclination of 30 degrees from horizontal. Minor adjustment in slope of the complete assembly was possible with the help of the tightening or lossening of the nuts of the support hangers.

Blower assembly – The thresher was provided with two sets of blowers. The upper twin blower has an impeller of 45 cm length and 26 cm diameter to supply air to the top and middle sieves. The lower blower has an 88 cm long and 36 cm diameter impeller to supply air over the lower screen. All blowers are straight blade type. The side plates were provided to the blowers for the control of the air volume.

Feeding trough – A feeding trough was provided to the thresher to facilitate easy feeding of materials. This trough is interchangeable so that it could be used for wheat as well as paddy threshing. The feeding trough was attached to the upper concave of the thresher. The position of feeding trough for wheat and paddy threshing is shown in Figs. 2 and 3. The feeding trough is almost in centre of cylinder in wheat threshing and at the extreme end for paddy threshing. The size of the feed opening was 20 x 51 cm.

Testing of Thresher

After fabrication of the multicrop thresher it was tested on paddy and wheat crops to optimize the cylinder speed, peg length, feed opening, louver position and its width and concave clearances. The thresher was operated with a 35 hp tractor and testing was conducted in the field. For the determination of power requirement of different components the test was carried out in the laboratory.

Pre-test Observations

The following crop factors were determined for each of the tests:

Moisture content of grain and straw – For determining the moisture content of grain and straw three samples of grain and straw weighing 50 gms and 200 gms respectively were taken. Moisture content was determined by oven dry method by heating the samples at 70°C for 24 hours. The weighing was performed with the help of a triple beam balance having a least count of 0.1 gm.

Grain-straw ratio – Grain-straw ratio was determined by selecting three samples of the crop from the lot which was to be threshed. Each sample weighed about 5 kg. The weights of the grain and straw were determined separately for each sample after separating them from each other and their ratio was calculated. The average of the three samples were considered as the straw – grain ratio for test purpose.

Power Consumption Test at No Load

The thresher was tested for power consumption by the individual components at no load in the laboratory at different speeds. The drive to the cylinder pulley was given by a speed variator of 10 hp through a flat belt. The power requirement was measured with the help of a 3-phase wattmeter. The speed of the different shafts were measured with a tachometer.

Before observing the power consumption, the variator was run for a period such that it reached stabilized condition at certain desired speed. In the first instance, power was given to the cylinder shaft with all the components in operation. The power was measured at different cylinder speeds and corresponding speeds of various shafts were also measured. The observations were repeated after disengaging the power to the screw conveyor and similarly after disengaging the other components one by one.

Field Testing of Thresher

The field test was done on paddy and wheat crop for its performance and to decide its parameters. To optimize cylinder speed, length of cylinder peg, cylinder-concave clearance and louver size and its position the observations were taken for the capacity, visible damage, cylinder loss and total loss occuring at different settings.

The capacity of the thresher was determined on the basis of grain available at the main outlet and total loss occuring in the thresher. The total loss included all the free grain thrown from the straw thrower exit and from sieves. The total loss was calculated by collecting all the materials coming at the rear of the thresher at the end of each test and free grain was separated from it. The cylinder loss and sieve loss were calculated on the basis of two minute sample taken at the end of the sieve by collecting the material over a cloth piece. Free grains in the sample were considered as sieve loss whereas unthreshed heads were taken as cylinder loss. Visible damage was determined by taking 50 gram sample from the main outlet of the thresher.

Results and Discussions

The thresher was tested on paddy and wheat crops to determine and optimize different parameters.

Thresher Tests on Paddy Threshing

The tests were conducted on paddy crop to find the optimum peg length, cylinder speed, cylinder-concave clearance, louver width, feed opening size and louver position.

Effect of peg length on throughput of thresher on paddy – The length of cylinder pegs was varied from 10 to 15 cm to determine the effect of peg length on throughput of thresher. The cylinder-concave clearance corresponding to 15 cm peg length was 2.5 cm and for each setting of cylinder peg it was increased by the amount equal to the decrease in peg length from this value. The moisture content of paddy grains during the tests ranged from 12.9 to 14.8 percent on dry weight basis.

The effect of peg length on throughput of the thresher in shown in **Fig. 6** and the corresponding data are given in **Table 2**. It is observed that there is an increase in the throughput of the thresher with the increase in peg length from 6.0 to 18.36 quintals per hour when the peg size was increased from 10 to 15 cm at 450 rpm of cylinder speed. This increase at 500 rpm of cylinder was from 6.2 to 18.92 quintals per hour. The increase in throughput with increase in peg length is almost linear at both cylinder speeds. The throughput of the thresher at all peg lengths is observed to be slightly more at 500 rpm than the throughput at 450 rpm of cylinder. The increase in throughput of thresher may be due to better suction capacity of cylinder at higher peg lengths and reduced cylinder-concave clearance.

Effect of cylinder speed and cylinder-concave clearance on cylinder loss and visible damage to paddy grains – The effect of cylinder speed and cylinder-concave clearance on cylinder loss and visible damage of paddy is shown in **Fig. 7**. The corresponding data are given in **Tables 3** and **4**. It is observed that cylinder speed is an important operating parameter with regard to cylinder loss and grain damage. It is seen from the figure that increase in the cylinder speed reduces the cylinder loss at the cost of increases in visible grain damage for all the cylinder-concave clearances. It confirms the studies of Delong and Schwantes (1942), Vas and Harrison (1969) and Singh and Kumar (1976). There is a rapid decrease in cylinder loss when the cylinder speed is increased from 370 to 450 rpm. From 450 to 490 rpm for all the cylinder-concave clearance it is almost constant. This may be due to the fact that almost 99.8 percent of the threshability is achieved at 450 rpm of cylinder speed.

When the cylinder speed is changed from 370 rpm to 490 rpm at a cylinder-concave clearance of 2.0, 3.5 and 4.5 cm the corresponding reductions in cylinder losses are from 0.60 to 0.07, 0.78 to 0.20 and 0.92 to 0.12 percent, respectively. It indicates that the threshability of the cylinder increases with increase in cylinder speed. It is also observed that visible damage of grain increase with increase in cylinder speed. The rate of increase in the damage is comparatively low up to 450 rpm of cylinder speed than the rate of increase between 450 to 490 rpm of cylinder. This may be due to the characteristics of the crop which allows the grain to deform without any visible damage. Variation in the cylinder speed from 370 to 490 rpm at 2.0, 3.5 and 4.5 cm cylinder-concave clearances caused corresponding variations in the visible damage as

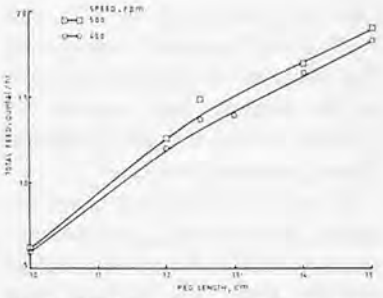


Fig. 6 Effect of peg length on capacity of the thresher on paddy

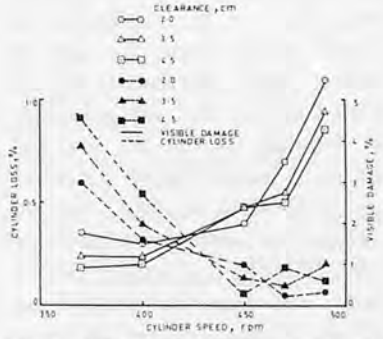


Fig. 7 Effect of cylinder speed and cylinder concave clearance on cylinder loss and visible damage on paddy

Table 3. Effect of Cylinder Speed and Cylinder-Concave Clearance on Cylinder Loss on Paddy

Cylinder Speed (rpm)	Cylinder Loss in Percent at Different Clearances		
	2 cm	3.5 cm	4.5 cm
370	0.60	0.78	0.92
400	0.82	0.40	0.54
450	0.20	0.14	0.06
470	0.05	0.10	0.18
490	0.07	0.20	0.12

M.C. of paddy: 22.7% db, M.C. of stem: 43.7% db, Feed opening full and louver width: 12 cm, Louver position at zero, Louver spacing: 30 cm

Table 4. Effect of Cylinder Speed and Cylinder Concave Clearance on Visible Damage of Paddy Grain

Cylinder Speed (rpm)	Visible Damage (%) at Different Clearance		
	2 cm	3.5 cm	4.5 cm
370	1.80	1.70	0.9
400	1.50	1.20	1.00
450	2.00	2.40	2.40
470	3.25	2.75	2.50
490	5.50	4.75	4.30

M.C of paddy: 22.7% db, M.C. of Stem: 43.7% db, Feed openig full and louver width: 12 cm, Louver position at zero, Louver spacing: 30 cm

1.80 to 5.50, 1.70 to 4.75 and 0.90 to 4.30 percent, respectively. The variation in cylinder loss and visible damage with respect to cylinder speed may be considered almost exponential in trend.

It may be concluded from the figure that reducing the cylinder-concave clearance tends to reduce cylinder losses and increase seed damage. This result was also obtained by Vas and Harrison (1969) and Singh and Kumar (1976). However, there is an overlapping of curves which might be due to varying crop conditions or experimental errors. The cylinder losses at 370 rpm and at 2.0, 3.5 and 4.5 cm cylinder-concave clearances are 0.60, 0.78 and 0.92 percent whereas at 490 rpm these are 0.07, 0.20 and 0.12 percent respectively. The damage at 2.0, 3.5 and 4.5 cm cylinder-concave clearances and at 370 rpm are 1.8, 1.7 and 0.9 percent and at 490 rpm are 5.5, 4.75 and 4.30 percent, respectively.

Effect of louver width and feed opening size on total grain loss in paddy threshing – The effect of louver width, feed opening size and cylinder speed was observed on total grain loss occuring in the thresher. The corresponding data are shown in **Table 5** and curves are plotted in **Fig. 8**. It is very clear from these curves that total loss is maximum at full opening of feed area at both the louver widths under consideration and at all cylinder speeds. At this opening with 6 cm louver width the variation in total loss is 12.3 to 14.2 percent whereas it varies from 12.5 to 13.3 percent at 12 cm louver width. Hence there is not much difference in total loss at these widths of louver. It may be concluded that the louver width does not play any important part in the loss occuring in the thresher.

The observed trend of the curve for two-thirds opening and 12 cm louver width is quite fluctuating which may be due to difference in

Table 5. Effect of Louver Width and Feed Opening Size on Total Grain Loss at Different Cylinder Speed on Paddy Threshing

Louver Width (cm)	Cylinder Speed (rpm)	Test Number	Total Loss (%)		
			Full Opening 20 x 51 cm	2/3 Opening 20 x 34 cm	Half Opening 20 x 25.5 cm
6	370	1	14.9	6.7	6.1
		2	13.8	6.1	5.9
		3	13.9	7.3	6.4
	Average		14.2	6.7	6.1
6	400	1	11.3	4.8	6.1
		2	14.1	6.2	6.9
		3	13.9	7.0	6.5
	Average		13.1	6.0	6.5
6	450	1	13.7	4.2	8.1
		2	11.3	6.8	4.2
		3	13.4	7.0	6.9
	Average		12.8	6.0	6.4
6	470	1	12.5	6.1	4.8
		2	12.2	6.3	5.8
		3	12.2	6.2	7.1
	Average		12.3	6.2	5.9
6	490	1	12.8	6.1	5.1
		2	12.0	4.9	6.2
		3	12.7	8.2	5.2
	Average		12.5	6.4	5.5
12	370	1	11.3	3.1	6.5
		2	13.2	2.7	5.4
		3	14.3	2.6	4.4
	Average		12.9	2.8	5.4
12	400	1	12.7	7.1	4.5
		2	12.5	3.2	5.5
		3	12.9	4.7	6.5
	Average		12.9	5.0	5.5
12	450	1	13.9	5.9	5.9
		2	12.9	6.1	5.9
		3	13.1	9.0	4.4
	Average		13.3	7.0	5.4
12	470	1	11.9	6.4	5.8
		2	15.0	6.8	6.0
		3	11.8	6.6	4.4
	Average		12.9	6.6	5.4
12	490	1	12.2	6.2	5.9
		2	12.8	6.2	4.9
		3	12.5	6.2	6.0
	Average		12.5	6.2	5.6

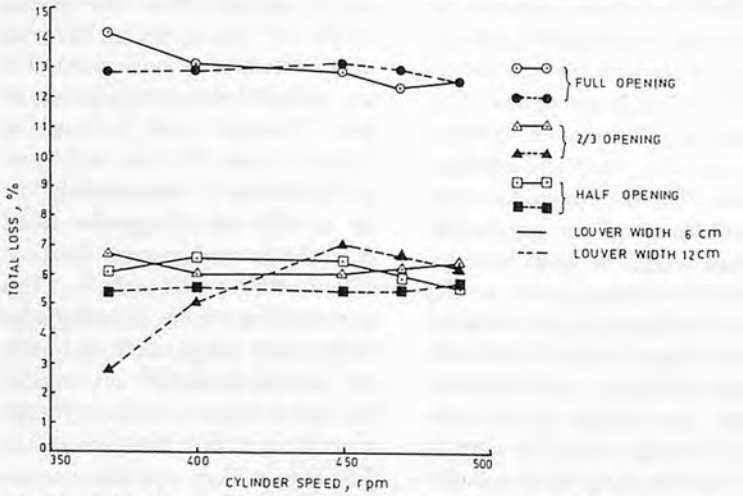


Fig. 8 Effect of louver width and feed opening size on total grain loss at different cylinder speeds in paddy threshing

crop conditions or experimental errors. The total loss at 370 rpm is 2.8 percent which increases upto 7.0 percent at 450 rpm of cylinder speed. After this speed there is a decrease in total loss up to 6.2 percent occuring at 490 rpm. But in the case of a 6 cm louver width it varies within the range from 6.0 to 6.7 percent which is almost constant. This also indicates that there is no significant effect of cylinder speed on total loss. The variation in the total loss at half opening of the feed area is 5.5 to 6.5 percent at 6 cm louver width and it is 5.4 to 5.6 percent at 12 cm louver width within the observed speed range of the cylinder.

It may be concluded that there is no significant effect of cylinder speed on the total loss occuring in the thresher. It is also clear that increase in feed opening area, which in turn results into increase in feed length, causes increase in total loss occuring in the thresher. It may be due to the fact that increase in feed opening area reduces the separation length of cylinder-concave assembly. Thus the grain quantity passing through the exit of the thresher is increased. The total loss occuring at full opening of feed area is almost double the losses occuring at two-thirds or half opening. There is not much difference in the total loss occuring at two-thirds and half opening of feed area. Therefore, a feed length of 34 cm is recommended corresponding to two-thirds opening as it allows easy feeding of crop along with reduced losses. The effect of louver width on the total loss is not very clear but it may be considered insignificant as observed from **Fig. 8**.

Effect of louver position with respect to feed end on the capacity of thresher at different cylinder speeds – The effect of louver position with respect to feed end on the capacity of thresher at different cylinder speeds is shown in **Fig. 9** and the corresponding data are given in **Table 6**. In all these tests the spacing of louver was 30 cm and louver width was 6 cm.

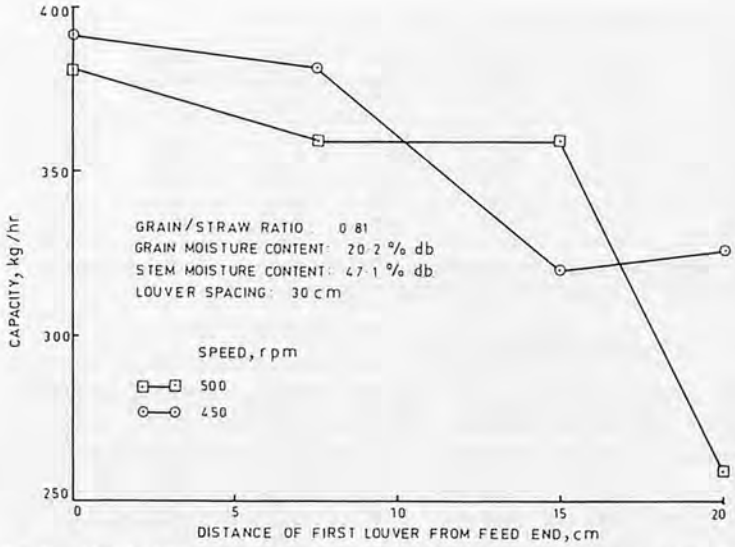


Fig. 9 Effect of louver position with respect to feed end on capacity of thresher at different cylinder speeds

It is clear from the figure that the trend of both the curves drawn for 450 and 500 rpm of cylinder speed is quite fluctuating. The fluctuations may be due to experimental errors and variation in crop conditions. However, it may be concluded that shifting of the first louver position from the feed end causes decrease in the capacity of the thresher. At 500 rpm cylinder speed the capacity of the thresher is reduced from 381 to 260 kg/hr when the louver position is shifted from extreme end position to a distance of 20 cm from the extreme end. Similarly the reduction in the capacity is from 392 to 327 kg/hr at 450 rpm speed of cylinder for the same change in louver position.

The position of the first louver in the upper concave plays an important role because it helps in the movement of material inside the cylinder-concave assembly from feed opening to exit opening. The extreme end location of the first louver allows easy entry and movement of material and, therefore, increases the capacity of the thresher.

Table 6. Effect of Louver Position with Respect to Feed and Capacity of Thresher at Different Cylinder Speeds

Cylinder Speed (rpm)	Test No.	Capacity (kg/hr) First Louver Position from Feed End (cm)			
450	1	406	400	299	266
	2	400	350	341	255
	3	370	396	323	466
Average		392	382	321	327
500	1	384	415	390	250
	2	400	344	310	220
	3	359	321	380	310
Average		381	360	360	260

Grain/straw ratio: 0.81, M.C. of Paddy: 20.2% db, M.C. of stem: 47.1% db, Louver spacing: 30 cm, Louver width: 6.0 cm

Thresher Tests on Wheat Threshing

Tests were conducted on RR-21 variety of wheat to determine the effect of cylinder speed on the capacity, cleaning efficiency, visible damage of grain and sieve loss of the thresher. The cylinder-concave clearance was 2.5 cm for these tests. The data regarding these tests are shown in **Tables 7 to 9**.

Effect of cylinder speed on the capacity of thresher on wheat – The effect of cylinder speed on the capacity of thresher is shown in **Fig. 10**. It is clear from the figure

Table 7. Test Result of Thresher on Wheat

Cylinder Speed (rpm)	Feed Rate (qtl/hr)	Capacity (qtl/hr)	Straw/ Grain Ratio	Grain Breakage (%)	Cleaning Efficiency (%)	Sieve Loss (%)
425	5.34	2.13	1.5	0.77	86.7	3.7
450	6.59	2.64	1.5	1.03	92.0	3.7
470	7.29	3.01	1.42	4.95	92.4	3.7
500	7.95	3.07	1.59	6.10	96.2	4.6
540	10.37	4.22	1.46	9.56	96.1	4.7

Variety: RR-21, Cylinder concave clearance: 25 mm, Average moisture content of grain: 10.54% db, Average moisture content of straw: 3.6% db

Table 8. Test Result of Thresher on Wheat

Cylinder Speed (rpm)	Feed Rate (qtl/hr)	Capacity (qtl/hr)	Straw/ Grain Ratio	Grain Breakage (%)	Cleaning Efficiency (%)	Sieve Loss (%)
420	5.24	1.63	1.59	0.29	81.2	2.1
460	5.51	1.81	1.38	1.20	92.2	2.1
475	5.26	1.89	1.78	3.38	93.1	4.2
500	6.52	2.26	1.88	1.87	95.2	4.8
540	6.92	2.63	1.63	4.55	96.1	4.7

Variety: RR-21, Cylinder-concave clearance: 25 mm, Average moisture content of grain: 12.1% db, Average moisture content of straw: 7.5% db

Table 9. Test Result of Thresher on Wheat

Cylinder Speed (rpm)	Feed Rate (qtl/hr)	Capacity (qtl/hr)	Straw/ Grain Ratio	Grain Breakage (%)	Cleaning Efficiency (%)	Sieve Loss (%)
425	5.29	1.88	1.68	2.6	83.2	2.1
450	5.87	1.95	2.00	2.35	90.1	3.8
475	5.51	2.39	1.31	1.38	95.7	3.5
500	6.43	2.74	1.34	0.34	95.2	3.9
540	7.20	3.17	1.27	1.38	97.0	4.2

Variety: RR-21, Cylinder concave clearance: 25 mm, Average moisture content of grain: 14.3% db, Average moisture content of straw: 6.88% db

that the capacity of thresher increases with increases in cylinder speed for all the moisture contents. It is found that the capacity of thresher at 10.54, 12.10 and 14.30% db moisture contents of grains varies from 2.13 to 4.22, 1.63 to 2.63 and 1.98 to 3.17 quintals per hour, respectively, in the speed range of 420 to 540 rpm of cylinder. The capacity at 10.54% moisture conent is found to be maximum at all cylinder speeds followed by 14.30 and 12.10% moisture. The maximum capacity of thresher is found to be 4.22 quintals per hour at 540 rpm and 10.54% moisture content of wheat.

The trend of increase in capacity with the increase in cylinder speed is not very smooth due to variation in the grain-straw ratios of test samples. The other factors causing variation may be experimental errors and crop condition. Effect of moisture content on the capacity is also not very much clear due to these variations.

The increase in the capacity of the thresher with increase in speed at all the moisture content levels may be due to the increase in the suction capacity of thresher. On the other hand, higher speeds of the cylinder pegs must have generated greater amount of impact and caused faster size reduction and threshing of the crop. The higher cylinder speeds might also have applied greater force on the threshed crop to pass through the concave opening.

Effect of cylinder speed on cleaning efficiency of thresher on wheat – The effect of cylinder

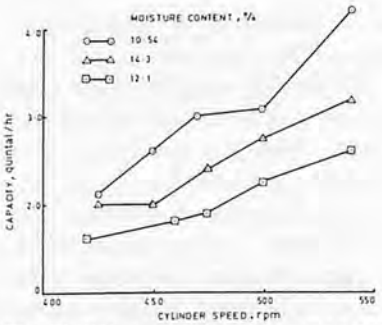


Fig. 10 Effect of cylinder speed on the capacity of thresher at different moisture contents of wheat grains

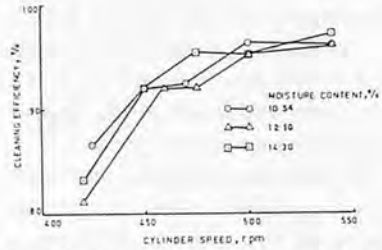


Fig. 11 Effect of cylinder speed on cleaning efficiency at different moisture contents of wheat

speed on cleaning efficiency of thresher is shown in **Fig. 11**. The cylinder speed was varied from 420 to 540 rpm while three moisture levels of crops were selected for the tests. At all the three moisture content levels, i.e., 10.54, 12.10 and 14.30% (db) the cleaning efficiency increases with increase in cylinder speed but at a diminishing rate. The change in cylinder speed indirectly causes change in blower speeds in direct proportion. Thus higher amount of air discharge causes better cleaning of the grains at increased cylinder speeds. The cleaning efficiency varies from 81 to 87% in the moisture range of 10.54 to 14.30% (db) in the observed speed range of cylinder. However, the effect of moisture content on cleaning efficiency is not very clear as there is overlapping of curves in the observed range of moisture content. This overlapping of curves might have been due to variation in the crop condition and experimental errors.

Effect of cylinder speed on visible damage of wheat grain – The effect of cylinder speed on visible damage of grain is shown in **Fig. 12**. The effect was observed at three moisture levels of 10.54, 12.10 and 14.30 percent (db). It was observed that with increase in the cylinder speed there is increase in the visible grain damage for all the moisture levels except 14.30%. At this moisture content level, the grain damage is reduced from 2.61 to 1.38%. The damage is increased from 0.29 to 4.55% at 12.1% grain moisture and 0.77 to 9.56 percent at 10.54 percent grain moisture when the cylinder speed is increased from 420 to 540 rpm. The increase in the visible damage may be due to the increase in impact force applied by the cylinder pegs on the grain at higher speeds. Similar trend was observed while testing the thresher on paddy. The experiments conducted by Delong and Schwantes (1942), Vas and Harrison (1969) and Singh and Kumar (1976) also gave similar results.

Effect of cylinder speed on sieve loss in wheat threshing – Curves have been plotted in **Fig. 13** to show the effect of cylinder speed on sieve loss at three moisture content levels of wheat grain viz. 10.54, 12.10 and 14.30 percent (db). The increase in the cylinder speed corresponds to a proportional increase in the speed of eccentric which oscillates the cleaning sieves. Due to varying straw-gain ratio and crop condition associated with experimental errors, the effect of moisture content on sieve loss is not clear. However, it may be concluded that the sieve loss occuring in the thresher increases with the increase in cylinder speed at a diminishing rate. The increase in the sieve loss at 10.54, 12.10 and 14.30 percent moisture content is 3.7 to 4.7, 2.1 to 4.7 and 2.1 to 4.2 percent, respectively.

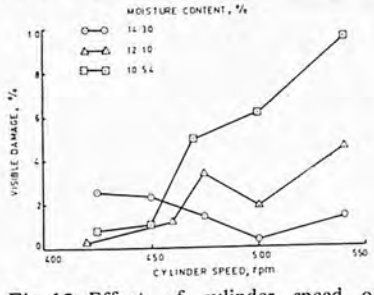


Fig. 12 Effect of cylinder speed on visible damage of wheat at different moisture contents

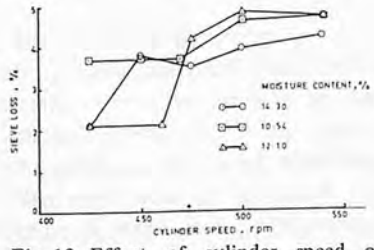


Fig. 13 Effect of cylinder speed on sieve loss at different moisture contents of wheat

Power Requirements of Different Thresher Components

Power required by the different components of the thresher at different speeds was observed at no load condition in the laboratory. The power required by the individual components at no load condition is plotted in **Fig. 14**. The corresponding data are given in **Table 10**.

The power required by the upper and lower blowers at load condition would be almost the same as at no load condition. However, there will be an increase in power requirement for eccentric, screw conveyor and cylinder at load condition. In the figure, the power is plotted against the cylinder speed for each thresher component. However, the actual speed

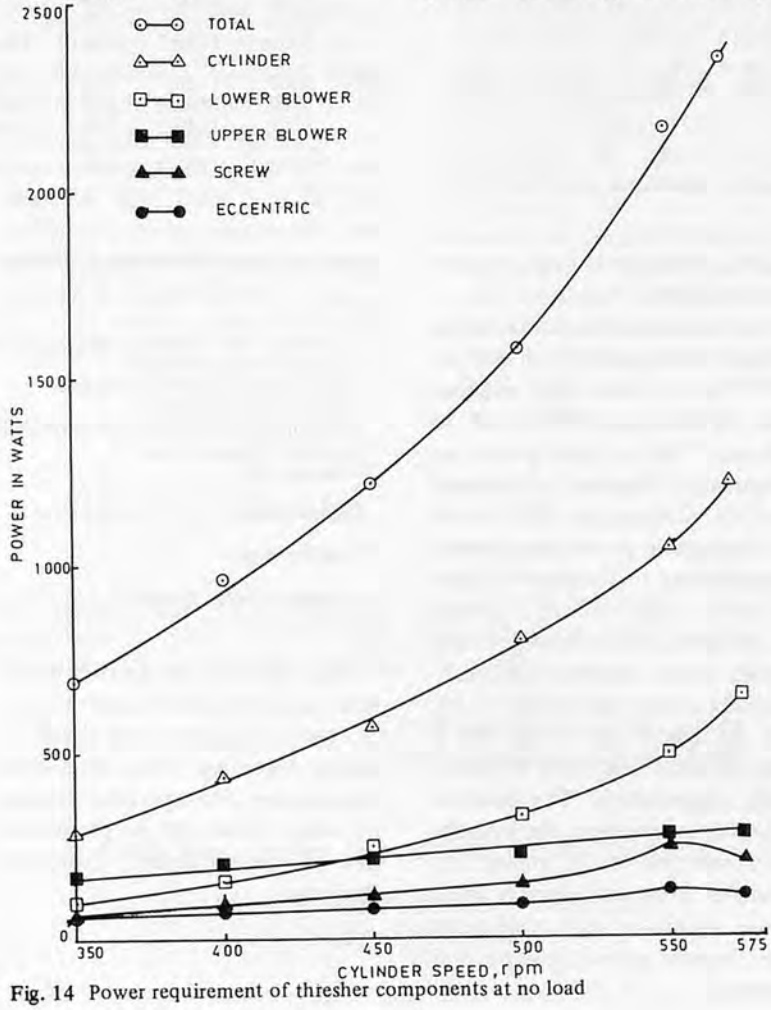


Fig. 14 Power requirement of thresher components at no load

Table 10. Power Requirement of Thresher Components at No Load

Cylinder Speed (rpm)	Upper Blower Speed (rpm)	Lower Blower Speed (rpm)	Eccentric Speed (rpm)	Screw Conveyor Speed (rpm)	Total No load Power (watt)	Variator Speed (rpm)	Variator No Load Power (watt)	No Load Power Requirement of Thresher Components in Watt					
								Total	Cylinder	Upper Blower	Lower Blower	Eccentric	Screw
350	600	580	165	280	1440	700	752	688	288	180	80	60	80
					1440	700	752	688	288	156	100	60	80
					1440	700	752	688	288	164	100	60	80
					1440	700	752	688	288	166.7	93.4	60	80
400	685	655	192	313	1760	800	780	980	440	220	120	80	120
					1740	800	780	960	440	180	180	80	80
					1740	800	780	960	440	200	160	60	100
					1746.7	800	780	966.7	440	200	153.3	73.3	100
450	760	720	210	350	2000	880	800	1200	560	240	220	80	100
					2020	880	780	1240	580	200	260	80	120
					2000	880	792	1208	568	200	240	80	120
					2006.7	880	790.7	1216	569.3	213.3	240	80	113.3
500	845	810	227	383	2440	980	840	1600	808	212	320	60	200
					2400	980	844	1556	796	220	300	120	120
					2400	980	836	1564	796	208	360	80	120
					2413.3	980	840	1573.3	800	220	326.7	86.7	146.7
550	940	895	258	437	3080	1090	912	2168	1048	280	480	120	240
					3120	1100	920	2200	1040	280	480	120	280
					3040	1100	916	2124	1044	260	480	140	200
					3080	1096.7	916	2164	1044	273.3	480	126.7	240
570	980	930	270	447	3260	1120	920	2340	1120	280	640	120	180
					3280	1140	920	2360	1108	312	620	100	220
					3280	1140	920	2360	1132	228	680	100	220
					3273.3	1133.3	920	2353.3	1120	273.3	646.7	106.7	206.7

of the component may be seen from the **Table.**

The total power required by the thresher is increased from 688 to 2,353 watts when the cylinder speed is increased from 350 to 570 rpm. The no load power requirement of thresher at designed speed of 500 rpm is 1573 watts. The increase in power requirement corresponding to increase in cylinder speed from 350 to 570 rpm for cylinder, lower blower, upper blower, screw conveyor and reciprocating system are 288 to 1,120, 93.4 to 646.7, 166.7 to 273.3, 60.0 to 206.7 and 60.0 to 106.7 watts, respectively. The increase in power requirement for cylinder and lower blower is almost exponential in nature. There is linear change in power requirement for upper blower, screw conveyor and eccentric.

Table 11. Design Parameters of Thresher

Item	Feature
Diameter of the cylinder at the tip of the peg	68 cm
Cylinder peripheral speed	1,068m/min
Design power to drive the thresher	20 hp
Length of cylinder drum	139.5 cm
Recommended belt speed for main pulley of thresher	994.9 ± 30.5 m/min
Diameter of main pulley	60 cm
Cylinder pegs	Mild steel pegs of 1.8 cm diameter and 15 cm length
Peg tooth bar	Mild steel flat of 40 x 5 mm section
Cylinder shaft	185 cm length x 4.5 cm diameter
Cylinder concave clearance	2.5 cm

The thresher was further modified and tested and it gave a capacity of 12 quintals per hour in paddy threshing. The total loss ranged from 2 to 4 percent. Testing on wheat could not be performed due to non-availability of crop at this stage.

Summary

A multicrop thresher capable of threshing paddy and wheat crops was developed that would thresh paddy of low moisture or immediately harvested conditions to dry paddy at the same time make good quality, fine straw in wheat threshing. The thresher was developed by combining the design

features of axial flow paddy thresher of the IRRI, and peg type wheat threshers of Indian design which are capable of producing good quality straw.

The thresher was provided with two upper concaves to facilitate paddy and wheat threshing. The concave for paddy was provided with louvers to impart axial movement to the crop inside the cylinder concave assembly. In paddy threshing the crop is fed from one end of the cylinder and most of the paddy stem is thrown out from the other end with the help of straw throwers. The grain and chaff pass through concave openings and fall over an oscillating sieve. Cleaning is achieved by two sets of blowers. In wheat threshing, all the grain and straw are forced to pass through the concave openings and are subjected to cleaning process. The maximum capacity of thresher in wheat and paddy threshing was 4.22 and 12.00 quintals per hour, respectively.

There was a decrease in throughput of thresher with decrease in peg length and increase in cylinder concave clearance. It was observed that increase in cylinder speed reduces the cylinder loss at the cost of increase in visible damage for all the cylinder concave clearance. There was no effect of the louver width on the total grain loss occuring in the thresher. The feed opening size had a significant effect on total loss and 34 x 20 mm opening was found suitable for the thresher. The louver position with respect to feed affects the capacity of the thresher and an extreme end location of first louver results into maximum capacity of thresher.

The capacity, cleaning efficiency, visible damage and sieve loss increased with an increase in the cylinder speed of the thresher at 10.54, 12.10 and 14.30% (db) grain moisture contents in wheat threshing.

At design speed of 500 rpm, the thresher required 1,573 watts power under no load condition. The total no load power required by the thresher increased from 688 to 2,353 watts per hour when the cylinder speed was changed from 350 to 570 rpm. It was observed that there was an increase in power requirement for all the thresher components with increase in cylinder speed.

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Small-Scale Rice Bran Oil Extraction System Using an Expeller

—An Approach to Integrated Rural Development and Industrialization



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Advantages of Extraction Oil from Rice-Bran

In many countries, nowadays, rice bran per se is used as animal feed. However it is not the best way to use it. Oil in rice bran starts oxydizing right after it is separated from rice. By oxydizing oil, free fatty acid is produced, which can cause disorder to digestive organs of the animal. The higher the temperature and moisture, the faster the process of oxydation. Therefore, feeding animals with stored rice bran may not be very good, especially in humid tropical countries.

Contrary to this, if oil is extracted from rice bran, the oil can be used as edible oil, etc., at the same time making bran-cake (de-oiled bran) good, stable feed.

Rice bran contains 18 – 21% of crude fat. Refined rice-bran oil is regarded as one of the best among various vegetable oils from the view point of human health. It works to remove cholesterol in blood, lowering high blood pressure. It contains tocopherol (vitamin E) and oryzanol, both of which work to accelerate human growth, facilitate blood circulation and stimulate hormonal secretion. Squalene, which has considerable pharmaceutical effect, is contained too.

Rice bran oil can be used for various industrial purposes also, such as for soap, wax, medicine, esther oil, etc.

By the extraction process, crude oil is stabilized as well as bran-cake, does not oxydize any more and can be stored for long time unlike raw bran. Crude oil might be sold to oil refinery at any time desired.

In Japan, rice bran being a single source of vegetable oil, about half of the total production, i.e., 600,000 ton is used for oil extraction, from which about 100,000 ton of crude oil is produced, recovering about 75,000 ton of edible oil.

In Burma, about 100,000 ton of rice bran, out of total production of 700,000 ton, is used for oil extraction. They get about 15,000 ton of crude oil, from which about 5,000 ton of edible oil is recovered.

In the USA, where almost all of the produced paddy is milled in large rice mills, much of the rice bran is used for oil extraction.

In India, it is reported that about 70,000 ton of crude oil and 5,000 ton of edible oil is produced.

In Egypt and Italy and in other countries, bran-oil extraction is practised to a limited extent.

Difficulties of Large-Scale Bran-oil Extraction

Today, almost all of the rice-bran oil extraction factory stand on solvent extraction system.

The system employs normal-

hexane as solvent to extract crude fat in rice bran. As the solvent is toxic and expensive, it needs to be evaporated completely from solvent-bran oil mixture (miscella), then cooled and collected for re-circulation. As it is highly explosive, care has to be paid in the extraction process.

The minimum processing capacity is 1-2 tons of bran per hour, which corresponds to rice mills of 10 to 20 ton per hour milling capacity. This is far greater than most of rice mills in the South-east Asian countries.

In the region, more than half or sometimes three quarters of rice is milled in small custom-hire mills which are mostly composed of Engelberg type hullers (except for Malaysia and Indonesia where a combination of rubber-roll huskers and whiteners are widely used). Bran produced by these mills cannot be used for oil extraction as it is mixed with rice-husk.

Also, the supply sources of rice bran for oil extraction are limited to a number of commercial rice mills, whose component machinery include huskers, paddy separators and whiteners. It naturally makes bran collection difficult and time-consuming, unless these rice mills are luckily located around an oil extraction factory in sufficient numbers and within short distance.

As a result, acidity of collected rice bran is liable to be at a high level. It lowers the economy of the oil extraction factory. As such, bran cannot produce low-acidity crude oil which can give high recovery of edible oil on refining. Therefore, much emphasis is being placed on the quick delivery of rice bran from rice mills to the oil extraction factory.

Fluctuation of commercial price of rice bran is very remarkable in many countries. When the price is very low, in addition to the generally bad transportation conditions, rice mills are naturally reluctant to deliver bran because it may not give them any profit. On the other hand, if rice bran is kept in rice mills waiting for better price, the acid value of rice-bran will increase further and the commercial value of bran is reduced.

This is one of the reasons of many rice mills are selling rice bran as animal feed to the near-by farmers and/or cattle growers, even if the price might be low, instead of selling it to distant oil extraction factories.

In summary, the difficulty of bran collection and the poor quality of bran threaten the existence of solvent system bran oil mill.

Can Bran Stabilizer be the Answer?

In order to cope with such difficulties, several trials have been made with the aim of introducing bran stabilizers to be attached to rice mills.

Indeed, with the use of a bran stabilizer, an oil-disintegrating enzyme, lipase, contained in fresh rice bran is destroyed and acidity of rice bran will not proceed any more even during a few weeks' storage. Then, rice millers need not dispose rice bran hurriedly at very cheap price but can transport and sell it to oil mills at the proper time in bulk. The oil mills are assured of getting low acidity rice-bran.

However, bran stabilizers are so far not widely used, chiefly due to the high cost of the equipment.

The process of bran stabilization is nothing more than heating and drying of rice-bran. But in order to perform the process successfully, temperature and duration of heating must be controlled adequately. Therefore, effort to design very simple bran stabilizers by use of direct fire and with no moving parts have been so far unsuccessful. Successfully operating bran stabilizers all utilize steam as heating media and are power driven, whose cost cannot be very cheap, though may not be prohibitive. Simply for the purpose of bran stabilization only, most of rice millers are not inclined to make such expenditure.

Advantages of Bran Oil Extraction System by Pressing

Other than solvent extraction system, there is a method of oil extraction by pressing. This is widely used for oil extraction from rape seed, cotton seed, peanut, coconut, etc. For bran oil extraction also, the press method had been used in pre-war Japan.

By pressing, oil cannot be extracted from the material as completely as by use of solvent. In the case of rice bran, only about half of the contained oil, i.e. 9 to 10% of bran weight is extracted by pressing, whereas by use of solvent over 90% of oil, i.e., 16 to 18% of bran weight can be extracted. However, the pressing method has advantages over solvent method as follows:

1) The cost of equipment can be much less as the system is simpler and the minimum economic scale is smaller.

2) The operation is easier and does not require skilled labour.
As it does not use volatile solvent, no danger of fire hazard nor explosion. Cooling by water is not required.

3) As the construction is simple, many parts of the system can be locally manufactured easily in developing countries.

4) Small capacity equipment can be designed so as to be coupled directly with the existing small or medium scale rice mills, i.e. 2 to 4 ton of paddy per hour. Then, produced bran in the rice mill is

fed to oil mill directly, resulting in following benefits:

a) Transportation cost and transportation loss of rice bran is saved.

b) Operation fund to purchase rice bran can be eliminated.

c) Acidity of the produced crude oil can be very low, which compensates reduced curde oil extraction rate.

d) Bran-cake is produced continually in parallel with the operation of rice mill which enables a scheduled and stable sales of bran-cake.

e) Overhead cost and operation and maintenance cost of oil mill can be reduced as it is jointly controlled with rice mill. Rice husk produced in rice mill can be used as fuel for steam boiler.

5) As the produced crude oil and bran-cake are solvent-free, they are always safe for human and/or animal consumption.

6) The remaining oil in bran-cake not only improves the calorific value of the feed but also gives the effect of accelerating animal growth, promoting the propagation and improving the resistance to disease.

However, due to the fact that oil content in rice bran is not so high as rape seed, etc. and the fluffy nature of rice bran necessitates very high compression ratio, conventional screw presses (expellers) as used for other vegetable oil could not be used. Machines used for the purpose earlier were batch type hydraulic pressing machines, such as the so-called cage press or box press, etc.

Batch type presses are troublesome, awkward and require much labour in operation. In addition, these machines are not manufactured anymore. Therefore, some alternatives have to be newly developed.

Newly Developed Rice Bran Oil Expeller

Recently, Dr. K. Yokochi, director, the Rice Bran Oil Technical Research Institute, has developed, in cooperation with Suehiro Iron Works Co., Ltd., Japan, a small scale continuous oil extraction system by use of a specially designed expeller. The processing capacity is 300 kg of bran per hour. It matches to a rice mill of about 3 ton paddy per hour milling capacity.

The schematic drawing is shown in **Fig. 1**.

Where

1) Sifter. Used to remove stones, brokens, germs, etc. from raw rice bran.

2) Steam cooker and dryer. Steam pressure: 3 - 4 kg/cm^2, temperature: 95 - 105°C, duration of steaming and drying: 20 - 30 min. (initial moisture of bran 11 - 13% and final moisture 6 - 7%).

3) Continuous expeller. Capacity: 300 kg of bran per hour, Power requirement: About 20 ps, maximum pressure: 850 kg/cm^2.

4) Filter press. Power requirement: about 2 ps.

5) Steam boiler. Husk fired. Pressure: 4 - 5 kg/cm^2, Evaporation: about 150 kg/hour.

By this system, about half of the contained oil is extracted from rice bran, the rest remaining in bran cake. Assuming that the crude fat content of rice bran to be 20%, about 10% of rice bran weight is recovered as crude oil.

This system can be used for other vegetable oil extraction also, simply by changing bars and screw of the expeller. Roller, crusher, screen, etc. need to be added for oil extraction from soybean, cotton seed etc. but these do not cost much.

Operation of rice mills in Southeast Asia is often seasonal. When the rice mill is not busy, the oil mill can be used for the extraction of oil from various other materials according to their availability in the locality and the season.

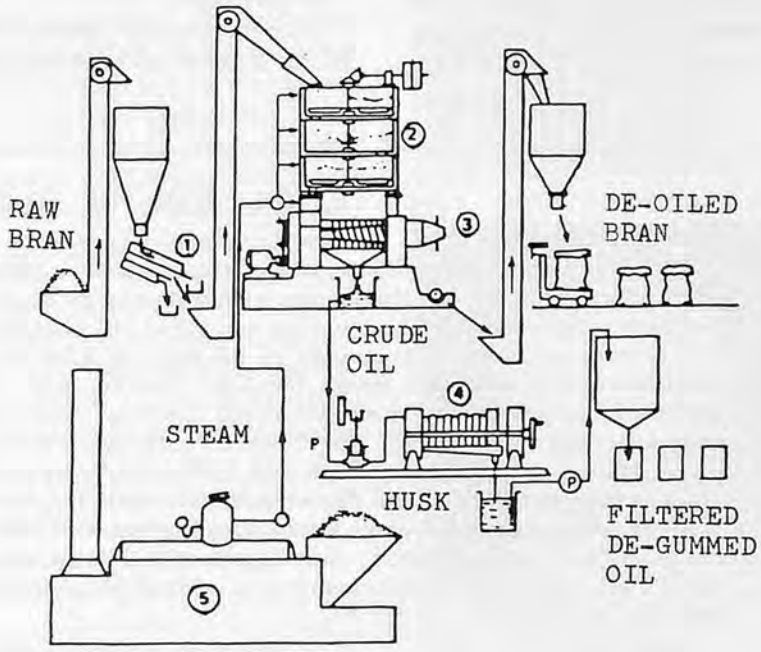


Fig. 1 Schematic drawing of the newly developed rice bran oil expeller.

Development of Related Industries

When such small oil mills are added to rice mills, the combinations can be a more stable and profitable enterprise than the rice mill alone.

Then commercial rice millers need not go for unfair bargaining with farmers for paddy and they can be socially-accepted authentic food processors. It puts the official paddy floor price into effect.

In the Southeast Asian countries, there are many vegetable oil sources other than rice bran which have not hitherto been utilized because of the scattered cultivation and limited quantity which make the commercial utilization difficult. Besides soybean, peanuts, sesame, rape seed, coconuts, oil palm etc. which are edible as they are or have been utilized in various ways, there are many other oil-containing materials such as cotton seed, kapok seed, castor bean, jute seed, sunflower, maiz germ, etc. These can advantageously be utilized by the proposed small scale oil mill.

Products of oil mills can be processed further:

a) **Feed mill**

Bran-cake and other oil-cakes might be sold as they are or further processed into assorted feed for various animals in combination with other feed crops. On the processing of assorted feed, some rice-husk might be mixed, which should not be done before oil extraction from rice bran. For the production of assorted feed, required equipment are small. Local supply of assorted feed makes animal growing easier and improves the utilization of feed crops.

b) **Soap making**

Crude bran oil can be utilized for soap manufacturing. The advantages of soap manufacturing are:

1) Small-scale operation is possible.

2) Various other kinds of oil can be mixed. Highly acidified oil can also be utilized.

3) As soap from bran oil resolves easily in cold water, it is convenient for use in rural area.

The quantity of produced soap is about twice of used oil. Local manufacture and wider use of soap will greatly improve the sanitary conditions in rural area.

c) **Oil refinery**

After starting the operation of 10 to 20 units of small expeller type bran oil plants attached to rice mills, installation of an oil refinery will be feasible. As the crude rice bran of supplied from these rice mills is low in free fatty acid content, expectable recovery of edible oil on refining will be as high as 80 to 90%.

After the installation of the refinery, crude oil mostly being processed into edible oil, the rest of the oil, which is chiefly composed of free fatty acids, can be utilized as the material for soap making, together with other kinds of oil and fat.

d) **Medicine**

Separated germ from rice bran might be processed into eutrophic medicine (health ingredients) for babies and patients.

These industries not only create job opportunities in rural society but will also help to improve technical knowledge and skill of rural people. These will also help rice monoculture around the area change into multi-crop rotation farming combined with animal/fish raising, resulting in higher agricultural productivity and farmers' well-being. Agricultural cooperatives might take up such type of activity with high priority. ■■

LETTER FROM THE EDITOR

Dear AMA Readers,

Beginning with the 1981 Winter issue of this magazine, a slight but very meaningful change in the cover will be instituted, i.e., the acronym AMA will no longer mean "Agricultural Mechanization in Asia" but instead "Agricultural Mechanization in Asia, Africa and Latin America."

This proposed change is occasioned by the fact that when the AMA made its debut in 1971, the management then envisioned serving the Asian countries only. However, over the past 10 years, its readership, and particularly the subscribers and co-editiors, have indeed come from far and wide, notably from Africa and Latin America. This "overspill" elates us and we can only attribute this to the usefulness of the magazine world-wide and of which the management is justly proud.

The change in the meaning of the acronym notwithstanding, the AMA name will stay considering that it has already become a household word among the engineers, farm machinery manufacturers and distributors and our esteemed readers. More importantly, we continue to look foreward to eliciting the usual support and cooperation of all concerned in sustaining this special magazine on agricultural mechanization in developing countries.

Thank you.

Yoshisuke Kishida

On-Farm Grain Storage in Nepal



by
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Introduction

The Kingdom of Nepal lies between 80 and 88 degrees east longitude and between 26.5 and 30.5 degrees north latitude and is surrounded by the Tibetan region of the Peoples Republic of China on the north and India on the west, south and east. The population is about 14 million of which two-thirds are living in the hills. Nepal has a total area of approximately 141,000 km^2 of which four-fifths is hilly and mountainous. Geographically Nepal can be divided into:

The Tarai which is the northern extension of the Gangetic plain and lies in the south of the country. This region reaches an elevation of 250 meters above sea level and has a tropical climate. The main agricultural crops in the Tarai are paddy, wheat, maize, jute, tobacco and sugarcane.

The Hills and Valleys vary in elevation from roughly 500 meters to 4,000 meters and exhibit a wide range of climatic conditions. Paddy is grown in the lower valleys while at higher altitudes maize, barley and millet are the major cereals. Subsistence agriculture is the most important activity in the hills and many of these areas are food deficient.

The Highlands represent the inner Himalayan valleys. Due to severe climatic condition crop production in these areas is limited and animal husbandry is the main source of livelihood.

About 90% of the population is involved in agriculture. Per capita GNP is about US$110. As nearly all the earth's bioclimatic zones are represented in Nepal, agriculture is very diversified. Transport and communication facilities in the hill and mountain area are very limited; of the 55 hill districts only 13 are serviced by roads. This renders agricultural development of the hill region very difficult and, consequently, agricultural development efforts in the past have been focused primarily on the Tarai and the Kathmandu Valley. During the previous Five-Year Plan, however, His Majesty's Government (HMG) realised the importance of development of the hill region. As a result the UNDP/FAO assisted Hill Agriculture Development Project was initiated in 1974.

Present Storage Practices

Grain storage practices in Nepal vary with the type of crop grown, climatic condition of the region and local customs. Some of the most common storage methods are described below:

"Bhakari" storage (Fig. 1) – The "Bhakari" is a widely used storage structure in the Tarai and lower



Fig. 1 "Bhakari" for storage of grain



Fig. 2 "Petara" for storage of grain

* R. B. Manandhar worked until August 1979 with the Entomology, Division of the Department of Agriculture, Nepal while A. G. Rijk was assigned to the UNDP/FAO assisted Hill Agriculture Development Project from January 1977 until March 1979.

hills. It consists of a mat woven from split bamboo and held together as a vertical cylinder. In some cases it is plastered with a mud-cowdung mixture. The "Bhakari" is placed inside the house or farm building. The storage capacity of the "Bhakari" is around 500 kg paddy.

"Petara" storage (Fig. 2) – The "Petara" is also woven from split bamboo and can best be described as a big (rectangular) basket. Its storage capacity varies around 200 kg.

"Mud bin" storage (Figs. 3, 4, 5) – A wide range of storage structures made of a mud-cow-dung-paddy husk mixture, sometimes reinforced with split bamboo, can be found in Nepal. Sizes and shapes vary according to the farmer's requirements and traditions. All designs have an opening at the bottom to remove the grains and are closed with a cover sealed with mud.

"Dhansar" storage (Fig. 6) – The "Dhansar" is a separate building situated in the farmyard to store grain. It is made of wood and raised above the ground (0.5 m). It is only used by bigger farmers in the Tarai. A smaller and cheaper version is made of woven split-bamboo plastered with mud and covered with a thatched roof.

"Suli" storage (Fig. 7) – The "Suli" is a simple vertical rack used for outdoor storage of maize on the cobs. It enables the maize cobs to dry after harvest in the wet season.

Other storage practices – In some hill areas farmers store grains in wooden boxes of approximately 1.5 m^3 capacity inside their house (Fig. 8). Small quantities of grains and pulses may also be stored in clay or copper jars (Fig. 8a) in temporary partitions within rooms, in pits dug in the ground or maize cobs are suspended on ropes from the ceiling of buildings. Barley may be stored unthreshed on the roof of buildings (Fig. 9)



Fig. 3 Construction of large "Mud bin"



Fig. 3a Completed "Mud bin" standing outdoors for drying

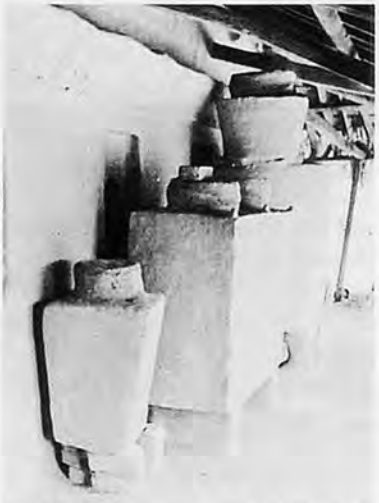


Fig. 4 Different sizes of "Mud bins" placed under roof of a farm



Fig. 5 Completed "Mud bin" standing outdoors for drying. Note decoration on top (Jumla area)



Fig. 6 Improved "Dhansar" at the Institute for Agriculture and Animal Science



Fig. 7 Storage of maize on "Suli"



Fig. 8 Wooden box for storage of grain (Jumla area)

On-Farm Grain Storage Activities

In the early 1970's an USAID-assisted pilot project built outdoor concrete silos, each about 5 tons capacity, on several farms in the Chitwan district of the Tarai (Fig. 10). Loans were provided to the farmers by the Agricultural Development Bank of Nepal to cover the construction costs. With the increasing price of cement these farm-sized silos have become too expensive to be economical for the average farmer. Moreover, the farmers complained about the grains becoming spoiled, likely due to moisture migration inside the silo as a result of the very hot climate in the Tarai.

The Entomology Division of the Department of Agriculture investigated the effects of herbs, mustard oil and oil cake as insecticide to protect stored pulses. Mustard oil was found to be an effective insecticide although its actual working was not investigated.



Fig. 10 A concrete silo constructed in a USAID assisted pilot project



Fig. 8a Clay jars and kerosene tins for storage

The Lumle Agricultural Centre (British Gurkha Resettlement Scheme) has storage activities in the hills of west central Nepal. The Centre experiments with replacement of the "Bhakari" by a galvanished metal sheet to protect the grain from storage pests and applied pesticides to the maize cobs stored on the "Suli".

As part of its agricultural engineering activities the Hill Agriculture Development Project (HADP) assisted during 1977 and 1978 the Entomology Division (ED) and the Agriculture with a programme to (AED) of HMG's Department of Agriculturale with a programme to investigate the problems with on-farm storage and to conduct trials with improved storage methods. Because of the shortage of personnel the programme was rather limited. It was proposed to be followed up by a FAO assisted Prevention of Food Losses project which started in 1979.

Activities Initiated by HADP

Survey on On-Farm Grain Storage

Preliminary surveys by HADP/ Entomology Division on grain storage proved that the storage situation in the hills varies considerably depending on climate, altitude and farming practices.



Fig. 9 Unthreshed barley stored on top of a farm house (Jumla area)

Jumla area

Altitude : 2,400 meters
Rainfall : 665 mm
Highest temperature : 25°C (May-June)

From November until April the daily minimum temperature is below 0°C.

Analysis of samples taken in Jumla showed that grain is safely stored in this area. Insects and fungi do not develop during storage because:

a. The stored grains have a low moisture content; b. Storage structures are adequate (wooden boxes and mud-bins placed inside the houses or storage pits under the ground); c. During the storage period the air temperature and humidity are low; and d. Storage periods are in general short (less than half a year) as the area is food deficit.

The only storage problem is the rather serious and continued treat of rodents that gnaw through the wooden boxes and mud-bins to feed on the stored grains.

Pokhara area

Altitude : 920 meters
Rainfall : 3,483 mm
Highest temperature : 30.4°C (May)
Lowest temperature : 7.2°C (January)

Temperature and humidity in Pokhara are considerably higher than in Jumla. As a result, storage problems are more prevalent especially with crops harvested in the rainy season. Paddy is stored in the "Bhakari" while maize cobs are stored on the "Suli". Crops

are generally stored with too high a moisture content. Maize harvested in the monsoon has a moisture content of about 30% but storage on the "Suli" enables it to dry. The most common storage pests found were grain moth (*Sitotraga cereallela*) and rice weevil (*Sitophilus oryzae*). In addition, rats are a treat to the stored and standing crop.

Trisuli area

In Trisuli the situation is almost similar to Pokhara although the rainfall is slightly less. Paddy is stored in the "Bhakari" but maize cobs are stored inside the house. Small quantities of cobs are hung on a rope suspended from the ceiling. Larger quantities of cobs are stacked in one quarter circle layers in a corner of a room (Fig. 11) as soon as they are considered to be sufficiently dry. The base of the cobs point outwards to protect the maize from rodent attack. Problems with storage are similar as those in Pokhara.

Kathmandu valley

Altitude : 1,324 meters
Rainfall : 1,361 mm
Highest temperature : 29.8°C
Lowest temperature : 1.0°C

Grain samples were taken in Kathmandu Valley at four different locations to investigate whether grain was infested prior to storage. It was found that most of the samples were already infested with rice weevil and grain moth prior to storage.



Fig. 11 Maize cobs stacked in one quarter circle layers in a corner of a room

Trials with Improved Bhakaris

In addition to the surveys, research and development activities were undertaken by the Entomology Division and Agricultural Engineering Division with assistance of HADP. During 1978, trials with improved "Bhakaris" were carried out in Kathmandu valley, Pokhara area and the Tarai. At each location the following prototype "Bhakaris" (capacity 75 kg) were constructed (Fig. 12):

A. *Sandwich Bhakari* – A cylinder of plastic sheet sandwiched between two walls of woven split bamboo; with spout at the bottom for removal of grains; with a galvanized metal strip (50 cm high) wrapped around the base of the Bhakari to prevent rodent attack; the top covered with plastic, straw and mud; fumigation with Celphos tablets (phosphine).

B. *Bhakari plastered with mud* – A woven split bamboo cylinder heavily plastered with mud both inside and outside; with spout at the bottom and metal strip for rodent proofing and the top is covered with straw and mud; fumigation with Celphos.

C. *Galvanized metal sheet Bhakari* – This is provided with spout at the bottom and the top is covered with straw and mud; fumigation with Celphos.

D. *Control Bhakari* – Woven split bamboo cylinder; top sealed with straw and mud.



Fig. 12 Trials with improved "Bhakaris". From left to right: Control-, Metal sheet-, Sandwich- and Mud plaster "Bhakari"

The "Bhakaris" were placed in buildings which were infested by rodents. In each Bhakari was stored paddy with a moisture content of 12 per cent. At the end of the storage period samples were taken and analyzed at the Entomology Division (Table 1). The galvanized metal strip proved to be very effective against rodent damage. Although no numerical data was collected on loss due to rodents it appeared that loss from the control "Bhakari" was high while no loss occurred from "Bhakari" A, B and C. The galvanished metal "Bhakari" is most effective against both insect attack

Table 1. Results from Paddy Storage Trials

Type of Bhakari and Location	No. of Insects Found in Sample (0.75 dm³)			Moisture Content (%)	Storage Period
	Weevil	Grainmoth	Total		
Kathmandu					
A	0	12	12	12.8	Feb-Nov '78
B	0	14	14	13.0	do
C	0	0	0	13.2	do
D	20	38	58	14.7	do
Pokhara					
A	0	32	32	13.9	14 Mar-13 Oct '78
B	0	10	10	14.4	do
C	0	6	6	13.0	do
D	0	45	45	15.5	do
Tarai (Bhairawa)					
A	0	2	2	13.3	22 Mar-14 Oct '78
B	0	17	17	14.9	do
C	0	0	0	12.0	do
D	0	26	26	15.0	do

Remarks: Fumigation at the beginning of the storage period.
Samples taken at the end of the storage period.



Fig. 13 Construction of metal storage bins

Table 2. Technical Specifications of Metal Storage Bins

Type	Capacity (litre)	Total Cost (1978 (NC Rs)*	Cost per Litre Capacity (NC Rs)	Height (cm)	Diameter (cm)	Material (galvanized sheet)
I	450	315	0.70	174	62	22 gauge
II	800	325	0.41	180	76	26 gauge
III	1,250	850	0.68	180	95	24 gauge
IV	1,050	650	0.62	120	95	24 gauge

* US$ 1.00 = Nepalese Rs. 11.90

and moisture. It is however more expensive and unavailable in remote areas. The durability of the transparent plastic sheet used in type A is low; it is easily punctured by insects or damaged in handling. "Bhakaris" are often placed inside the house and in this case fumigation with Celphos should be avoided for health reasons. Fumigation with Ethylene dibromide ampoules may be safer but the practice of fumigation of stored grains in remote areas will be difficult to introduce. The size of the experimental "Bhakaris" is such that they are far too small for the average farmer. Larger sizes (capacity 500 kg) must be constructed in order to learn the technical problems involved.

In addition to the improved "Bhakaris", metal grain-storage bins have been developed and installed in a village for trial purposes (Fig. 13). The technical specifications of these bins are given in Table 2. The bins are placed on pieces of wood to prevent rust forming on the bottom. The bins must be placed in the shade as direct exposure to the sun will cause moisture condensation. Both the opening at the top and at the bottom are sealed with a rubber strip to prevent air leakage. It must be emphasised that prior to storage in an airtight structure grain must be well dried otherwise substantial losses may occur during storage (safe moisture content depends on storage temperature). For bins of 300 to 400 litre capacity 26 gauge metal sheet is recommended. Dimensions should be such that the storage bin can pass through the door of the traditional farm building. Larger bins should be made of heavier sheet.

Pilot Grain Storage Programmes

A pilot storage programme in Jumla was implemented during October – November 1978. Rodenticides were provided and farmers were trained in their use. A blacksmith from Kathmandu instructed local blacksmiths in the manufacture of metal storage bins. In total 35 bins were made, 16 of 175 litre capacity and 19 of 370 litre capacity.

In Pokhara and areas with similar climatic conditions the maize harvested during the monsoon has a high moisture content (up to 30%). To facilitate drying the maize cobs are stored on open-air racks "Suli". However, after a few months insect infestation becomes serious. It has been recommended that as soon as the maize cobs have been dried on the "Suli" to a moisture content of approximately 12%, the cobs must be shelled and the maize be fumigated in an airtight bag or bin and properly stored. A pilot programme was proposed around Pokhara to investigate such a practice but the programme could not be started in time to show results.

Rodent Control

Rodents seem to be a major cause of loss of foodgrains, as well as fruits and vegetables (2). Consequently, a pilot rodent control was initiated and a village was selected in Pokhara area. The programme started in April 1978. The following methods were used:

Back-breaker traps (snap-traps) baited with peanut butter, meat or fish;

Cage-traps baited similarly as the back-breaker traps;

Zinc phosphide baiting – The poison is put inside small wheat flour balls which are rolled in butter. The bait is placed in bamboo tubes of about 1 foot in length;

Warfarin (anti-coagulant) baiting – The poison is mixed with wheat flour and butter. Placing of baits is similar to zinc phosphide;

Gassing with Celphos tablets (phosphine) of burrows in the field.

The preparation of baits and placing of traps was demonstrated to farmers and the local extension worker. Records were kept of bait consumption and number of rats caught. Although the programme appeared to be effective in reducing the rodent population, it was too limited in time and area to collect statistical information.

Some Conclusions and Recommendations

Storage losses in Nepal vary considerably according to the climatic conditions, type of product stored and storage practices. In higher hill areas the only storage loss is caused by rodents while in lower areas, where higher levels of humidity and temperatures and longer storage periods are common, many of the storage problems are related

to the high moisture content of the stored grain.

No statistical data are, however, available on farm storage losses in Nepal and the economic and social benefits of a storage improvement programme are therefore difficult to assess. Subsistence farmers who form a large majority in the hill areas will not be able to invest cash in improved storage structures (e.g. metal "Bhakaris" or storage bins) while improved, inexpensive methods may be difficult to introduce because of technical, social and other reasons.

A national rodent control programme should demand top priority. Rodents not only consume the stored crops as well as standing crops but also carry diseases. Field studies in 1974 on a mature wheat crop in Kathmandu and the Tarai revealed an overall mean damage by rodents of 7.2%. Villagers are very much aware of loss due to rodents and were keen to assist with rodent control activities. Zinc phosphide seemed to be a more effective rodent poison than anticoagulant but this may not hold true in the long run. Anticoagulants do not result in bait shyness as does zinc phosphide over time, and are much safer to use. Backbreaker traps (snaptraps) proved efficient but due to the rats' intelligence frequent changing of bait material is necessary. Cage traps are difficult to transport, place and set and proved hardly effective. Rodent trapping and poisoning in the field is a new concept to farmers and requires much more attention and time. Therefore the most suitable season for rodent control is the winter when no crops are standing in the field and rodents have to come to villages to obtain food. Some rodent species may not come to houses, however, and must be killed in the field. Celphos tablets are inexpensive and effective for fumigating rodent burrows in the field. More attention must be given to rodent proofing of buildings, godowns, "Sulis" and other storage structures.

As mentioned before losses of stored grain are often related to an excessive moisture content of the stored crop. This may be due to ignorance and adverse climatic conditions. It was found that before milling the farmer often dries the grain to improve milling performance. It should be recommended to the farmer that proper drying must be carried out soon after harvesting as weather permits to improve both storage as well as milling performance. Such innovative practices, however, are not easily introduced; some religious castes are allowed to take grain out of their store only on certain days; in case the grain is later sold the farmer objects to (additional) drying because it not only requires extra labour but also reduces weight.

Notes:

For more details see: *"Agricultural Engineering in Support of Hill Agriculture Development"*. by A.G. Rijk; Hill Agriculture Development Project; January 1979.

The 1973 – 1974 Annual Report of the *Rodent Research Project in Nepal* by Dr. S.C. Frantz mentions infestation rates of 87.0% for Hetaura (Tarai), 73.6% for Kathmandu and 50.0% for Jomosom (an arid and cold region close to the border with Tibet). ■■

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Development of the Indian Tractor Industry



by
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Abstract

The main subject of this study is an analysis of the development of the Indian tractor industry between 1960 and 2000. Within this context at first the criteria of microeconomic and macroeconomic prerequisites are particularly described to develop an indigenous tractor industry restricted to Indian conditions. One criterion is an international comparison of the land and labour productivity of agricultural production and prices paid for tractors in several countries.

The sector is described by the market shares of single firms, the development of tractor prices is compared to agricultural product prices and the locations of the facilities. The growth path of the tractor industry during the next two decades is discussed under the framework of the political impacts of the Government's targets in agricultural and economic policy.

*The author acknowledges gratefully the helpful comments obtained from Ms. Andrea A. Belter and Professors Dr. Ulrich Koester, Dr. Wilhelm Scheper and Dr. Adolf Weber, all Kiel. Furthermore he would like to thank the "Sonderforschungsbereich 86 – Weltwirtschaft und Internationale Wirtschaftsbeziehungen" of the DEUTSCHE FORSCHUNGSGEMEINSCHAFT (DFG) for travel assistance to visit India.

Introduction

The production of tractors in India in 1979 was about 60,000 units; domestic sales were about 58,000 units this year. This led India to the sixth or seventh place in tractor sales for the whole world. The total number of tractors increased from 228,000 (1975) to more than 400,000 (1979).

Regarding the whole country the degree of tractorization is very low in terms of agricultural workers or arable land, but the development of agricultural mechanization is discussed controversially. Derived from studies already finished it is concluded, that a misguided policy concerning this topic has negative impacts both in the agricultural and industrial sectors (1). *Binswanger* (2) surveying a lot of farm level studies with regard to tractorization in India and adjacent countries points out, that "Tractorization of agriculture in low-wage countries has been the center of one of the most virulent and emotional choice-of-techniques debate for the past twenty years".

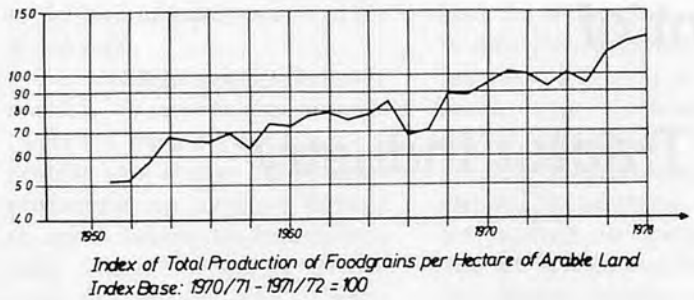
Contrary to the bulk of surveys this study emphasizes the development of the tractor industry. The agricultural sector will be regraded where necessary. The main problem to be solved by this study is to judge whether the development of the Indian tractor industry had positive impacts in agricultural and industrial sectors. Until now there have been little information available concerning this topic.

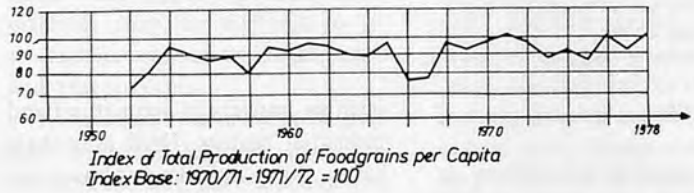
Importance of Indian Agriculture

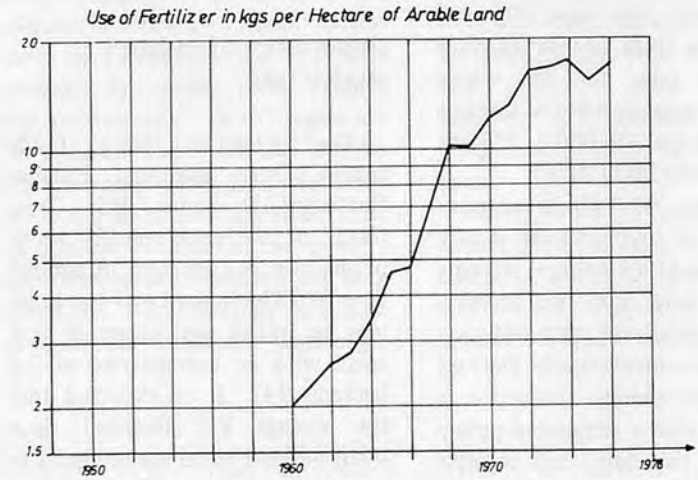
The agricultural share of the Indian Gross National Product fluctuates at about 40%. Two-thirds of the economically active population is employed in agriculture (3). The majority of the holdings in Indian agriculture is very small with an average size of 2.3 hectares (4). It is expected that the average size declined since 1970 because there are attempts to introduce ceilings on land holdings and in the process the holdings tend to be parcelized for each male heir in the family.

The differences of the large agro-climatical zones and the variability of sizes of farm holdings do not permit only one strategy of mechanization policy in India. In the short run, tractor use will be limited to those farms having specific economic conditions or which cultivate more than 10 hectares of arable land. It is expected that several stages of mechanization will be supported by agricultural research and found in the countryside at the same time.

Hayami et al (5) listed 43







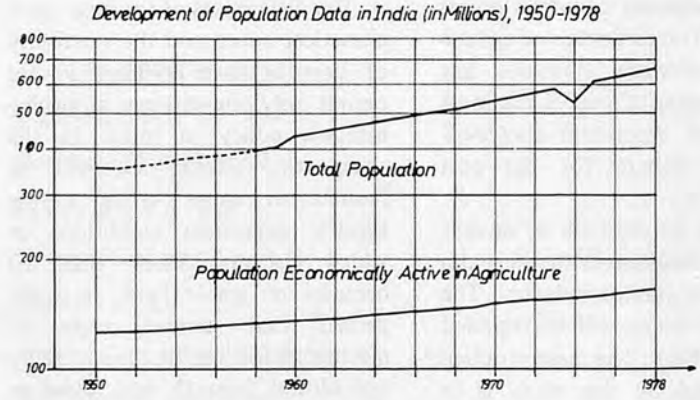


Fig. 1 Population trend and agricultural development indices in India, 1950-1978 (Semi-log. Scale)

countries and compared their agricultural land and labour productivity in 1955 and 1965. India had the least range in labour productivity in both years.

Fig. 1 shows the population trend and agricultural development indicators in India from 1950 through 1978.

The graph underlines the main tendencies in the development of India's agricultural production. Though the increase of total agricultural production' and of commercial inputs like fertilizer use is immense, the rise of the index of per capita production of foodgrains is low. This indicates the intensive growth of total population.

Development of the Indian Tractor Industry

The four-wheeled tractor was well-known in India before World War II. Before the first Indian tractor plant came into production in 1961 ("Eicher Tractors India Ltd.") there were to be about 34,000 tractors found (6). Since that time eleven other plants erected facilities to produce tractors.

Table 1 gives a brief impression of the development of the tractor industry. However, there is little information concerning the regional distribution of tractor stock before 1961. It is assumed that they were used in large farms and institutions such as state cooperatives mainly located in districts of arable farming like Punjab.

Besides the plants in production two firms received their licence for production and two further ones requested for it. The granting of a licence is a prerequisite to tractor production in India. Within the licence received the maximum amount of production is determined. Each firm is allowed to establish their actual production facility within the scope given in

Table 1. Development of Indian Tractor Industry, 1960–1977

Year Licenced	Names of Firm	Location of Facility	Technical and/or Financial Collaboration	Produced Model (H.P.)	Capacity of Production		Actual Production 1977 (Units)
					Licenced	Installed	
1960	Eicher Tractor, India	Faridabad	Eicher GmbH, Germany (F.R.)	Eicher (26.5)	2,000	3,600	3,485
	Tractors and Farm Equipment	Madras	Massey Ferguson, (U.K.)	MF-1035 (35) TAFE (50)	7,000	8,000	5,726
1966	Hindustan Tractors Ltd.	Pinjore	Zetor, Poland	Hindustan (35) " (50)	7,000	3,000	2,026
1970	Escorts Tractors Ltd.	Faridabad	Ford Motor Co., USA	Ford 3600 (46)	6,000	6,500	5,500
	Kirloskar Tractor Ltd.	Nasik	Deutz, Germany (F.R.)	Deutz (D 2506) " (D 7506)	10,000	3,000	252
1971	Harsha Tractors Ltd.	Ghaziabad	Tractorexport, USSR	T 25 (25)	10,000	5,000	1,028
	Punjab Tractors Ltd.	Chandigarh		Swaraj 724 (23.6) Swaraj 735 (34.7)	12,000	5,000	3,281
1972	International Tractor	Bombay	IHC, U.K.	B 275 (25) B 444 (45)	10,000	12,500	1,932
	Pittie Tools Ltd.	Poona		Pittie-4000 (37)	10,000	1,000	110
	Hindustan Machine Tosh Ltd.	Baroda	Zetor, Poland	Zetor-2511 (25)	12,000	12,000	2,056
	Escorts Ltd.	Faridabad	Escorts, Poland	E-3036-4WD (35)	16,000	11,000	7,138
	Auto Tractors Ltd.	Lucknow	Leyland, U.K.	Leyland 154 (25)	12,000	–	–
	United Auto Tractors Ltd.	New Delhi	Rumania	Romania U-445-(45) " U-650-(65)	5,000	–	–
	Premier Irrigation Equipment Ltd.	New Delhi	David Brown, U.K.	David Brown (55)	5,000 *		
1975	Bihar Agro-Industries Corporation Ltd.		Zetor, Poland	HMT-Zetor 2511 (25)	6,000	2,000	1,000
1977	Eicher Tractor, India, Ltd.	Faridabad		Eicher (26.5) " (34)	8,000	–	–
	Perfect Tractors Ltd.	Hyderabad	Hanomag, Germany (F.R.)	Hanomag (32)	5,000*	–	–

M.A. *Baig*, The Tractor in India - A Significant Instrument for Future Development, "Farm Mecahnization-Problem and Prospects", Indian Society of Agricultural Engineers. New Delhi, 1978, p.61, Annual Licensed and Installed Capacity of Tractor Manufacturers, "Agricultural Engineering Today", Vol. 1, No. X, New Delhi 1977, p.15f.

* Requested

the licence. Furthermore, the table shows that the bulk of Indian tractor plants went into production since 1970 as a consequence of the rapid increase in domestic demand for tractors. The sales of tractors increased four times since 1965. In those days the demand for tractors could not be satisfied by indigenous production. The declining tendency of import share of the tractor availability expected from theory turned to the opposite direction. These reasons supported the idea to expand indigenous tractor production in India.

The contracting partners of the Indian tractor plants are mainly located in European countries. The origin of these partners is not chosen between countreis of free enterprise or planned economy. Thus the Indian tractor plants show two main distinctive forms of cooperation: eight of them are private enterprises and the rest are more or less managed by Governmental organizations.

The capital requirements for the facilities are predominantly provided by domestic capital formation. As a rule, the financial cooperation of the foreign or joint venture collaborations are restricted to minority interest. Some of the collaborators act only as licencers without any financial engagement. They confined themselves exclusively to the provisions

Table 2. Development of Tractor Market in India, 1961–1979.

Year	Import Nos.	Domestic Production Nos.	Stock Nos.	Domestic Availability Nos.	Domestic Sales Nos.	Import as Percentage of Domestic Production	Stock as Percentage of Domestic Sales
1	2	3	4	5=2+3+4	6	7=2 : 5	8=4 : 6
1961	3,248	612	800	4,660	3,660	530.7	21.9
62	3,033	1,470	1,000	5,503	4,330	206.3	23.1
63	1,523	1,788	1,173	4,484	3,111	85.2	37.7
64	2,999	3,630	1,373	8,002	6,429	82.6	21.4
1965	2,064	5,673	1,573	9,310	7,537	36.4	20.9
66	2,884	8,107	1,773	12,764	10,791	35.6	16.4
67	2,591	10,510	1,973	15,074	12,601	24.7	15.7
68	4,038	13,794	2,473	20,305	17,332	29.3	14.3
69	12,397	18,093	2,973	33,463	29,990	68.5	9.9
1970	12,701	19,927	3,473	36,101	32,101	63.7	10.8
71	16,679	21,139	4,000	41,818	33,500	78.9	11.9
72	16,465	18,283	8,318	43,066	33,300	90.1	25.0
73	2,000	23,609	9,766	35,375	31,000	8.5	31.5
74	500	29,002	4,375	33,877	30,000	1.7	14.6
1975	750	32,463	3,877	37,090	32,500	2.3	11.9
76	4,000	34,607	4,590	43,197	36,500	11.6	12.6
77	900	35,176	6,697	42,773	41,000	2.6	16.3
78	n.a.	53,003 a)	n.a. b)	n.a.	53,000 c)	n.a.	n.a. d)
1979 a)	n.a.	5,012	1,814	n.a.	53,544	n.a.	41.7

a) Production during November.
b) Stock stated as on 12.12.1979.
c) Sales: January through November.
d) Dated only available for November.

Data provided by Escorts Ltd., Faridabad, India.

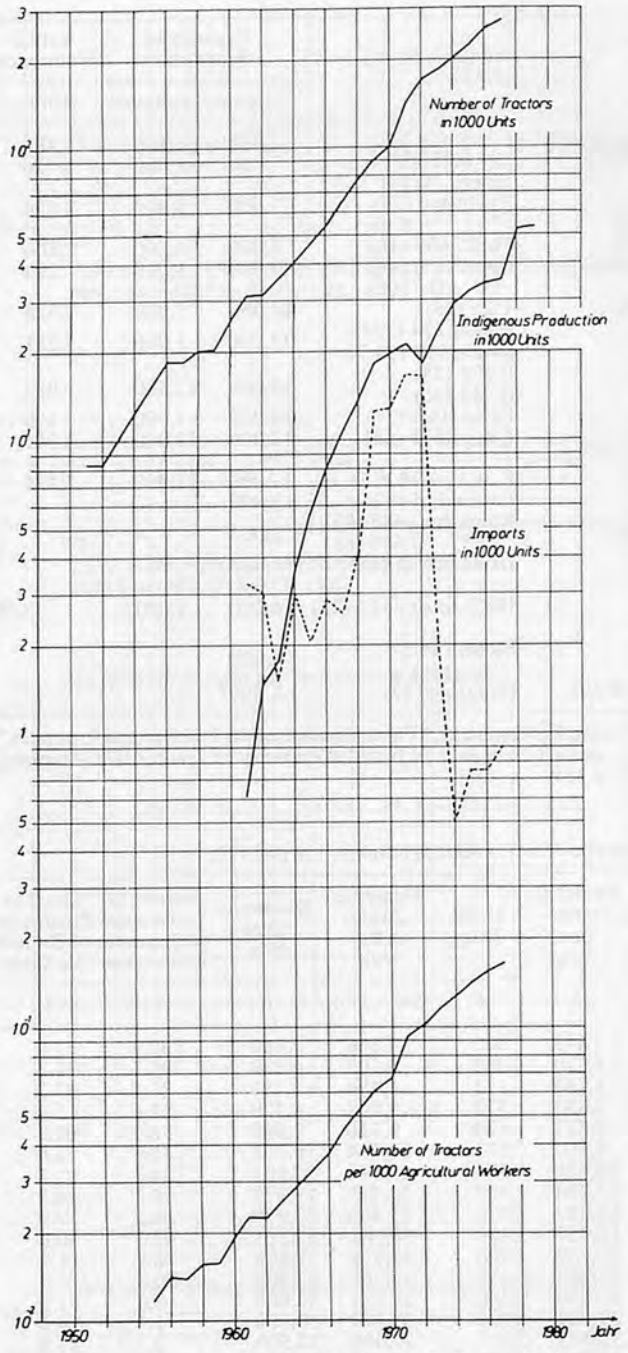


Fig. 2 Development of tractorization in Indian agriculture, 1950-1979 (Semi-log. Scale)

of patents and blue prints. No foreign engineer support or provide assistance in tractor production.

Supply of Tractors in India

The market share of tractors domestically produced increased since 1961. After domestic demand exceeded the indigenous production capacity installed (1969 to 1972) the decline of the import share of tractors was interrupted. The number of imports reached 80% of the indigenous tractor production, though production increased at 12% a year between 1967 and 1972. After this period sales stagnated until 1975 because

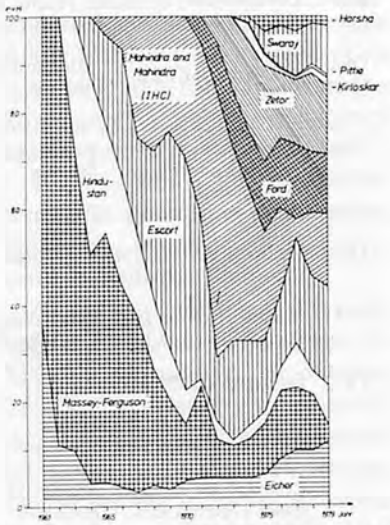


Fig. 3 Percentages of market share of Indian tractor plants, 1961-1979

of the low harvests of food grains. The stock of tractors was rising and equivalent to the amount of production requiring six months. Thus imports were limited to one exception. Tractors had to be purchased in foreign currencies by relatives of farm holders staying abroad.

Imported tractors originated mainly from firms also producing in India. This phenomenon is explained by the theory of technology transfer. The pure import of a certain product is followed successively by domestic production (7). The manufacture of tractors requires a firm specific transfer of technology (8) and sales of tractors are linked closely to the availability of service and distribution networks. In 1978 there were about 1,200 repair and distirbution centers for tractors in India. Because of the lack of the ability to satisfy a market by indigenous production, these firms try to supply this market through importation. Furthermore, there is a chance to export Indian tractors, but besides some years India has been in the stage of a net importer. The exports realized were turned to adjacent countries like Nepal and Burma.

Production Technique

Each production technique is characterized by its specific capital/labour ratio. In developing countries one often views unemployment or underemployment and lack of capital formation for investment. Thus frequently a labour intensive production method is used in those countries. In 1979 one tractor plant reached minimum capacity as mentioned by FAO (9). All the remaining facilities were below minimum. Their share of labour costs is assumed to be high. In reality the share of wage of the whole production costs runs up to 6 or 7%. Some of the reasons are discussed below.

a) The minimum wage of an industrial worker in India was about 500-650 Rs. a month (1979). In Germany (F.R.) the same worker would receive about 8,000 Rs. a month.

b) The interest rate of borrowed capital is equal for both countries, fluctuating around 10% a year in 1978, but the rate of inflation differs.

Furthermore it is impossible to defend a total substitution of the capital/labour ratio in tractor production. A fixed ratio should be expected because of high share of overhead cost. To some degree the production method used may be adopted to the existing capital/labour ratio of developing countries, but as far as tractors are produced under licence of international collaboration the adoption to these ratios seems to be quite impossible.

Structure of Indigenous Model

One of th plants without any international collabration is producing a model developed and adapted to India's domestic market. This model seems to be appropriate to the conditions of developing countries both from an economic and technical view. The "Swaraj-Sartaz" is the cheapest tractor entirely supplied in India and among the less expensive ones in terms of traction power (10).

Aurora and *Morehouse* (11) gave a brief overview of the problems before this model could be produced. They demonstrated that first of all a demand potential has to exist before starting to construct a tractor which deviates from the well-known European or American pattern.

Table 3. Arable Land in 1,000 Hectare per Tractor in Selected Indian Regions in 1972 and 1976

Region	Arable Land (in 1,000 Hectares)		Number of Tractors		Arble Land (in Hectare per Tractor)		Reduction in Land: Tractor - Ratio
	1972	1976 a)	1972	1976	1972	1976	
Andra Pradesh	12,700	13,300	6,300	14,100	2,010	940	53.2
Bihar	10,700	11,300	5,600	11,600	1,910	970	49.2
Gujarat	10,000	10,500	7,900	15,600	1,270	670	47.2
Haryana	5,000	5,300	18,400	36,600	270	150	44.4
Karnataka	11,000	11,600	5,700	11,600	1,930	1,000	48.2
Madhya Pradesh	20,900	22,000	5,000	14,500	420	150	64.3
Maharashtra	17,500	18,400	5,600	11,100	3,120	1,660	46.8
Punjab	5,300	5,800	42,400	84,000	125	69	44.8
Rajastan	16,800	17,700	11,700	36,600	1,440	480	66.7
Uttar Pradesh	23,200	24,400	27,600	54,600	840	450	46.4

a) Computed from *FAO*, Production Yearbook, various issues, arable land increased in each region.

Source: a) Arable Land: H.P. *Binswanger*, The Economics ..., a.a.O., p. 96.
b) *Number of Tractors:* M.M.A. *Bain*, Tractors in India: Need and Impact. "Agricultural Engineering Today", Vol. 1, No. X, p.9.

Tractor Industry and Regional Distribution of Tractors

Based on the extent of India's area the average data permit an international classificaiton, but the variances from the mean require a more exact analysis. If the density of tractorization is compared between India and Germany (F.R.) and by neglecting the differences of the yield level of cereals these results were found: In India one tractor was available per 420 hectares of arable land. In Germany the same figure run up to 5.7 hectares. Punjab, Haryana, and Uttar Pradesh account for 60% of the whole tractor number and have the highest density of tractor population. In this region there are six facilities. Those plants located in the Bombay region gain from their locaiton in an industrial center. There are some districts of arable farming around Hyderabad and Madras, where three facilities are found.

These considerations lead to the conclusion that the demand-oriented choice of location in the tractor industry shows no distinction between India and Europe or North America (12).

Economic Considerations

Microeconomic Considerations from a Farmer's Point of View

A farmer carries out an investment such as tractors if he expects a positive change in his actual income. By neglecting prestige and demonstration effects of purchased tractors this analysis is confined to rational and economic arguments.

Each farm is faced by a certain ratio of factor prices. The ratio is mainly determined by its cropping system, its location, and farm size. In 1979 the average daily wage of farm hands in India was between 4.5 Rs. and 6.25 Rs. In several areas of Punjab, Haryana, and Uttar Pradesh employees received up to 20 Rs. a day during the peak harvesting season. Thus about 75

man-days are equivalent to the price of one tractor-H.P. (1,100 Rs.–1,900 Rs. (13)). If farmers needing a lot of hired workers receive the opportunity to increase yields by multiple cropping and if they are able to use custom hiring then they consider whether to purchase a tractor at a price of 30,000 to 40,000 Rs.

The arguments mentioned support the effectiveness of tractors compared to draught animals. A lot of surveys based on the level of a sample of single farms prove the advantages of increasing level of tractorization. Derived from this level of consideration a domestic tractor production is opened to meet the demand coming from those farmers able to purchase tractors.

Macroeconomic Aspects

The indigenous production of tractors is a part of the strategy of import substitution. This strategy is followed if negative impacts are expected, particularly on balance of payment. In India the Foreign Exchange Reserves decreased steadily between 1950 and 1970. The lowest reserves compared to 1950 were viewed from 1957 through 1970. This may have influenced the decision to establish a domestic tractor industry. In general and as a consequence, this decision leads at first to an increasing demand for foreign currencies because new machines, licences, blue prints, foreign advisers and so on have to be imported. Thus the foreign exchange reserves remained low till 1976. After two years of bumper crops a rising stock of exchange reserves occurred (14).

One of the instruments judging the efficiency of import substitution is proving the development of prices paid for a similar good produced and supplied in different countries. It should be noted that a discussion concerning the judgement of internal price ratios compared to foreign exchange rates is neglected.

This table implies that German tractor plants were not able to export tractors to India at competitive prices in the years discussed. Though selling prices of Great Britain's plants were below India's in 1972 and 1974 the additional costs of shipment would have led to equivalent prices at Indian market. Thus India's tractors were able to compete with foreign imports within the framework of official prices. Some of the reasons may be low wages and the subsidization of certain inputs such as steel.

Development of Agricultural Production

Fig. 1 shows the general trend of agricultural production as analyzed under the application of political implements by *v. Urff* (15). In his study the impacts of "green revolution" are discussed, but mechanical power sources were excluded. The increasing use of tractors contributes to the rise of total agricultural production where timely soil cultivation permits multiple cropping. On the basis of a sample of farm holdings, often an increase in cropping intensity is given. However, the results are seldom significant. Perhaps rising yields would be affected stronger by the increasing level of mechanization as *Giles* (16) approach suspected. This approach, proved on the microeconomic level, demonstrates a high correlation between traction power and yields of crops (17), but as a rule simultaneously improved seed, better soil cultivation, new irrigation techniques, and palnt protection were used. Though regression analysis is used the single effects of these accompanying measures cannot be readily carried out.

Effects on Employment

Though the share of the Indian population economically active in agriculture will decline by 2000, the absolute number of workers in agriculture is expected to rise. Governmental policy will certainly respond to this expectancy. Thus from the economic point of view a labour-intensive structure for the whole economy has to be implemented. However, the burden on hand labour should be reduced. The impact of the demand for work places stemming from the growth of population has to be investigated very intensively. This is particularly true for the rising level of tractorization in India. The effects gained from different levels of aggregation of the agricultural sector are altogether controversial (18). In spite of all this information it cannot be foreseen towards which direction the employment situation is

Table 4. Comparative Tractor Prices: India, Germany (F.R.), and the United Kingdom (40 H.P. Tractor, 1972, 1974, 1976 and 1978)

Year	Domestic Prices			Foreign Prices in Rs.	
	Germany (F.R.) (DM)	United Kingdom (£)	India (Rs.)	Germany (F.R.)	United Kingdom
1972	15,308	1,470	32,420	49,020	37,670
1974	16,806	1,532	36,660	56,470	29,080
1976	18,270	2,822	48,230	68,440	42,440
1978	19,550	4,330	51,070	87,280	71,870

Source: *Prices of Tractors:*
Germany (F.R.): dlz-Typentabelle, dlz-"Deutsche Landtechnische Zeitung", Munich, various issues.
United Kingdom: "Power Farming", Agricultural Press Ltd., London.
India: Data provided by Escorts Ltd., Faridabad.

Table 5. Development of Factor-Product-Price-Ratio Leading to Tractorization in India, 1960–1978

Year	Gross National Product in Current Prices Billions of Rs.	Gross National Product at Constant Prices (Base: 1970) Billions of Rs. a)	Gross National Product per Capita at Constant Prices (1970) R.s.	Price Index of Industrial Production 1970= 100 b)	Whole sale Price of Cereals per 100 kgs. Rs.		Average Price per Tractor Rs. d)	Average per Tractor H.P. H.P. d) Rs.	Ratio of 100 kgs. of Cereals per Tractor H.P.	
					Wheat c)	Rice c)			Wheat	Rice
1	2	3	4	5	6	7	8	9	10 = 9 : 6	11 = 9 : 7
1960	150,2	298,0	644	–	47.7	69.6	–	–	–	–
61	159,8	309,7	672	–	43.8	60.8	–	–	–	–
62	171,0	316,7	681	57.6	46.4	67.4	–	–	–	–
63	196,6	323,4	670	60.9	45.8	84.5	–	–	–	–
64	230,4	338,3	706	66.6	55.5	65.1	–	–	–	–
1965	241,1	315,2	658	72.0	59.7	68.0	–	–	–	–
66	276,9	300,0	655	80.6	71.9	80.7	–	–	–	–
67	323,3	325,9	692	92.7	89.5	82.0	–	–	–	–
68	334,0	346,8	695	92.2	85.2	119.0	–	–	–	–
69	370,0	371,9	725	94.2	93.1	111.7	–	–	–	–
1970	403,6	403,6	749	100.0	93.8	109.0	18,760	534.8	5.7	4.9
71	431,8	404,6	739	103.9	94.0	109.0	23,900	685.9	7.3	6.3
72	480,6	410,7	726	112.7	96.1	109.0	27,890	740.0	7.7	6.8
73	491,9	426,5	739	131.2	83.2	109.0	29,440	830.0	10.0	7.6
74	700,3	425,8	723	168.7	116.5	145.2	36,180	904.8	7.8	6.2
1975	729,5	462,1	769	175.3	113.0	149.8	42,160	1160.3	10.3	7.7
76	771,9	468,2	763	171.9	113.3	149.8	42,650	1185.7	10.5	7.9
77	–	–	–	184.0	–	–	44,800	1267.4	11.0	8.5
78	–	–	–	184.0	–	–	48,400	1501.0	–	–

Source: a) *United Nations*, Yearbook of National Account Statistics, New York, International Tables, various issues.
b) *Statistisches Jahrbuch der Bundesrepublik Deutschland, Wiesbaden*, various issues.
c) *FAO*, Production Yearbook, Rome, various issues. Rice was computed as average between high price and low price.
d) Computed from unpublished data provided by Escorts Ltd., Faridabad, India.

turning by the intorduction of a turning into by the introduction of a rising tractor stock. Thus for further calculations it is assumed that the net effect on agricultural employment, including those depending upon draught animals is nil below Indian conditions. So the rising tractor stock will have effects only in the non-agricultural sector.

Data on employment caused by the tractor industry in India (19) refer to the following:

a) Employees in the tractor industry and their input industry: 60,000
b) Employees in farm machinery industry (share depending on tractor industry): 177,000
c) Persons engaged in the distributional organization of tractor plants: 123,000

Total: 360,000

The figure shows that one tractor is equivalent to one person employed depending on Indian tractor production. In the short run an increasing production of tractors may raise demand for labourers slowly becuase the installed capacity was utilized at 60 % in 1977.

This cpacity remained constant until 1979; and even increased to 90%. It may be assumed that each additional tractor will create 0.8 new jobs. The manufacture of 50,000 tractors per year provides 40,000 additonal non-agricultural work places. For the growing population about five million additonal workplaces are needed each year.

Ratio of Prices and Variables of Income

The most important economic indicators explaining the agricultural mechanization are the changes of factor prices and income variables. The real per capita income increased between 1970 and 1976 only at 3%; the nominal GNP at about 90%.

Favourable conditions of tractorization develop from specific price ratios and a rising income. The real economic position of farm holdings deteriorated since 1970, because at that time 570 kgs. of wheat were equivalent to one tractor H.P. and 1100 kgs in 1977. The price ratio of rice was similar. In theory the increasing development of total productivity should absorb decreasing prices. The total producitvity of agricultural production increased only about 13%. This advantage seems not to be enough to absorb the disadvantages caused by increasing tractor prices. A general tendency towards tractorization cannot be based on the changes of price ratios and the overall income situation.

Prospects of the Indian Tractor Industry

Projections of Future Need for Tractors

The NCAER (20) carried out a very detailed study concerning tractor demand and estimates of future development based on a

multiple regression model. For example, in 1977/78, there was a forecast of 64,000 tractors but in 1978 only about 58,000 tractors were sold. Thre reason for a general trend of overestimation of tractor demand in that study could not be proved.

Bergmann (21) considers the magnitude of the tractor number. By neglecting econometric analysis he uses comparative analysis between India and some high industrialized countries like Germany (F.R.). His forecasts gain from plausible estimates concerning tractor density in India, e.g., he forecasts one tractor per village. But no remark is given as to when these estimates would be reached. To supervise the tractor industry and to establish the production facilities to meet the prognosticated demand, it is necessary to surely know the sequence of the development of demand, because the plants depend mainly on sales per year.

Starting from the results of a cross-section analysis of 107 countries and the principal world regions (Asia: 24 countries) an elasticity of per capita income of tractor demand was computed at 2.17 (World) and 1.88 (Asia), respectively (22). The prognosis based on this result forecasts a constant demand for tractors till 1990; the tractor number will be increasing slowly. The average level of agricultural mechanization will be far below than some of the Indian states have already reached. Model II is a trend prognosis with the base period 1970 through 1980. The continuation of this trend would lead to a degree of tractorization which would exceed the existing one in terms of arable land 60 times and in terms of agricultural workers 50 times in the year 2000. The FAO assumes that the tractor number will increase rapidly until a limit of one tractor per 100 hectares of arable land is reached and afterwards the growth rate would decline to 3% a year (Model III).

These different results open divergent prospects for the development of the tractor industry. Based on the estimates from Model I there is no need to give additonal licences, because in 1978 a production capacity was permitted at about 110,000 tractors a year. The remaining calculations show a completely positive path of development. Plausible expectations lead to the opinion that Model I may be too optimistic, but derived from Model II the demand for tractors per year could increase three or four times. The tractor industry would have to expand actual production capacity considerably to meet the forecast.

These estimates assume that no changes will occur to the economic parameters. In India this assumption is extremely risky because Government policy interferes with the economic development very strictly. In Draft-Five-Year-Plan 1978-83 there is a hint that production of 45,000 units tractors is expected in 1983. In 1979 the production of tractors was already 60,000 units. This lower level of production is explained "...unrestricted mechanization of agricultural operations will not, however, be in the interest of our country as it will severely worsen the rural employment problem..." (23). Thus the Government of India enforces those political instruments that lead to a solution of the employment problem. Certain agroclimates, recultivation of arable land, and successive harvests and land preparations require a higher supply of tractive power. In these

Table 6. Prospects of Number of Tractors, Demand per Year and Other Important Variables Derived from Different Models, 1990 and 2000

Model	Year	Number of Tractors [a]	Demend [b]	Arable Land in 1,000 Hectares [c]	Agricultural Labour Force in Mill. [d]	Tractors per 1,000 Hectares of Arable Land	Tractors per 1,000 Agricultural Workers
	1970	100,000	–	160,610	151.2	0.62	0.66
	1980	400,000	70,000	164,670	168.3	2.43	2.38
I	1990	590,000	68,000	168,830	182.1	3.50	3.24
	2000	933,000	110,000	173,100	194.06	5.39	4.80
II	1990	1,600,000	318,000	168,830	182.1	9.48	9.79
	2000	6,400,000	127,000	173,100	194.6	36.97	32.89
III	1990	1,600,000	31,8,000	168,830	182.1	9.48	8.79
	2000	2,150,000	236,000	173,100	194.6	12.42	11.05

Description of the Model calculations:

Model 1. Number of tractors and demand per year derived from the estimations cited in reference no.1. Thus the stock of tractros increases at about 3.95% a year between 1980 and 1990 and at about 4.7% per year between 1990 and 2000.

Model II. Number of tractors increases at the same rate of growth as computed between 1970 and 1980 (14.9% a year).

Model III. Number of tractors increases at the rate of growth of 14.9% a year till a level of one tractor per 100 hectares of arable land is reached. Afterwards the rate of growth of tractor is about 3% a year (FAO assumption).

Source:
a) Number of tractors: FAO, Production Yearbook, Rome, various issues.
b) Demand: Calculated with the assumption that 8% of tractors have to be replaced.
c) Arable land: FAO, Production Yearbook, various issues. It is assumed that arable land is spread at about the same rate of growth like 1970 through 1975 (0.38%).
d) Agricultural labour force: Unpublished data provided by FAO.

cases tractors should be used by custom hiring or state cooperations. The impact derived from Governmental decisions concerning economic and agricultural policy affect the prognosis of tractor demand seriously.

What will be the tasks of India's tractor industry in the forthcoming decades? Even the Government has no doubt about the fact that the expanding use of arable land will lead to increasing demand for tractive power. Particularly this expansion requires an additonal mechanical power source because the numbers of draught animals will grow only at low rates (24). Confined to Indian conditions single-axle-tractors or garden tractors would be appropriate to use in producing paddy or probably occupy a great share in the agricultural production as a whole. Derived from the latest assumptions, the technological development of the tractor industry is considered as follows:

a) Holdings above 10 hectares of cultivated land and farmers using custom hiring of tractors will demand for those types of tractors currently known. This demand potential will increase by raising per capita income.

b) A decisive aspect of further tractorization in India will be the willingness to supply low cost and yet capable tractor models. Perhaps the model "Swaraj-Sartaz" corresponds to these ideas. It has to be kept in mind, that in developing countries there is the possibility of constructing tractor models adapted for local conditions. The technology transfer needed is based on the acquisition of technological knowledge generally available. There is often cause for complaint because small holdings are not able to purchase a tractor adapted to their size of holdings (25). The bulk of Indian tractors purchased have more than 30H.P. and there are prospects of expanding tractor production in the category of more than 50H.P. (26).

c) The Indian production of rice – in 1977 about 40 million of hectares were harvested (27) – is mechanized at a very low level. If mechanical power source is used the production technique requires mainly single-axle-tractors. However, nowadays their actual number is very small. In 1976 six plants produced about 2,540 power-tillers against a licenced capacity of 40,000 units a year (28). This is reasoned from a high price level based on the poor economic situation of the facilities producing these aggregates (29).

The development of the industry concerned will be further determined by its price policy and supply of models. One model will not be capable of meeting the requirements of agriculture on this subcontinent. With regard to the production costs and the economies of scale it should be questioned whether a standardization of components or the whole tractor could reduce production costs. *Zachariah* (30) suggests that in the case of high production costs in the tractor industry the tractorization of agriculture is restricted. Therefore, tractors of the same power category should be provided with equal construction parts such as common gear boxes or hydraulics. He also shows that this is usual in Japan in the construction of power-tillers. To supply standardized products, joint research expenditures and mutual interests of the producing plants are essential. On a low level of economic development and lack of capital formation it seems to be rational to follow this strategy.

Conclusions

It is difficult to judge the present development of the Indian tractor industry within the frame of microeconomic and macroeconomic criteria. Both 1978 and 1979 were successful years for the tractor industry as a whole because a large increase in the tractor population occured, the utilization of the installed capacity of the facilities was around 90%.

The establishment of a domestic tractor industry is one instrument of import substitution. One of the methods to prove the efficiency of this instrument is an international comparison of a similar good produced in several countries. Using the official rates of exchange of foreign currencies in India the prices of tractors domestically produced were competitive compared to imports. But these imports were restricted for years with the exception of foreign aid.

Presently a trend leading to an overall tractorization in Indian agriculture within the framework of the current economic and agricultual situation is less suited because of the low level of land and labour productivity in the agricultural sector. There is little hope that an effective improvement will occur in the short run. The deviations from the trend develop from comparative advantages based on a higher level of agricultural mechanization by single holdings. Though only a small percentage of farmers are able to purchase tractors, their absolute number utilizes the production capacity actually installed by the Indian tractor industry.

The most difficult question to be answered in this study is that of the prospects of that tractor industry. The agricultural sector has to provide the growing population with sufficient food, but a rising level of tractorization has to regard cautiously the employment situation. If the Indian Government is going to realize the targets expressed in the Draft-Five-Year-Plan 1978-83 it has to be feared that tractorization will be limited. As no further expansion of the indigenous

tractor industry will be required, the transfer of technology will be reduced to the development of low cost aggregates. In this task the single-axle-tractor should be included.

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Regional Seminar on Appropriate Mechanization for Rural Development to Be Held in Jakarta

This seminar will be held on January 26–31, 1981 in Jakarta, Indonesia, organized by Department of Agricultural Engineering, Bogor Agricultural University, Indonesia in cooperation with the Department of Agricultural Engineering, LHW, Wageningen and the Netherlands Universities Foundation For International Cooperation.

This seminar aims

1. To promote the transfer of experiences and results of appropriate agricultural mechanization technology among the developing countries, particularly in the ASEAN.
2. To promote a more effective flow of information on agricultural mechanization among scientists, decision makers, manufacturers and advisory services.
3. To enhance the role of agricultural engineering in planning and decision making of implementing appropriate agricultural mechanization policies, both in the selection of farm mechanization systems and in the promotion of farm machinery manufacturing and distribution.

The objectives are:

1. To identify the problems in developing and applying appropriate agricultural mechanization on small farms.
2. To determine the role of small-scale agricultural mechanization in solving those problems, taking into account the future needs for increased food production and increased farmer's income as well as the future development of the rural labor force.
3. To formulate recommendations for agricultural mechanization policies in the ASEAN countries.
4. To formulate future requirements of manpower in agricultural enginering and related fields to serve both the public and private sectors.

The seminar will concentrate on the programs and achievements in various countries in the following topics.

1. *Land Development Particularly in Less Populated Regions* – Land-clearing, land improvement and irrigation in rural development areas.
2. *Pre-Harvest Technology* – Development and prospects of equipment for tilling, planting, seeding, fertilizing and crop protection operations in small farming.
3 *Harvest and Post-Harvest Technology* – Development and prospects of equipment for harvesitng, threshing, drying, processing and storage operations in small farming.
4. *Management Aspects in Agricultural Mechanization* – Development of appropriate mechanization systems for small farming under various agro-ecological and socio-economical conditions.
5. *Mechanization Policy* – The role of agricultural engineering in development planning and implementation including government policies, machinery manufacturing and manpower planning.
6. *Exhibition and Demonstration* – During the seminar, agricultural machinery exhibitions and demonstrations are planned on the Bogor Agricultural University campus at Darmaga, Bogor.

International Symposium on Sweet Potato to Be Held in Taiwan

First International Symposium on Sweet Potato will be held on 23 – 27 March 1981 Taiwan.

Program Outline

Session 1. Background
- Sweet potato – A world crop and its potential impact in developing countries
- Origin, history and distribution
- Stigmas against eating it
- Nutritional aspects

Session II. Plant Physiology
- Life cycle and growth stages
- Physiology of rooting
- Carbohydrate metabolism
- Control of flowering
- Fertilizer and mineral nutrition

Session III. Plant Protection
- Weevil research
- Fungal and bacterial diseases and their control
- Virus diseases and their control

Session IV. Crop Management
- Production of planting materials
- Soil moisture relationships and irrigation
- Cropping systems
- Mecahnizaton of planting and harvesting

Session V. Plant Breeding
- Genetics and phylogeny of *Ipomoea batatas* and the related *Ipomoea* species
- Techniques
- Development of varieties for intensive cropping systems
- Human consumption
- Animal feed in Taiwan
- Industrial uses (starch, alcohol, etc)
- Insect resistance
- Disease resistance

Session VI. Post-Harvest Handling and Utilization
- Marketing
- Storage problems
- Processing
- Utilization for animal feed and industrial uses: potential and problems

Sponsors

Council for Agricultural Plan-

ning and Development National Science Council
Taiwan Agricultural Reserach Institute, Asian Vegetable Research and Development Center, International Society for Horticultural Science.

Pakistan Society of Agricultural Engineers Organized

The Pakistan Society of Agricultural Engineers came into being on March 15, 1980. Mr. A.U. Khan of IRRI-PAK Agricultural Machinery Programme was convenor of PSAE Organizing Committee. The objectives of the society are to advance the theory and practice of engineering in agriculture and allied sciences and arts.

The first Annual Convention of the Pakistan Society of Agricultural Engineers was held on May 8 – 9, 1980. It was inaugurated by the Federal Minister of Food, Agriculture and Cooperatives. Beside, general lectures to the plenary session, four technical sessions were held. A number of technical papers were presented and discussed. It has also been decided to publish the proceedings of the convention in the near future.

International Seminar on Mechanization of Small Peasant Farming

An international seminar was held at Hokkaido University from 7th to 10th July, 1980. The agenda was the followings.

July 7 –Field trip; Farm mechanization, land consolidation in the rural area near Sapporo City.

July 8 –Opening Remarks

Session 1, Chairman: A. Weisblat, Agricultural Development Council.

1. "The Development of Farm Mechanization in Japan after the Second World War", by Keizo Tsuchiya, Kyushu University.
2. "Mechanization of Small-Scale Farming in Japan", by Osamu Kitani, University of Tokyo.

Session 2, Chairman: Kenzo Hemmi, University of Tokyo.

3. "The Farm Machinery Industry and Farm Mechanization: In Reference to Rice Production in Post-War Japan", by Hiroyuki Nishimura, Kyoto University.
4. "Impact to Farm Mechanization on Farm Organization: A Case Study of Typical Field Crops Producing Area in Eastern Hokkaido", by Yoshiharu Kudo, Obihiro University of Agriculture and Veterinary Medicine.

Session 3. Chairman: Rudolph S. Sinaga, Rural Dynamic Project, Agroeconomic Survey, Bogor.

5. "Operating Cost of Rice Harvesting Patterns in Saga Central Plain Area", by Zyuro Kudo, Kagoshima University.
6. "Economic Effects of Government Investment in Farm Mechanization: Japanese Experiences", by Toshio Kuroyanagi, Hokkaido University.

July 9

Session 4. Chairman: Thomas Walker, Food Research Institute, Stanford University.

7. "The Priority and Sequence of Agricultural Mechanization in China", by Le Xiumei, Chinese Society of Agricultural Machinery.
8. Paper on Korean Situation, by Young Ku Shim, Suel National University.
9. "Mechanization of Small Farms in Malaysia: Recent Development and Future Needs", by Ahmad Mahdzan Ayob, University Pertanian Malaysia.

Session 5. Chairman: Tadashi Temma, Obihiro University of Agriculture and Veterinary Medicine.

10. "Status and Needs of Farm Mechanization in India", by R.D. Ghodake, International Crops Research Institute for Semi-Arid Tropics.
11. "Need for Mechanization Tillage Operations in Bangladesh", by M.A. Jabber, Bangladesh Agricultural University.
12. Farm Mechanization in Indonesia, by Rudolph S. Sinaga, Rural Dynamic Project, Agroeconomic Survey, Bogor.
13. Paper on Experiences of International Cooperation, by Bart Duff, International Rice Research Institute.

July 10

Session 6. Chairman: Bryant Kearl, University of Wisconsin.

General Discussion

The main discussion in the seminar was as follows. Farm mechanization has to take economic and social factors into considerations and has to suit the local needs. Farm machinery should be developed to suit each regional plan.

It was confirmed that Farm machinery should be adapted to the requirement of agricultural technology, on the other hand technology should also be made to suit the operation of machinery.

It is considered necessary to speed up the mechanization in tillage, plant protection and transportation, agricultural products processing, as well as to develop all types of energy resources.

The value of the seminar is also in maintaining linkages among the participants. ■■

Shibaura Tractor SF1040T



This 4 wheel drive tractor is mounted with the most powerful engine among the SE-SF series tractors and features as follows:

Tilting handle, suspension seat with shock absorber and power steering for driver's benefit.

Engine has exhaust gas-driven turbo-compressor, thermo-starter for cold weather and synchro-balancer ensures low vibration.

Hydraulic position, draft and mixed control systems are automated by IC device.

[Specification]

Dimension: 4,075 x 2,025 x 2,740 mm (L x W x H), Wheel base: 2,450 mm, Engine: 4 cycle water-cooled (Output 105 PS · Displacement 4,561 cc), P.T.O.: 540/800/1000 rpm

(Ishikawajima-Shibaura Machinery Co., Ltd.: 6-8, 1-chome, Nishishinjuku, Shinjuku, Tokyo)

John Deere New Mannheim Tractors



The entire line of under-110-hp John Deere Tractors has been upgraded to boost productivity. All six "Schedule Master" models have improvements that increase power, performance, reliability and operator comfort and convenience.

These tractors have bigger engine displacements to develop more power more reliably. To match the power, these diesel engines have stronger oil pumps, improved bearing lubrication, and specially-coated piston rings.

In all, there are two 3-cylinder models, three 4-cylinder models and a 6-cylinder model. They include the 53-hp (SAE) 1040, 59-hp 1140, 66-hp 1640, 74-hp 2040, 90-hp 2140 and the 103-hp 3140.

Note there is a new turbocharged 4-cylinder engine in the 2140 model. The John Deere design assures dependable, efficient turbocharging in a compact tractor size.

Mechanical Front Wheel Drive (MFWD) is available on all tractors. A tractor with MFWD will gain pulling power in soft fields to challenge 2-wheel drive tractors with 20% more horsepower.

Streamlined integrated design of the MFWD components leaves high axle clearance while reducing need for extra ballast to maintain weight distribution. The MFWD can be electrically engaged or disengaged on-the-go with a pushbutton, and can be optionally equipped with automatic limited-slip differential action.

(John Deere International Ltd., Farm Equipment Sales Branch, 909-3rd Avenue, Moline, IL 61265, USA)

Fuji Robin Power Rotor PR18Y



The PR18Y is equipped with a powerful air-cooled 4-cycle engine which has high torque but with low noise.

The rotor is 400mm diameter which is the largest size applied among the same class machines.

Moving parts are covered for operator's safety.

High capacity air cleaner is equipped which is designed for easy maintenance.

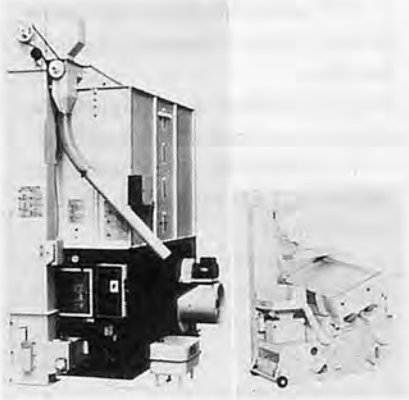
The steering handle turns 25° to the right and left for ease of operation. Level adjustment is also made easily.

[Specifications]

Dimension: 1,520 x 636 x 1,065 mm (L x W x H), Weight: 72 kg, Engine output: 3.5 PS/1,800 rpm, Displacement: 182 cc, Total speed: Forward 6 Reverse 2, Tire size: 4.00-7

(Fuji Robin Industries Ltd.: 8-1, 1-chome, Nishishinjyuku, Shinjyuku-ku, Tokyo, Japan)

"SATAKE" Integrated Dryer-Husker



This system is a combination of "SATAKE" tempering dryer (photograph left) and Ricemaster husker (photograph right) and performs drying and husking in one-pass operation.

The circulation type dryer is capable of handling both rice and wheat and has following features.

1) Powerful conveyor helps quick feed of the materials.

2) A sensor is equipped to signal by buzzer when the tank is fed to its full capacity.

3) The spreader scatters paddy evenly in the whole space of the tank to ensure efficient circulation.

4) Before the system is starting to process different variety of grains, the grains left in the machine is cleared out by pushing the button on the front panel.

5) The burner is ignited by simply pushing the button.

6)"OK" monitor on the control box gives alarm by buzzing and flickering to indicate location of hazard.

7) Automatic moisture meter, grain thrower and so on are supplied as option.

The rice husker is incorporated with automatic control system and has following features.

1) The gap of the rollers is set when the machine starts operation. Thereafter the gap is maintained by the automatic control device.

2) The automatic control device is set free against improper handling.

3) A buzzer is equipped for alarming overload of the motor.

4) Operating conditions are visible by LED indicators for easy monitoring.

This system, combined with "SATAKE" rice grader and pack-helper, is capable of performing complete processing which includes drying, husking, grading and packing.

(Satake Engineering Co., Ltd.: Uenohirokoji Bldg., Ueno 1-19-10, Taito-ku, Tokyo, Japan)

Ochiai Hedge Trimmers



Engine Hedge Trimmer E-6 (photograph above) is light in weight and compact in design.
The blades are made of heat-treated high quality steel and have sharp cutting edge. The grips are vibration free and hazardous action to the human body is minimized.

[Specifications]
Engine: 0.73HP/7,000rpm (2 cycle, air-cooled), Blades: Overall length 750mm·Tooth pitch 35mm·Speed 1,020mm/sec., Weight: 4.7kg

Heavy-duty Hedge Trimmer E-6R1100 (photograph below) is for professional use by 2-man operation. It features in light weight and simple action of handle for easy operation. The blade assembly is driven by two series of cam which ensures very smooth counter-action, equipped with an automatic centrifugal clutch.

[Specification]
Engine: Displacement 22.6 cc (2 cycle air-cooled), Blades; Overall length 1,170mm·Tooth pitch 35 mm·Speed 1,020mm/sec., Weight: 10.5kg

(Ochiai Cutlery Mfg. Co., Ltd.: 38, Chokaiji, Kikugawa-cho, Ogasa-gun, Shizuoka-Ken, Japan)

Yamamoto Husk Burner HB-50B



This burner unit can utilize volatile matter of the rice husk for heating and the remaining solid material is recovered in the carbonized form for different types of application.

The gas generating section is made of stainless steel and the temperature of the reaction is kept comparatively low (about 600°C). Thereafter the gas goes to combastion chamber which is made of ceramics to reach higher temperature (max. 1200°C).

[Specifications]
Dimension: 1,670 x 1,140 x 1,900 mm (L x W x H), Weight: 300 kg, Fuel consumption: 50 kg/hr, Gas temperature at the exit: 300°C, Heat generation: 100,000 kcal/hr, Power required: 640 W

(Yamamoto Mfg. Co., Ltd.: Tendo, Tendo-shi, Yamagata-ken, Japan)

■■

BOOK REVIEW

CIAT Report 1980

(CIAT – Colombia)

CIAT's primary dedication is to help improve agricultural production in a region – the tropics of Latin America and the Caribbean. Over its years of development CIAT has attempted to mold its overall program into one which best utilizes the Center's comparative advantage in international research and training. To this end, it has focused on four food commodities important in the region – dry beans, cassava, rice and tropical pastures (for beef and milk production). With beans, cassava and rice, the primary goal is to increase the productivity of each on lands where they are presently grown. In the case of tropical pastures and again cassava, the Center is developing improved technology that will enable increased production of both crops on lands where they are adapted and can potentially be more productive. Such lands include milllions of hectares of acid, infertile soils where other crop species cannot be grown economically.

Because of the interactions within the international centers network, each center has clearly defined zones of responsibilities. Therefore, while CIAT is fully responsible for the international development and improvement of four commodities within the tropics of the Western Hemisphere, it also works in other regions. Among the centers, CIAT has worldwide responsibility for work with Phaseolus beans, and responsibility in all regions except Africa for improvement of cassava. Rice improvement activities are restricted to Latin America but still depend somewhat upon technical cooperation with the International Rice Research Institute, especially for the interchange of germplasm material. While not a part of CIAT's basic program, the Center also furnishes a base location for maize improvement activities in the Andean region, in cooperation with the Centro Internacional de Mejoramiento de Maiz y Trigo, in Mexico.

Size: 23cm x 18 cm, 101 pp, with paper cover.

Published by Centro Internacional de Agricultura Tropical, Apartado Aéreo 6713, Cali, Colombia.

Agricultural Tropica et Subtropica, Universitas Agriculturae Praga, 11, 1978

(Czechoslovakia)

This is the 11th issue of collection of scientific papers of the Institute of Tropical and Subtropical Agriculture, College of Farm Economics and Management, Agricultural University Prague. Among the 17 articles contained in this issue, following two are concerned about farm machines;

Oubrecht Josef, Energy-demand rate in the cultivation of cotton.

Otto Karel, Modern methods for securing the operational reliability of tractors under the difficult conditions of developing countries.

Size: 20cm x 14cm, 220pp, with paper cover.

Technical Fundamentals/Grain-maize – Mechanical Production in the Tropical and Subtropical Regions

(German Democratic Republic)

by Peter Glanze

In the present work, the agro-technical requirements of maize growing in the tropics and subtropics are analysed from the angle of agricultural engineering and conclusions drawn from the experiences made in the temperate climate with respect to the application of means of mechanization to the tropics and subtropics. Machines and implements are only explained in detail when their design and function deviates from those of the standard equipment for grain production in the temperate zone. Emphasis in the exposition is placed on modern technical means. Besides, simple measures for partial mechanization are taken into consideration because the transition to full mechanization will probably take a longer period of time and be carried out in steps.

The results of tests and investigations are represented according to sections of production, taking into account various natural conditions of production. They should on no account be considered a scheme of mechanized maize production. They are suggestions which are meant to give impulses for finding the most favourable technology of maize production under the given conditions. With this, the author hopes to make a contribution towards a rapid development of the agricultural production in tropical and subtropical countries where maize growing is extensive.

Size: 21cm x 15cm, 196pp, with paper cover

Published by Edition Leibzig, G.D.R.

Components for Harvesting Pineapple Stumps – A Progress Report –ASAE Transactions, Vol. 22 No. 6

(USA)

BOOK REVIEW

by G.E. Monroe, M.R. Smith

The utilization of pineapple by-products in Hawaii can be increased greatly and, thereby, improve the economics and stability of the pineapple industry. Increased recovery of pineapple stumps requires new harvesting equipment because existing equipment is excessively expensive, heavy, and inefficient. Components were developed that can be incorporated into new equipment that will weigh and cost much less than existing equipment and recover pineapple stumps four times faster than existing equipment.

A Trans-Cam Mechanism for Harvesting Wet and Dryland Taro
—ASAE Transactions, Vol. 22, No.6
(USA)

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by L.A. Jakeway, M.R. Smith

An improved version of a single operation, one-row harvester for removing complete taro plants from the ground is reported. This machine performed the same functions as a previously developed harvester, but had the following major improvements:

1 Vertical adjustment of digging auger.
2 Reduction of overall harvester weight by over 30 percent.
3 Reduction of rotor loads in pickup mechanism by 50 percent.

Field trials demonstrated that the new version of the harvester performed satisfactorily, especially the redesigned pickup mechanism. This report gives major emphasis to the description of this new pickup mechanism.

Forage Mechanization Systems for Hawaii
—ASAE Transactions, Vol.23, No.1
(USA)

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by J.B. Dobie, H.M. Gitlin, M.R. Smith

Forage for Hawaii's livestock industry is currently imported in cube form from the mainland. Forage can be produced in Hawaii either from alfalfa or grass, or by utilizing residues from pineapple or sugarcane. These materials were tested for cubability. Systems for cubing and baling are compared for alfalfa, including artifical drying.

1980—1981
Agricultural Engineers Yearbook
(ASAE—USA)

The ASAE **Agricultural Engineers Yearbook** for 1980-81 will include a new feature section spotlighting developments, techniques, advences, innovations, and inventions of particular interest to agricultural engineers who are responsible for equipment and/or systems design. Exclusive product information which has been solicited from manufacturers and developers will be presented in a brisk, readable, technically accurate format with ample illustration.

All material accepted for TECHNOLOGY '80 has been screened by a panel of experts. Specifically that ASAE panel has followed these criteria in making its selections from among the multitude of proposals submitted:

- The development embodies the application of new technology or the innovative application of an older technology
- The development was introduced and made commercially available no earlier than July 1979 and no later than December 1980
- The development is intended principally for use in the production, processing, research, storage, packaging or transportation of agricultural products

The new **Agricultural Engineers Yearbook** will, of course, include such other traditional and vital features as Standard Engineering Practices and Data and the ASAE member roster. The Standard Engineering Practices and Data have been edited to reflect additions or alterations authorized since the 1979-80 **Agricultural Engineers Yearbook** was published.

The 1980 edition of the **Yearbook** will be mailed free in June to all ASAE members. ASAE'ers requiring additional copies may purchase these at $9.50 each. For others that purchase price is $19.50. Send orders to Yearbook, ASAE Head-quarters, Box 410, St. Joseph, MI 49085. ■■

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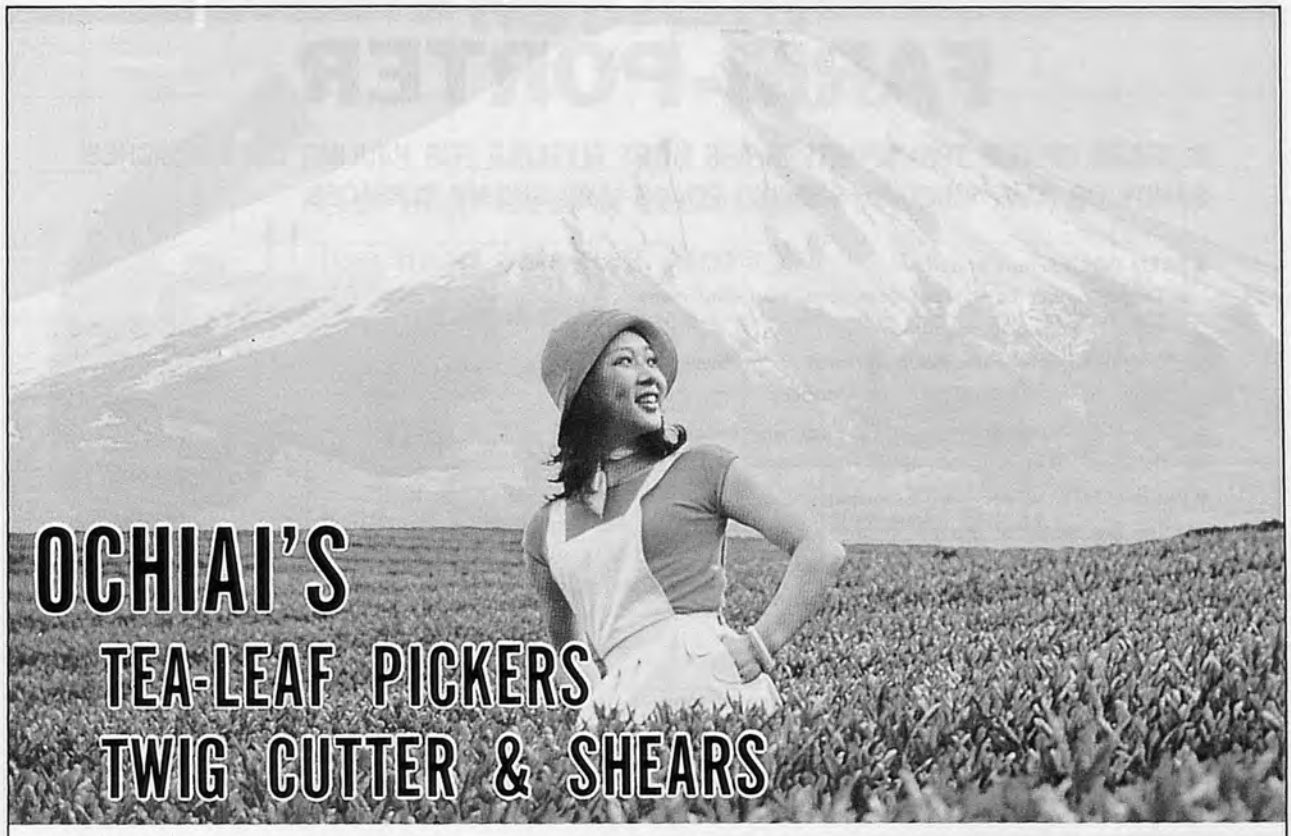
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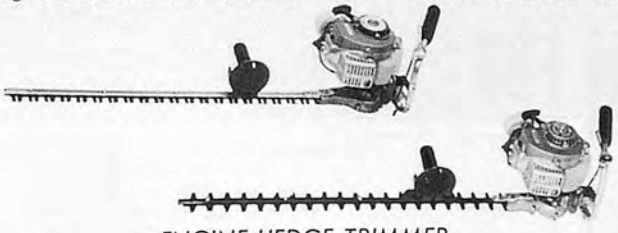
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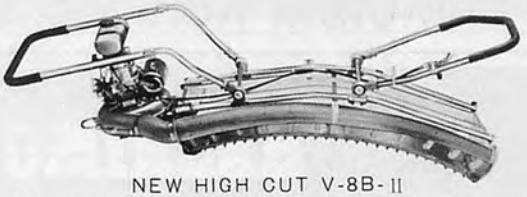
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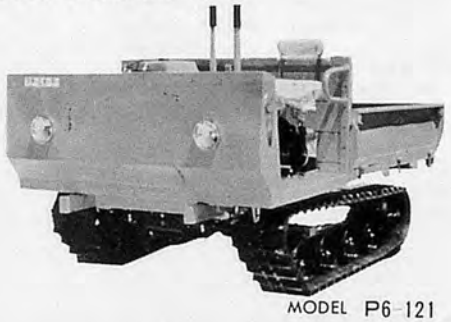
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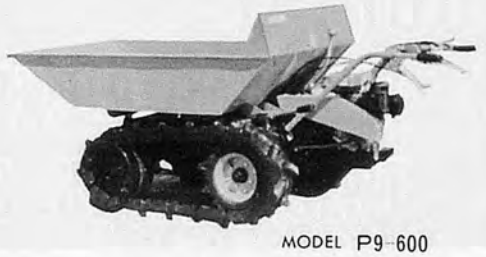
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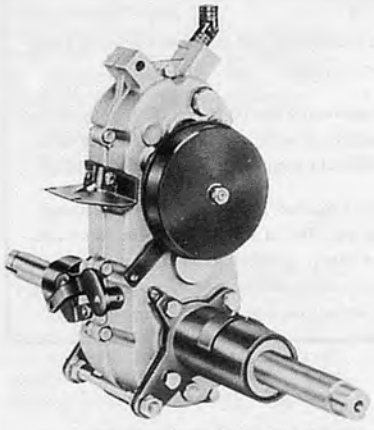
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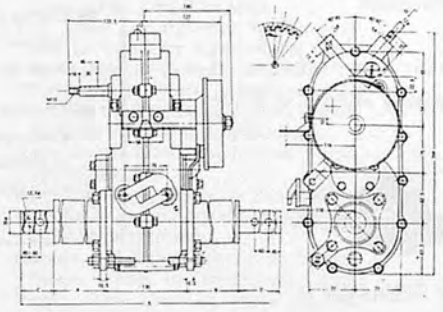
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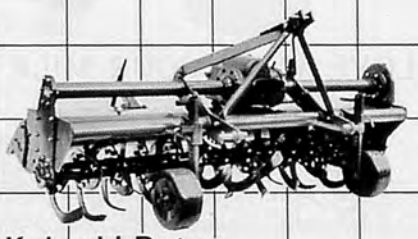
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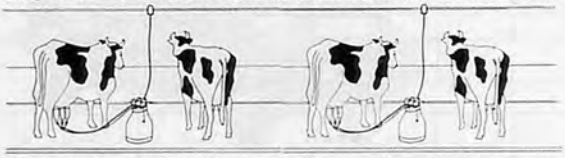
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